ECONOMIC ASSESSMENT OF MINING TECHNIQUES OF BARYTES DEPOSITS AT AZARA, NASARAWA STATE

BY

SALATI, LUQMAN KAREEM

HND, PGD

(MNE/01/0406)

A Thesis in the Department of Mining Engineering Submitted to the School of Post Graduate Studies in Partial Fulfilment of the Requirements for The Award of Master of Engineering (M.Eng.) Degree in Mining Engineering (Mine Management and Mineral Economics Option) of the Federal University of Technology, Akure, Ondo State, Nigeria.

July, 2010.

CERTIFICATION

a. (By the student):

This work has not been presented elsewhere for the award of a degree or any other purpose.

Candidate's Name: Mr. L. K. Salati

Signature: .... Date: ...30-07-10.

b. (By the supervisor (s)) :

I certify that this work has been carried out by Mr. Luqman Kareem Salati in the Department of Mining Engineering of the Federal University of Technology, Akure.

Supervisor's Name: Dr. J. M. Akande Msc. Ph.D (Donetsk)

Signature: .... Date: 30.07.10.

ACKNOWLEDGEMENT

I am most grateful to ALLAH for giving me the opportunity to carry out this arduous task and strengthening me throughout the entire period. Without God's special favour and permission, this work would not have been completed. So, I say "Alhamdulillah" (praise be to Allah).

Encouragement and assistance have come from individuals, academicians and professionals both within and outside the mining industry. I am indeed indebted to them for being part of the completion and success of this work.

My unreserved, deep and sincere appreciation goes to my supervisor, Engr Dr. J.M. Akande, whose unrelenting efforts, fatherly advice, constructive criticism and invaluable wealth of knowledge largely contributed to the completion and success of this thesis write-up. I also thank other lecturers in the Department of Mining Engineering, Federal University of Technology, Akure, for their guidance and positive contributions to this work. They include Prof. Z.O. Opafunso, Dr. B.M. Olaleye (H.O.D), Engr. Gafar Oniyide (for his great assistance), Engr M.A. Idris, Mr. T.B. Afeni, Dr I.A. Ajaka, Mr. Ifelola, Mr. S.K. Osasan, Mrs. Melodi, Engr. Adebayo, Dr. Saliu, Engr. Akinbinu, Mr. Isiaka, Mrs. S. Akande, as well as other academic and non academic staff in the Department.

Engr. Tasiu Umar (Former General Manager, Nigerian barytes Mining and Processing Company Limited, Azara) was highly instrumental to the success of this work and is duly appreciated for adequate release of vital information, accommodation and hospitality, as well as kind permission to have access to mine sites and equipment. Engr. Habu Galadima of Emo-Ashapura Energy and Mining Company Limited, Azara, is equally appreciated for his assistance.

Alh. Mustapha Ajibola Animasaun, my senior brother, sponsored critical stages of my education despite his financial challenges. I owe him a great gratitude and duly appreciate his kindness.

Malam Adam Taiye Mudi of the Department of Maths, Statistics and Computer Sciences, Kaduna Polytechnic, also assisted in data analysis and is equally appreciated.

The following people are also acknowledged for their technical assistance: Engr. D.A. Awojobi, (Mines Officer, Nasarawa State), Mr. B.O. Aderotoye, (Nigerian Geological Survey Agency Lafia), Engr. I.S. Amoka (Former Director, College of Engineering, Kaduna Polytechnic Kaduna), Engr J.Z. Kwaha, (Former Dean, School of Natural Resources Engineering, Kaduna Polytechnic Kaduna), Dr. E.O. A. Damisa (Former. H.O.D, Mineral Resources Engineering Department, Kaduna Polytechnic Kaduna), Alhaji Mohammed Ali (H.O.D, Mineral Resources Engineering) Dr. B.S. Jatau (Former H.O.D., Mineral Resources Engineering Dept. Kaduna Polytechnic Kaduna), Alhaji Imam – Akeyede Ganiyu (Mines Inspectorate, Minna) and Mr Ismail Adegoke (CBN, Akure Branch).

The contributions of Dr. Asiwaju-Bello (Dept. Applied Geology),Dr. R.D. Aladesanwa (Dept. of Crop Soil and Pest management) and Dr. Kareem (Dept of Mechanical Engineering), Federal University of Technology, Akure, are highly acknowledged.

Without doubt, I am deeply indebted to my dear wife, Hajia Kudirat Ajibola Salati, my beloved son, Muhammad Salis and my lovely daughters, Saleemat Wuraola and Shifa' Abolore for their patience, endurance, understanding, prayers and encouragement throughout the busy and hectic period of my study and research work. I owe my parents the greatest debt, for giving me sound moral upbringing and good education. I say 'thank you'. 'God bless you.'

The entire members of staff of Mineral Resources Engineering Department, Kaduna Polytechnic, Kaduna, also deserve my appreciation, as well as my fellow Masters colleagues at FUTA.

Mallam Mansur (Pako Ventures FUTA), also assisted in no small measure through manuscript typing and data analysis. I am grateful to Mal. Ismail Ibrahim for re-typing the original manuscript and rendering further technical assistance. I thank all my brothers, sisters, cousins, all my family members, my colleagues at work, and indeed my dear friends who assisted me with serious prayers towards the success of this work

This acknowledgement would not be complete without appreciating the positive contributors of all authors whose works have been used as reference materials in this research. Their knowledge has enriched this work and added glamour to it in so many ways.

Thank you all for your supports and prayers.

L.K. Salati.

DEDICATION

This research work is dedicated to the **Almighty ALLAH** for His Divine Mercy and Favours upon me and the entire members of my family while undergoing this programme.

ABSTRACT

This research work presents the economic assessment of mining techniques practiced on veins 1 and 17 of Azara barytes deposits in Nasarawa State. The mechanized, semi-mechanized and artisanal mining techniques were appraised based on certain economic indices such as productivity, extraction cost, selling price, importation trend and net profit. Global Positioning System (GPS) was used to take readings of veins 1 and 17 and determine their coordinates which were then transferred to the topographical map. Statistical Package for Social Sciences (SPSS) was used for the statistical analysis of the data collected ` for economic indices such as daily, monthly and annual productions and cost of production used for assessing the three mining techniques. The data were subjected to analysis of variance (ANOVA), while Duncan's Multiple Range Test was used to verify significant differences among the treatment means at the 5% probability level. Polynomial regression curves between productivity (y) and extraction cost (x) for the different mining techniques were determined using Microsoft Excel (R).Results of the study showed that semi-mechanized method satisfied all the set economic indices more than other methods, thereby emerging as the most suitable mining technique used in the area. Semi-mechanized method recorded the highest productivity of about 33,500 tonnes per annum, while mechanized and artisanal productions were only limited to about 23,908 and 18,050 tonnes per annum respectively, due to technical and financial problems. Results also indicated that lower extraction cost and higher net profit for semi-mechanization gave it an edge over other methods, despite its lower selling price and ever-increasing importation level. It was however, observed that lack of funding, poor management, incessant flooding and inadequate working equipment were the greatest obstacles facing sustainable barytes production. Therefore, adequate funding and technical supports have been indicated as a recipe for the re-organization and integration of the present artisanal mining in the area into formal mining sector.

TABLE OF CONTENTS

CHAPTER TWO- LITERATURE REVIEW **14**

CHAPTER THREE – METHODOLOGY **34**

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE

1.0 INTRODUCTION

Barytes is the most common and abundant ore mineral of Barium. Barytes is a combination of Barium and Sulphur. In its natural form, barytes is composed of Barium Sulphate. According to Eromosele (2005), it is represented in the elemental description as $BasO_4$ because its principal constituent's elements are Baron (BaO), 32.50% and Sulphur (S), 51.10%. Nwoko and Onyemaobi (1997) analyzed Azara barytes ore and found its barium content to be 98%.

Its demand as a major raw material in the oil industry has necessitated a need for regular supply of petroleum production. Barytes occurs as veins filling the fissures in the sedimentary rock (Aderotoye, 1998). It is formed by the process known as secondary enrichment. Brobst (1994) described a class of barytes as occurring in vein and cavity filling deposits. Nwosu (1998) also categorized vein deposits as those formed as a result of the filling of cracks in the earth crust. The vein thickness is usually non-uniform and not beyond ten (10) metres.

MSMD (2003) indicated barytes deposition mostly in hydrothermal veins in faults and fractures within the Benue Trough of Nigeria, notably in Benue, Taraba, Cross River and Nasarawa States. The Middle Benue Trough within which Azara, the study area, is located, is particularly endowed with huge barytes potentials that can adequately serve the oil industry. Government's estimates (MMSD, 2008) put barytes reserves in Nigeria around 10million metric tonnes. However, despite these endowments, barytes exploitation is yet to meet production targets in Nigeria due to shortfalls in its supply. According to Adegboye (2003), Nigeria consumes about 120,000 metric tonnes of barytes per annum and the demand may rise to 300,000 metric tonnes by the year 2010.

In view of this challenge, production constraints have been identified as major obstacles facing regular sourcing and utilization of barytes in Nigeria. While Government's estimates (MSMD, 2005) put barytes production by informal miners at 99.5%, Umar (1999) and Bida (2004) cited major constraints facing a typical mining company operating within Azara barytes veins. These include lack of capital, unfriendly business climates, lack of infrastructures, aged and inadequate equipment and incessant flooding. These problems have placed the artisanal miners at the centre of mining barytes and other mineral deposits thereby limiting production capacity to insignificant volume. Damisa (2007) partly attributed the root cause of the problems to the indigenization policy of early 1970s which drove away foreign investors from Nigeria. This has given way to Government's domination over private sector-led mining activities; hence, total neglect of the solid minerals sector by successive Governments. Adamu (2005) also identified bank's reluctance to invest in the sector as a major contributor to the problem. Miners are solely dependent on bank's funds but banks are conservative in their lending since the solid minerals sector has not yet been developed (Barsky, 1999). Amoka (1998) also cited the need to import equipment, machinery and spare parts for mineral exploration, mining and processing, which cost huge foreign exchange and involve stringent importation processes, as part of the problem.

However, studies have shown that the mining sector has the potentials to attract Foreign Direct Investments (FDI) for accelerated growth in the economy (De Gregorior, 2004). Adegboye (2007) opined that these potentials could be translated into sustainability, only if the random and pick-rooting nature of the artisanal miner's operations were upgraded and controlled to fit into conventional mining methods. This requires not only a change in Government's orientation towards solid minerals development, but also the need to address the shortage of indigenous professionals and technical manpower facing the sector (Nwude, 2007). According to Worth (1991), relaxation of conservative and stringent conditions for small mining companies can also help them attain greatness in production in future. Competent private investors will readily open up barytes deposits, if artisanal miners' operations are adequately integrated. This will boost their production and expand their operational capacity.

1.1 Objectives of the Study

The specific objectives of this research work are to:

(a) carry out the economic analysis of mining techniques for Azara barytes deposits; and

(b) determine economic models for Azara barytes production.

1.2 Justification

The decline in local production and supply of barytes for the preparation of drilling mud in petroleum production in Nigeria has become a major source of concern over the years. The urgent need to boost its production has, therefore, necessitated a review of the present mining techniques employed in working barytes deposits.

In view of under development, wasteful mining and other associated problems, huge economic losses rather than anticipated profits have been recorded. An attempt to boost local production through the ban on barytes importation could not even salvage the situation. Hence, allowing competent private investors to come in and expand the horizon and operational capacity of artisanal and small-scale miners appears to be a feasible alternative (Salati and Amoka, 2007). The improvement of their local technology is also key to achieving this goal, since they control the production of minerals to a large extent (Nashuni, 2003). A combined effort through a private sector-led initiative could be an impetus to achieving the 2010 target of 300,000 metric tonnes of barytes demand per annum set by Adegboye (2003).

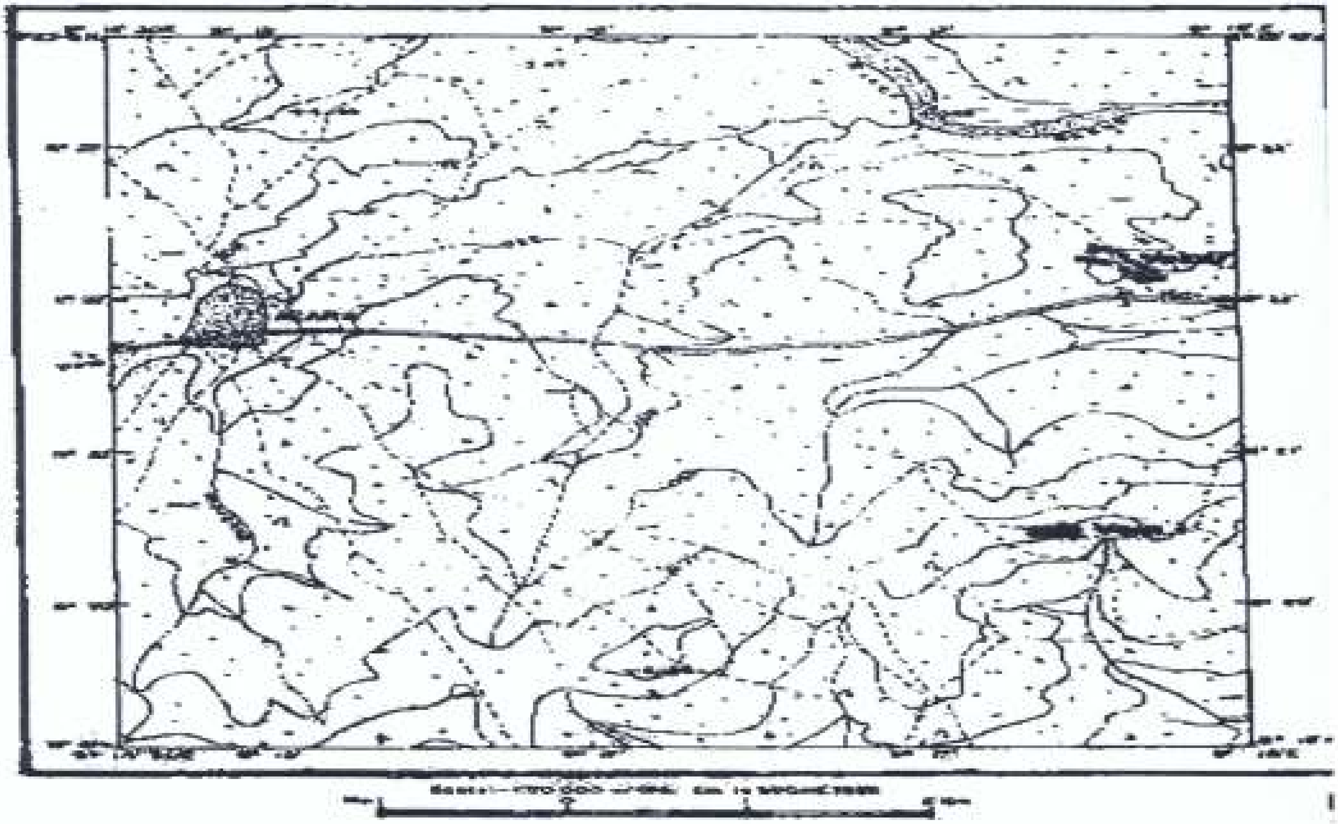
Hence, the choice of barytes as one of the 'seven strategic minerals' by the present government (Ishola, 2008) is a welcome idea. It is only hoped that such a lofty policy would be vigorously pursued through objective and holistic implementation. This study, therefore, appraises the economic outlook of the major aspects that are central to boosting barytes production in Nigeria. Table 1.1 shows the GPS readings at veins 17 and 1 of Azara, Nasarawa State.

Table 1. 1: GPS Reading at Veins 17 and 1.

VEIN	POINT	ELEVATION (M)	COORDINATES (NORTH)	COORDINATES (EAST)
17	1	113	$08^{0}22.254^{1}$	$009^{0}17.554^{1}$
17	2	111	$08^{0}22.279^{1}$	$009^{0}17.568^{1}$
17	3	113	$08^{0}22.293^{1}$	$009^{0}17.585^{1}$
17	4	116	$08^{0}22.280^{1}$	$009^{0}17.607^{1}$
17	5	113	$08^{0}22.268^{1}$	$009^{0}17.618^{1}$
17	6	114	$08^{0}22.248^{1}$	$009^{0}17.552^{1}$
17	7	113	$08^{0}22.224^{1}$	$009^{0}17.696^{1}$
17	8	114	$08^{0}22.204^{1}$	$009^{0}17.725^{1}$
17	9	119	$08^{0}22.183^{1}$	$009^{0}17.715^{1}$
17	10	108	$08^{0}22.155^{1}$	$009^{0}17.698^{1}$
17	11	111	$08^{0}22.175^{1}$	$009^{0}17.671^{1}$
17	12	112	$08^{0}22.203^{1}$	$009^{0}17.638^{1}$
17	13	114	$08^{0}22.218^{1}$	$009^{0}17.595^{1}$
17	14	114	$08^{0}22.240^{1}$	$009^{0}17.587^{1}$
1	1	151	$08^{0}20.431^{1}$	$009^{0}17.513^{1}$
1	2	148	$08^{0}20.460^{1}$	$009^{0}17.481^{1}$
1	3	147	$08^{0}20.474^{1}$	$009^{0}17.436^{1}$
1	4	145	$08^{0}20.487^{1}$	$009^{0}17.401^{1}$
1	5	143	$08^{0}20.473^{1}$	$009^{0}17.369^{1}$
1	6	146	$08^{0}20.447^{1}$	$009^{0}17.359^{1}$
1	7	151	$08^{0}20.426^{1}$	$009^{0}17.427^{1}$
1	8	153	$08^{0}20.418^{1}$	$009^{0}17.483^{1}$
1	9	144	$08^{0}20.473^{1}$	$009^{0}17.500^{1}$
1	10	142	$08^{0}20.506^{1}$	$009^{0}17.473^{1}$

1.3 Location and Accessibility of the Study Area

Azara, the study area and headquarters of Azara Development Area is located under Awe Local Government Area of Nasarawa State. The town is located 97 kilometres South-East of Lafia, the State capital. It lies between latitude 8^0 North and longitude 9^0 East and is accessible through Kanje, a village located on Lafia-Awe Benue road (axis). Kanje stretches to Azara through a 23 kilometre untarred road. Figure 1.1 shows the topographical map of Azara, indicating veins 17 and 1 respectively.



Legend

Town Sample *GPS point* ●●●● Light forest

Road *River/stream* *Awe formation* :::

Template --- --- ---- Contour lines 555 Area-Liable flood

Scrub..................

Figure 1.1: Topographical Map of Azara indicating barytes Veins 17 and 1 (Modified After the Federal Surveys, Nigeria,1967).

Figure 1.2 also shows map of Nasarawa State, showing the study area and other neighbouring barytes mineralized zones.

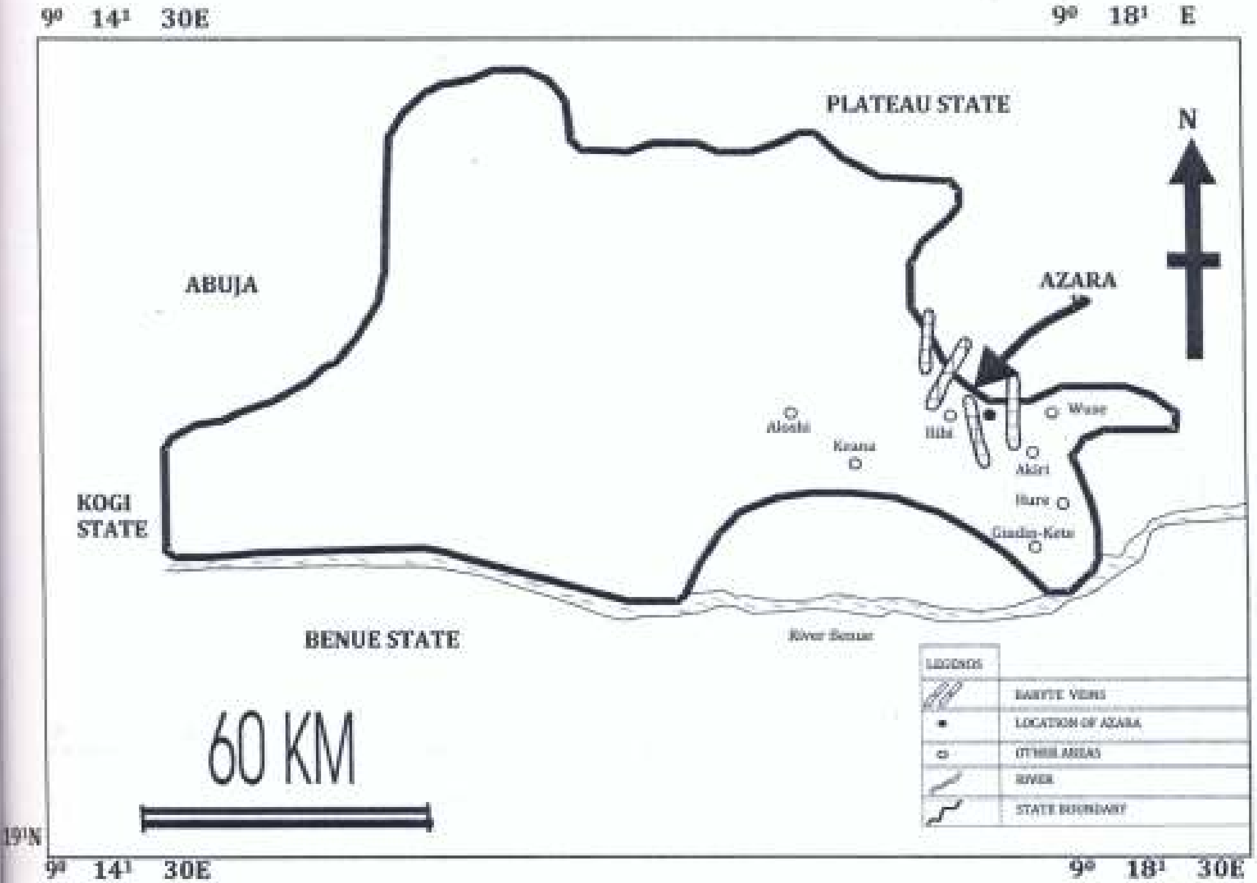


Figure 1.2: Map of Nasarawa State showing Azara and other neighbouring barytes mineralized areas (Adapted After Aderotoye, 1988).

1.4 Occupation, population and other information about Azara community

Azara falls within the Middle Benue Trough located in the Middle Belt Zone of which Nasarawa State is part. The area has high annual rainfall and good vegetation that supports farming to a large extent. Azara has a population of about 20,000 people.

The initial occupation and means of livelihood of Azara people include farming, fishing along some part of River Benue, as well as salt mining which had been carried out for two (2) centuries up to date. Many agricultural products are produced within Azara, with rice farmers scattering along the Benue Valley. Fishing is carried out along River Wuse and other rivers around Azara. The rivers also serve as sources of water to the people.

At present, barytes mining has become a dominant occupation of Azara indigenes alongside other means of livelihood like farming and fishing. Presently, hundreds of residents and indigenes within and outside Azara are seriously engaged in barytes mining, taking it as their sole occupation and main source of livelihood.

The two main seasons namely, rainy (wet) and dry season afford the people in the area to carry out their occupations of farming/fishing and mining respectively. During the dry season, mining activities are carried out intensely, while in the rainy season (when the mining pits are flooded), the farmers and fishermen return to their farms and rivers respectively.

1.5 Brief history of barytes mining in Azara

According to Eromosele (2005), barytes deposits were discovered in Azara in the early 1960s. Exploratory search lasted for about a decade, between 1975 and 1985 by the Nigeria Mining Corporation. The Nigeria barytes Mining and Processing Company (NBMPC) Limited, incorporated in 1988, was charged with the exploration and exploitation of barytes in Azara and any part of Nigeria where it is found.

The company (NBMPC Ltd) was wholly owned by the defunct Nigeria Mining Corporation (NMC) with its headquarters in Jos. Initial reconnaissance revealed eighteen (18) veins in areas like Azara, Aloshi, Akiri, Wuse and Keana in Awe Local Government Area. Out of these eighteen (18) veins, detail exploration works were carried out on five (5) veins and these established a total of seven hundred and thirty thousand (730,000) metric tonnes of barytes. Veins 1, 2, 5, 17 and 18 are the five veins presently in use.

1.6 Previous works done

Though geological prospecting and reports on Nasarawa State barytes are scanty, Umar (1999) and Bida (2004) reported initial reconnaissance work covering Azara and Wuse/Akiri districts across River Wuse. The work carried out by the defunct Nigerian Mining Corporation (NMC) between 1975 and 1985 under exploration carried out on five (5) out of the eighteen (18) veins further established an indicated reserve of about 730,000 metric tonnes. The remaining thirteen (13) veins are yet to be fully explored.

Offodile (2002) reported a ground water hydrology of about 24m for Awe formation of the Middle Benue Valley within which Azara falls. The borehole results for the formation indicated a water depth of about 19.30m, while the rise of water in borehole attained 9.3m. During mining activities, however, water is sometimes noticeable at a depth of about 10 to 15m, especially in the water – lodged areas of the study area.

All the previous works carried out showed that the deeper open cast barytes deposits in Azara have been extracted by mechanized and semi-mechanized open cast mining methods between 1984 and 2004 (Umar, 1999 and Bida, 2004). But artisanal mining had already taken over around 1998, when the operation machineries could no longer be maintained, and the depth of working had gone beyond economic mechanical operation.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Geology of the Study Area

Azara falls within the cretaceous sedimentary series in the Middle Benue Basin. Barytes bearing veins in the Azara lode occur as lenticular bodies within sandstone and clays at the fracture zones (Aderotoye, 1998). The veins are open-space fissure filling and are characterized by pinching and swelling. Figure 2.1 shows a typical vein deposit.

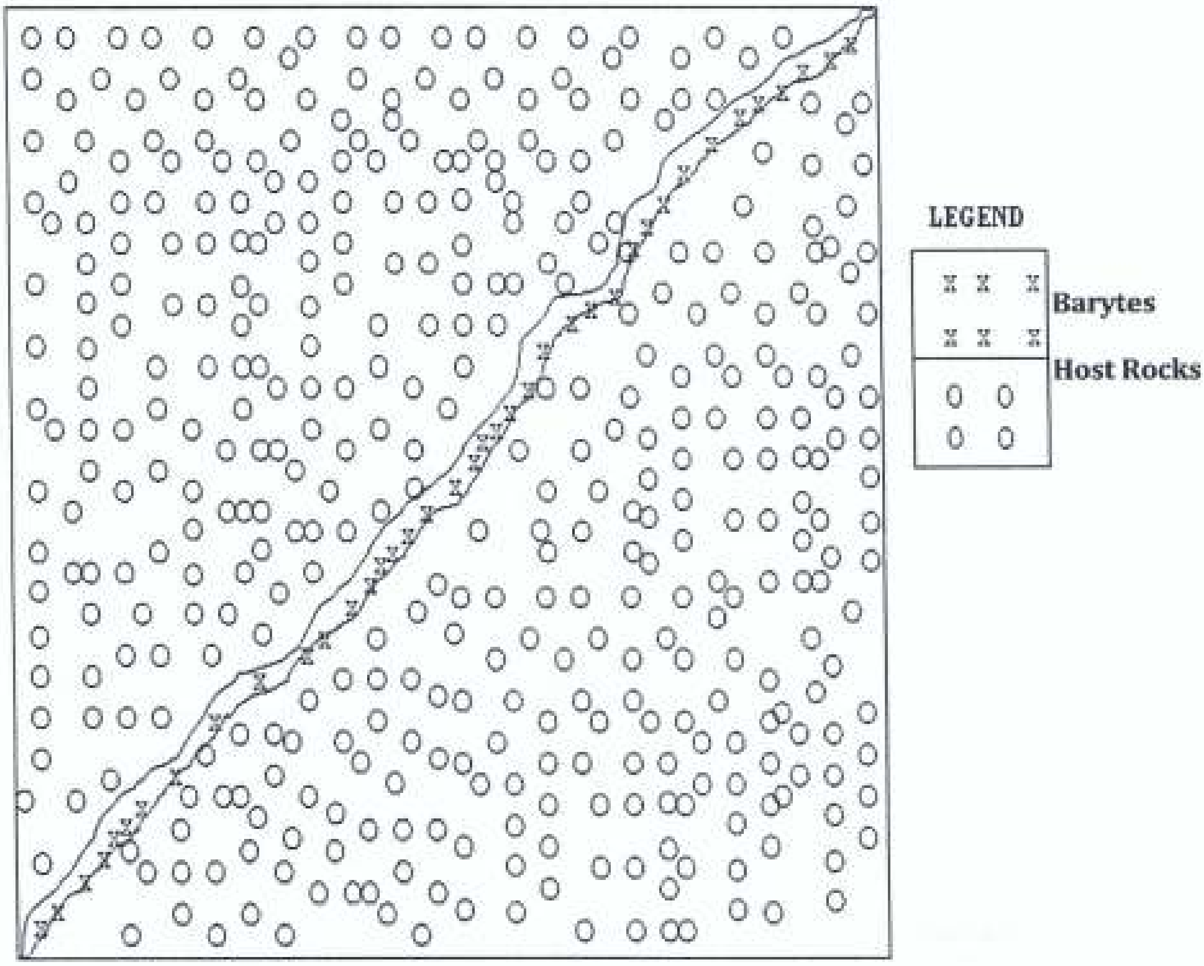


Figure 2.1: Typical Veins Deposits Such as those Occurring within the Benue Trough (Modified after Nwosu, 1998).

The veins trend generally in the N-S direction. A few of them trend in NW-SE direction. It contains tiny vulgs measuring about few millimeters to 2 centimetres. The veins strike is 0^{0} or 180^{0} and the dip is steep or vertical ($80 - 90^{0}$). Other strikes observed are between 110^{0} and 120^{0}. The veins dimensions also vary from 0.5m to 4m in width by 100m to 1km in length. The thickness is, therefore, about 3.5m.

The Awe formation within which Azara is located was deposited as passage (transitional) beds during the late Albian. Early cenomanian regression. The type locality is in the town of Awe where the thickness is about 100m. The formation according to Obaje et al (2006), consists of flaggy, whitish, and medium to coarse-grained calcareous sandstones, carbonaceous shales and claystones. The sandstones become finer grained and more micaceous towards the base with fine current beddings.

Associated minerals are gangue of iron probably ($FeCO_3$ siderite), sulphide and quartz (Aderotoye, 1998) which tend to reduce the specific gravity of the unprocessed barytes (MSMD, 2003).

2.2 Opencast Mining Methods

Barytes deposits have been exploited by opencast mining techniques in recent times using both conventional and manual means. The following mining techniques have, therefore, been identified for working barytes veins such as those in the study area, Azara:

2.2.1 Mechanized Mining Technique

In mechanized mining, mineral deposits are worked in accordance with the stipulated rules and standards, adequate equipment and best mining practices that safeguard both economic and safety interest. Hartman (1987) argued that the mechanical extraction class (such as opencast mining) employs mechanical processes in a dry environment to free minerals from the earth. Macfadzean and Tyler (1990) cited the working of barytes veins situated at a very high altitude by open-casting. Fritts (1990) also reported large scale barytes mining, with shafts sunk as deep as 150 metres, and tunnels about 1.609 kilometer in length. Working levels could reach 198 metres to 195 metres, thus indicating great depths of underground mining.

Drilling and blasting are the initiating processes of exposing and loosening a mechanized open pit mine. According to Mallo and Nwude (2007), blasting process involves drilling and cleaning of blast holes, loading the holes with a suitable explosive and igniter or detonator, stemming the hole and firing or setting off the charge. Explosive materials consist of explosives and firing devices. The degree of rock fragmentation, however, depends on the amount of explosives used as the spacing and burden of the drill holes (Isife and Adeloye, 1999).

Excavation and loading entail the extraction and movement of the material or ore to the haulage vessel (Nwosu, 1998). According to Rzhevsky (1985), haulage units have been identified thus (Hartman, 1987): loading, traveling loaded, dumping and traveling empty. Cost of haulage constitutes about 50 to 70% of the total unit cost of mining. Isife and Adeloye (2001) argued that such cost of hauling is lessened materially by introducing haulage vehicles or by replacing hard labour by mechanical hauling.

Waste disposal involves dumping of unwanted rock materials in waste dump. The most practical way of disposing barren rocks is by dumping into mined out space (Nwosu, 1998). The use of waste – dump excavators, plough and bulldozer to carry out such operation has been identified (Rzhevsky, 1985 and Rzhevsky, 1987). Waste disposal is, however, sometimes incorporated in production cycle.

Dewatering is used to solve flooding problems partially or completely in open cast mine to avoid jeopardizing safety and productivity. Umar (1999) and Bida (2004) observed that persistent flooding of mines could potentially lead to damage of mining equipment, stoppage of mining activities and staff retrenchment. Dewatering, however, ensures the stability of bench high-walls and open-pit banks (Popov, 1971). Nwude and Mallo (1999) have advocated the use of submersible dewatering pumps which have the inherent advantage of simply adding airline extensions at great deaths. Hendricks and Dahlstrand (1979) also argued that it is very difficult to operate with much water in the pit, while its presence in the pit walls usually reduces slope stability. Water affects blasting, equipment, operation and maintenance, road construction and even ore quality. Plate 2.1 shows dewatering process at Azara.

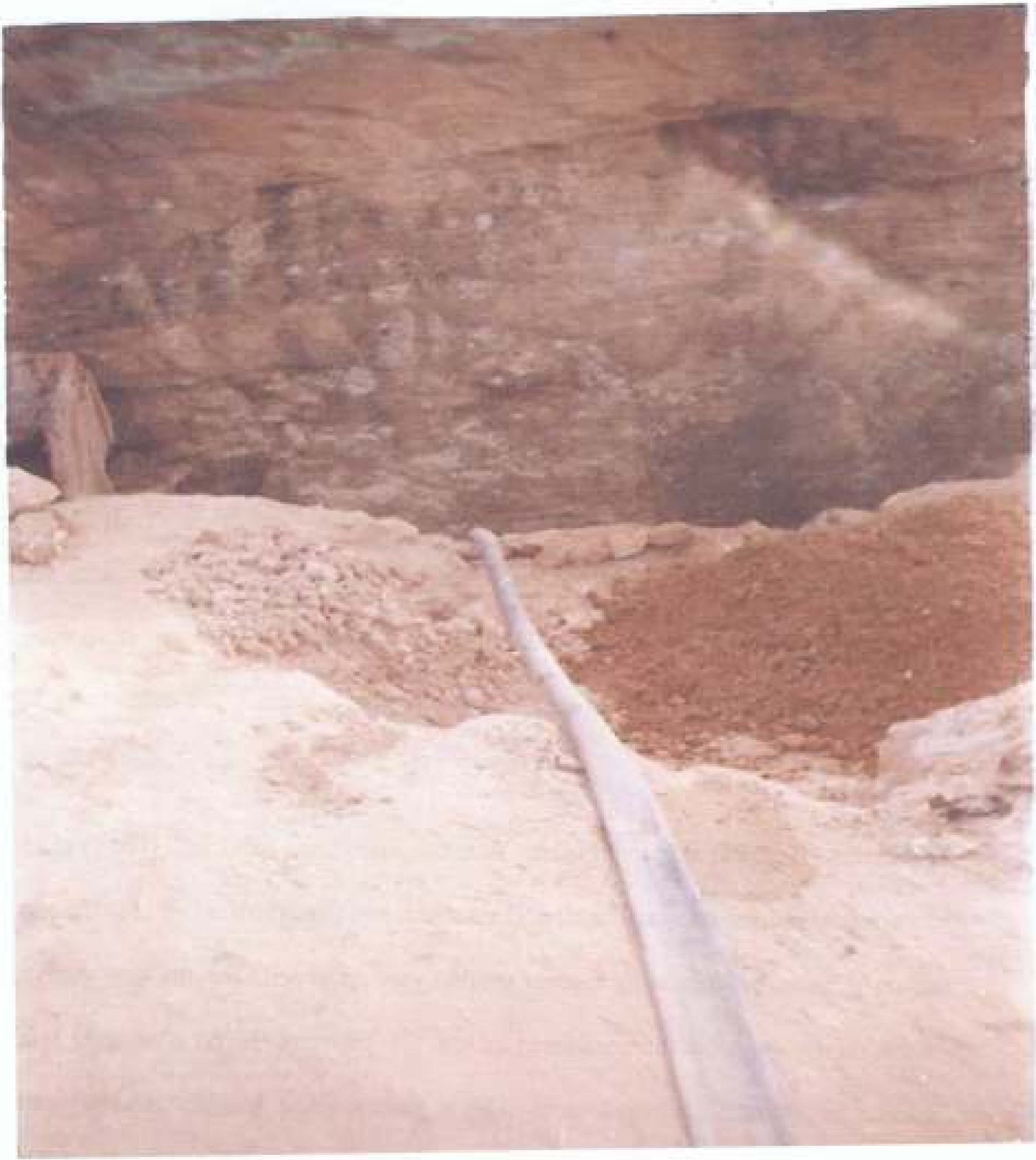


Plate 2.1: Dewatering in Progress at Azara

Opencast operations also require slope stability measures to safeguard lives and properties in the mines. Akande and Idris (2006) argued that the development and protection of infrastructures, home and natural resources constitute a major need for a stable slope. Failure along pre-existing structural discontinuities formed through intact rock may give rise to rock slope instability in a mine.

2.2.2 Semi-Mechanized Mining Technique

In semi-mechanization, mine development, drilling and blasting are done manually, while haulage is fully or partially mechanized. The search for higher ore recovery mostly necessitates semi-mechanized mining, especially in special geological situations. Umar (1999) cited the use of selective mechanized stripping of overburden and manual wining of ore in Azara barytes deposits which occur in narrow veins.

Bida (2004) also cited semi-mechanization of barytes veins which is sometimes necessitated by lack of funds and incessant flooding. The semi mechanized tribute system was employed to mine very narrow veins with minimal dilution. Amoka and Ogunbajo (2003) reported the use of semi-mechanized methods for mine development, drilling and blasting as well as haulage in a number of surface mines.

2.2.3 Artisanal Mining Technique

Artisanal mining method involves mining with minimal capital and labour requirements. Miners involved are generally unskilled, using simple implements such as diggers, shovels and spades (Amoka and Ogunbajo, 2003). Akande and Amos (2005) reported artisanal mining of barytes veins with implements such as diggers, shovels, hammers and so on. Plates 2.2 (a) and 2.2(b) show artisanal miners working along Azara vein deposit.

Plate 2.2 (a): Miners working manually along Azara vein Orientation.

Plate 2.2 (b): Miners working manually along Azara Vein Trend

In cases where rocks are encountered such are manually drilled and blasted to fragment the rocks.

The pits worked with this technique could be as deep as 20metres and more than 2 kilometres in length. Presently, barytes veins in Azara, the study area, are largely being won manually. Semi-mechanization is, however, used to complement artisanal mining operations in order to achieve higher ore recovery. Akande and Adebimpe (2007) also identified artisanal mining as a means of reducing poverty among rural dwellers, when properly exploited. Plate 2.3 shows local miners working inside a pit at Azara.

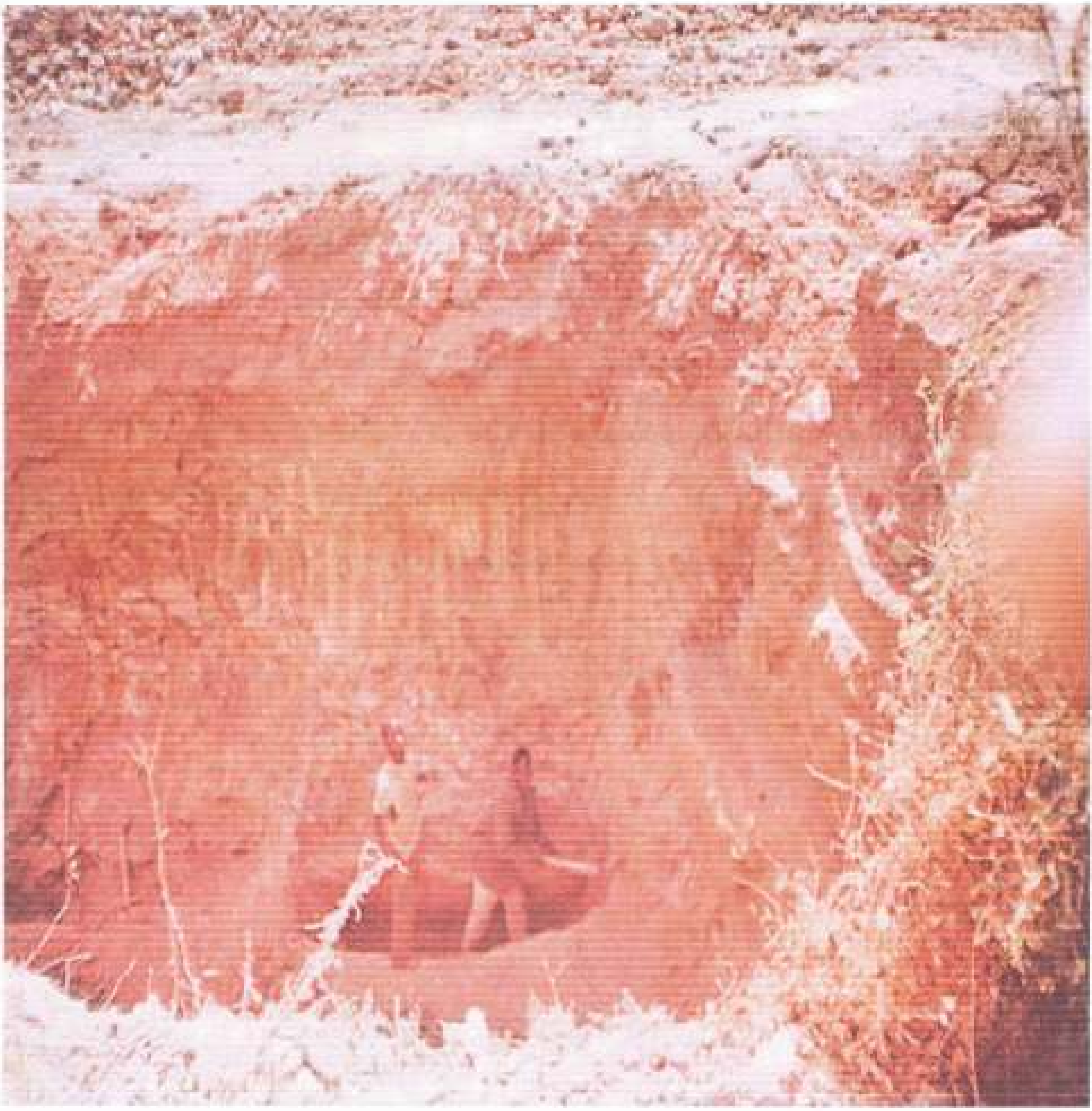


Plate 2.3: Local Miners working in a pit

2.2.4 Loto (Sub-Surface) Mining Technique

Lotoing is an artisanal and small-scale mining device whereby small underground openings are created in an open mine to gain access and win ore maximally. The innovation targets higher mineral recovery and hence, higher productivity. Mallo (2007) identified sub-surface 'loto' mining as an unscientific method of mining mineral deposits. The method involves the sinking of vertical cylindrical pits of various depths to establish contact with the mineral. Once the mineral deposit is struck, it is won through horizontal excavation in the direction of the deposit. Figures 2.2 and 2.3 show loto mineral deposits and profile of loto workings respectively.

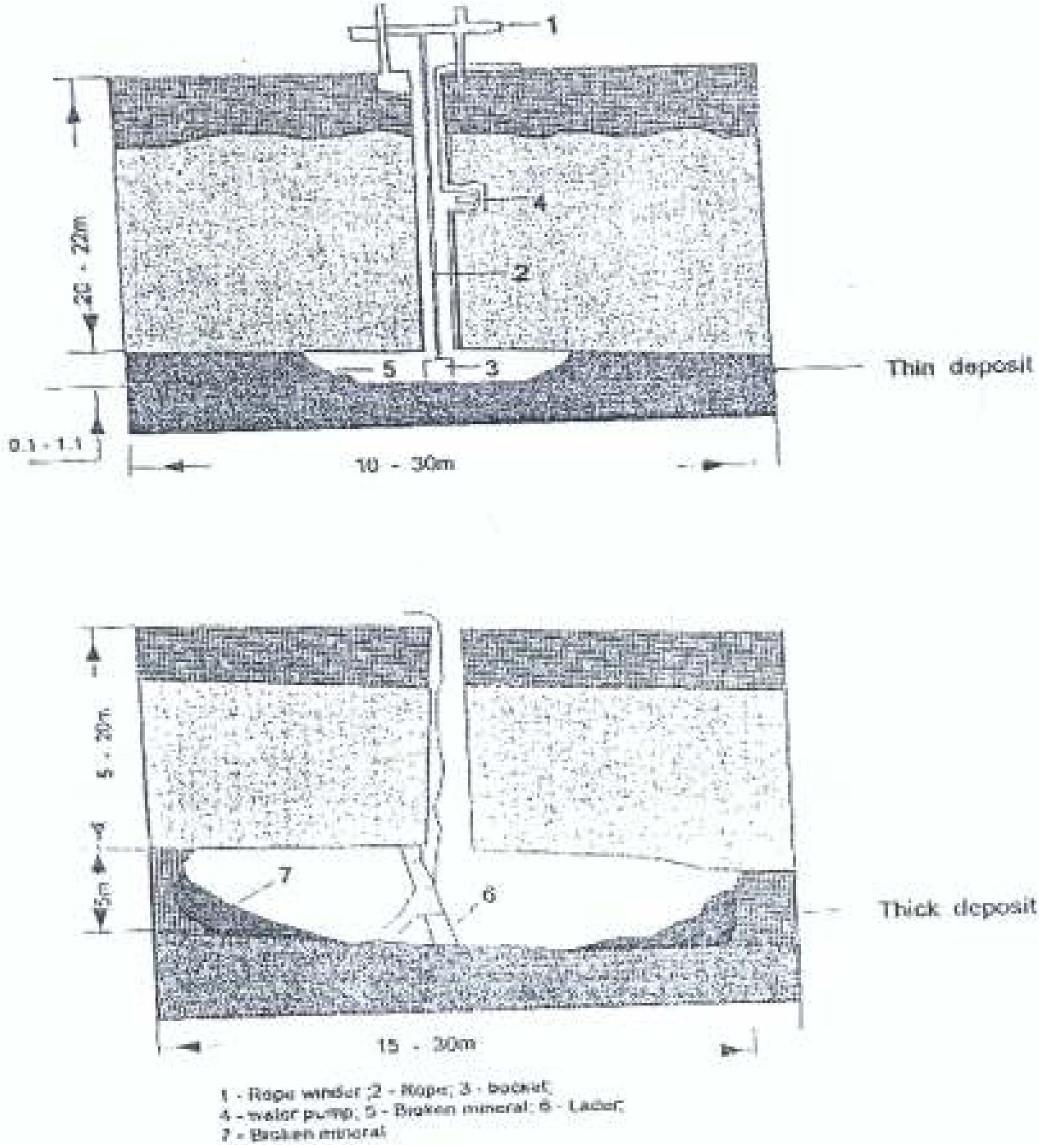


Figure 2.2: Sub-surface "Loto" mining of thin and thick mineral deposit (source: Mallo,2007).

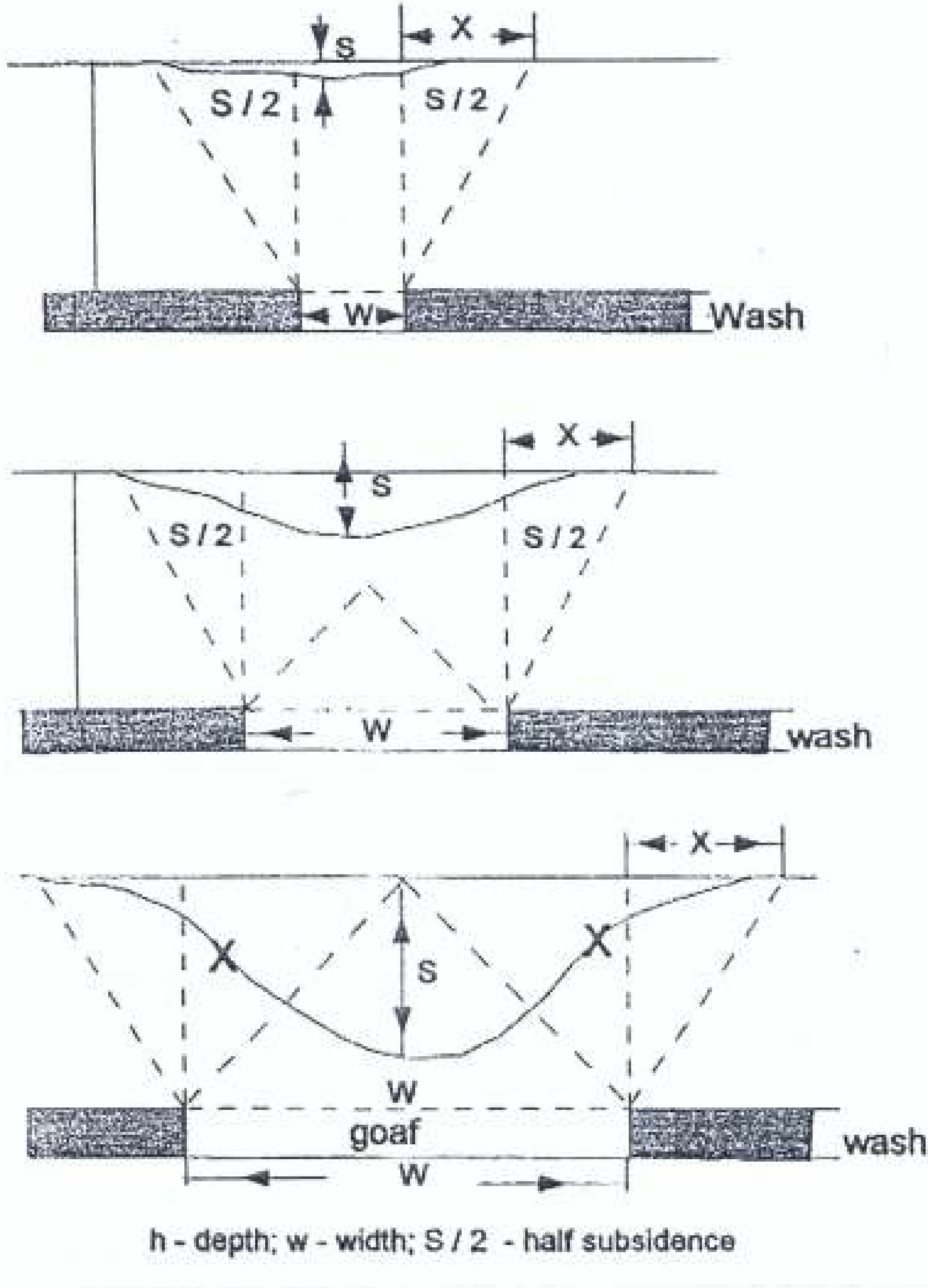


Figure 2.3: Subsidence profile of Loto workings of various widths

(source: Mallo, 2007).

Amoka and Ogunbajo (2003) reported loto mining around Plateau, Kaduna, Niger, Osun, Kogi and Edo States. In Azara loto mining is not pronounced as the normal artisanal mining method has gained prominence, except around vein 1 where 'anitromising veins' (veins with a network of formations) are worked. Akande and Amos (2005), however, reported the creation of large open pit holes due to unplanned and indiscriminate mining around few veins at Azara. A major disadvantage of loto mining is the susceptibility of hanging walls to caving which poses a threat to miners' lives.

2.3 Uses of Barytes

Barytes has a lot industrial uses. It is extensively used as slurry in the preparation of drilling mud for well drilling in the oil industry (Umar, 1999; Bida, 2004). This singular use as a weighing agent or weight fillers in oil well drilling mud consumes more than 90% of world's production of barytes (MSMD, 2003). Since it is the chief constituent of lithopone paint, it is used as colour pigments in paints and textile industries (Adetoroye, 1998; Umar, 1999; MSMD, 2004). It is the main source of Barium chemicals and also finds application in glass making. Eromosele (2005) has also identified the use of barytes in the making of animal feeds, fertilizers and so on. The whitish colour of Azara barytes and its high specific gravity (S.G) account for its better use in the paper industry. It is also used for coagulating rubber in rubber processing industry, even in the absence of sulphur which helps in vulcanizing rubber. The ability of barytes to absorb gamma radiation makes it useful in concrete for nuclear shielding.

2.4 Grade (Specific Gravity) of barytes

There are two broad grades of barytes. These are high specific gravity grade (High S.G) and low specific gravity grade (Low S.G).

The grades are commonly called high grades and low grades respectively. The grades are measured in specific gravity unit of measurement which can be determined in the laboratory. A grade that falls below 4.0 (S.G) is classified as low grade baryte, whereas a grade that rises above, between 4.2 (S.G) and 4.5 (S.G) is classified as high grade. The high grade is that which suits the oil and gas industry. This accounts for its high demand and higher cost. For example, at Azara mining site, the low grade barytes sold for between two thousand naira (N2,000) and three thousand naira (N3,000) for a metric tonne, whereas the high grade sold for five thousand naira (N5,000) for a metric tonne as at 2005 (Eromosele, 2005). Currently, low grade barytes sells for four thousand naira (N4,000) while a high grade sells for six thousand naira (N6,000) and above per metric tonne.

However, Government's reports (MSMD, 2003) cited low specific gravity (S.G) as the premise on which lack of patronage of Nigeria's barytes by the major end-users, especially from outside Nigeria, is based. While Bida (2004) put the average specific gravity of Azara barytes at 3.8 for the five (5) currently worked vein deposits, Nwoke (1997) attributed the low percentage of such impurities as Fe_2O_3 and SiO_2 in Azara barytes to its upgraded status geared towards meeting the specifications of oil and gas companies. This is in addition to the fact that upgrading and blending efforts were being made at different periods to meet the minimum API (American Petroleum Institute) standard of 4.2 (Umar, 1999; Bida, 2004). Price of barytes products varies across the world markets depending on purity and conformity to API. There is, therefore, need for latest standard experimentation to determine and confirm the actual grade of barytes deposits in Azara and neighbouring areas.

However, it is interesting to note that at Port Harcourt, the price is remarkably higher as a metric tonne of high grade barytes sells for about twenty thousand naira (N20, 000). This is apparently because there are both processing factories and refineries there (Eromosele, 2005). This product could also be locally processed and sold as finished product for delivery to refineries in Nigeria. It is particularly interesting to know that a metric tonne of finished product sells for one hundred and twenty thousand naira (N120, 000).

According to ICON Groups (2007), a tonne of barytes at the international market sells for $325 and above (about N37, 375). This, therefore, implies that Nigerian barytes stands a bright chance of earning huge revenue for the country's economy from the international market, if exported. Although mineral market and prices are unpredictable and are subject to frequent fluctuations and inflation (Amoka, 1997), Nigerian barytes market enjoys a very competitive situation. Such a competitive market faces price increase, better patronage and consequently, greater revenue (Campbell, 1999). It is, therefore, hoped that barytes exploitation and processing in Nigeria would be improved upon to attain this expectation.

2.5 Demand and Supply of Barytes

The world annual output of barytes has risen in the early 2000s, with production increasing from 5.8million metric tones in 2000 to an estimated 7.8million metric tonnes in 2005, an average growth rate of over 6% per annum.

Demand for drilling grade barytes has increased exceptionally strongly since 2003 (Roskill, 2007). In the longer term, oil and natural gas are expected to increase their share of total energy requirements from 62% in 2005 to 67% in 2020, which will increase demand for drilling grade barytes in exploration and development. There has been a rapid decline in production of Barium carbonate in the Western world, with a significant move to China.

World's barytes reserves in 2006 are estimated to be approximately 200million metric tones. China and India together account for almost 60% of the world's barytes reserves and resources. The only other country with substantial barytes reserves is the USA, which has 9% of the world's total.

China has been the largest producer of barytes for many years, but during the 1990s it strengthened its position, accounting for 52% in 2005, compared with 30% in 1990. The USA is easily the largest barytes consumer, accounting for 52% in 2005, compared with 39% of world demand in 2005, some 87% of which was imported (Roskill, 2007). In contrast, China is the other major barytes consumer, accounting for 13% of world demand, although in this case demand was met entirely from domestic production.

In Nigeria barytes production from Azara declined drastically in 1993 and 1994 due to fall in demand (Umar, 1999). As at 1999, the total barytes requirements remained around 60,000 metric tonnes per annum. But this target could not be met due to continuous decline in production amidst increasing local demands. Bida (2004) reported that barytes production from Azara rose from about 2,200 metric tones in the year 2000 to about 3,400 metric tonnes and 5,000 metric tones in the years 2001 and 2002 respectively.

Government reports (MSMD, 2003) put 150,000 metric tonnes of barytes as the estimated annual demands in Nigeria, while about 40,000 metric tonnes were only attainable. This low production figure, amongst other factors, is occasioned by lack of patronage of Nigeria's barytes by the major end-users, especially from outside Nigeria.

Three US companies account for about 85% of world's sales of drilling fluids (Roskill, 2007). These are MI – SWACO (42%), Baroid Drilling Fluids (30%) and Baker Hughes Inteq (13%). They also control a significant proportion of barytes production and processing capacity world wide. Umar (1999) also cited certain oil drilling companies which contracted Azara barytes products to service their rigs.

These include M – I Drilling, Baroid Drilling Chemical Products Ltd., Dowell Schlumberger and Millpark Nigeria.

Demand for Barium chemicals is expected to rise more slowly as the growth of LCD and plasma TVs displaces barium carbonate in traditional CRT technology. Overall, a growth of 2-3% in the barium chemicals market is expected through 2015 (Roskill, 2007). Fillers are the third significant market for barytes, accounting for 600,000 tonnes or 8% of world's consumption in 2005. About half of this is used in the automobile industry. The market for filler applications is expected to grow to about 2.5% per annum by 2015.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Materials

The approach to this research was through data collection methods such as field measurements, personal interviews, personal observation and photograph shots. Global Positioning System (GPS) was used to determine the coordinates of barytes deposits in the study area, which were then transferred to the topographical map. Personal interviews granted by field engineers, production supervisors and former chief executives of defunct companies in the area were complemented by researcher's personal observations of operations and equipment used. Photographs of the various spots, equipment and operations were also taken in addition to World Wide Web data collection for global comparison. Data collected for economic indices such as daily, monthly and annual productions, as well as cost of production were used for assessing the three (3) mining methods (mechanized, semi-mechanized and artisanal mining techniques) and were analyzed using Statistical Package for Social Sciences (SPSS).

3.2 Approach to Data Analysis

Statistical Package for Social Sciences (SPSS) was used for the statistical analysis of all field data collected. The data were then subjected to for analysis of variance (ANOVA) at $\alpha \leq 0.05$, while Duncan's Multiple Range Test was used to verify significant differences among the treatment means at the 5% probability level.

Polynomial regression curves between productivity (Y) and extraction cost (X) for the different mining techniques were determined using micro-soft Excel (R).

ANOVA (Analysis of Variance) is a statistical technique used to compared three or more sample means to determine whether they differ significantly or not. Here we are comparing the mean productivity, extraction cost, selling price of barytes, importation trend and net profit, with respect to the three methods of extraction (Mechanized, Semi-Mechanized and Artisanal) and were found to be significantly different from each other.

Duncan Multiple Range Test is a multiple comparison technique applied after ANOVA had detected a significant difference among the sample means. It used to determine which pair of treatment means differ significantly in order to possibly recommend any of them.

R^2 means the Coefficient of Determination. It measures the percentage of the variation in the dependent variable (Y) that is explained by the variation in the independent variable (X). it used to determined the adequacy of the model. The closer the value of R^2 to 1 the more adequate the model.

In this research, $R^2 = 1$ implies that 100% variation in the productivity (Y) is explained by the variation in the extraction cost. Hence, the polynomial regression model fits the data adequately.

$R^2 = 0.3662$ implies that only 36.62% of the variation in the productivity is explained by the variation in the extraction cost. Hence, only 36.62% of the productivity can be explained using the polynomial model.

3.3 Economic Analysis

Barytes production employs different exploitation methods which require adequate economic appraisal in order to determine their profit potentials. But before any economic analysis or decision making can be undertaken, the operating and capital costs of equipment must be estimated (Rungel, 1998). At Azara costs of mechanical equipment could not be undertaken as all the machines previously used for barytes mining are presently dilapidated and rotten.

However, costing of simple implements and production materials used by artisanal miners has been done to justify their usage and profitability of the entire mining project.

But another socioeconomic analytical technique that enable meaningful evaluation over larger period of time (and where discounting is actually incorporated in the process) is the Benefit – Cost method. In this method the present value of all quantifiable potential benefit arising from a given project (economic, social and environmental) are summed up and compared with the present value of all corresponding costs. As long as the ratio of the cumulative present value of the benefits to the cost is unitary or exceeds one, the potential project is socially desirable. Rudawsky (1986) summed up the method algebraically thus:

$$\sum_{i=0}^{i=n} B_i (1+r)^{-n} \div \sum_{i=0}^{i=n} C_i (1+r)^{-n} \geq 1 \text{------------------------(1)}$$

Where
Bi= values of the annual benefits,
Ci= values of costs,
n= expected life- time of the project, and
r= the social discount rate.

3.4 Production Evaluation

During mechanized mining an average of 95 tonnes of barytes were produced per day around 1987. Thus, for 22 effective days, (22 x 95 about 2090 tonnes were produced monthly).

Therefore, (2090 x 12) about 25,080 tonnes of barytes were approximately produced per annum. Semi mechanized peak mining period (1991 – 1997), however, witnessed higher production per day as an average of 130 tonnes of barytes were produced daily.

Histrulid and Kuchta (1998) also defined cash flow of a mining project as the net inflow of money that occurs during a specific period.

Thus, For 22 effective days (22 x 130), about 2,860 tonnes were produced monthly. So, (2,860 x 12) approximately 34,320 tonnes of barytes were produced annually.

On the other hand, semi mechanization during the glut period (2000 – 2002) witnessed serious cut in production. About 13 – 18 tonnes of barytes were produced daily.

Thus, for 22 effective days (22 x 13 or 22 x 18), about 286 to 396 tonnes were produced monthly, while (286 x 12 or 396 x 12) about 3,432 to 4,752 tonnes of barytes were approximately produced during the said period.

During artisanal mining (2005 – 2007) an average of 75 tonnes of barytes were produced daily. Thus, 22 effective days produced about (75 x 22) 1,650 tonnes of barytes monthly. Annually, about (1,650 x 12) 19,800 tonnes of barytes were produced.

3.4.1 Revenue and Expenditure

An average of 75 tonnes of barytes are extracted by the artisanal miners daily at Azara. Therefore, at about N5,000 naira per tonne of barytes, approximately sum of (N5,000 x 75 tonnes / day) N375,000.00k is expected to be generated daily as revenue from sale of barytes. A breakdown of expected monthly and annual revenue generation is thus given below:

75 tonnes x 22 effective days = 1,650 tonnes/month

Therefore, 1,650 tonnes x 5,000.00k = N8,250,000

So, about N8,250,000 is expected to be generated monthly at Azara, if daily sale targets of barytes are met.

1,650 tonnes/month x 12months = 19,800tonnes/annum

So, 19,800 tonnes/annum at 5,000tonnes = N99, 000,000

Therefore, about 99 million naira is expected to be generated from barytes sales at Azara annually.

Breakdown of expenditure is also given below:

Drilling and blasting	N100,000 / day
Excavation and haulage	
(Fuelling and lubrication cost)	N25,000 / day
(Labour cost)	N18,000 / day
Dewatering (fuelling & labour)	N7,000 / day
Waste disposal	N4,000 / day
Wooden support (for slope stability support)	N1, 250
Total	**N155,250**

Since about N155,250 is spent daily on mining operation at Azara, monthly expenditure is about (N155,250 x 22 effective days) N3,415,500.

Therefore, about (N3, 415,500 x 12months) N40, 986,000 is expended annually.

Apart from the above, other expenses incurred by the miners include the following:

Federal Government (on every departing trailer daily)	N3,600
Local Government	N3,000
Miners association levy (State Government)	N500
Community development levy	N500

Total	**N7,600**

Grand total monthly = N228, 000

Grand total annually = N2, 736,000

Royalty is also paid monthly by miners to the tune of (N10,000) ten thousand naira. Thus, annually a total sum of N120,000 is paid as royalty.

Therefore, total expenditures at Azara are as follows:

Total monthly expenditure

-	Expenses relating to mining operations directly	N3,415,500
-	Levies to government and others	N228,000
-	Royalty	N10,000
	Total	**N3,653,500**

Total annual expenditure

-	Expenses relating to mining operations directly	N40,986,000
-	Levies to government and others	N2,736,000
-	Royalty	N120,000
	Total	**N43,842,000**

3.4.2 Net profit

The net profit generated by mining operations at Azara is calculated as follows:

1. Monthly Gross Profit = Gross Revenue - Operating expenses

   = N8,250,000 – N3,653,500 = N4,596,500

   (Monthly Gross Profit)

   Therefore, Monthly Net Profit

   = Monthly Gross Profit – Tax =

   N4, 096,500 – (228,000 + 10,000)

   = N4, 596,500 – 238,000

   = N4, 358,500 (Net Profit per Month)

2. Annual Gross Profit = Gross Revenue – Operating Expenses

   = N99, 000,000 – N40, 986,000 = N58, 014,000

   (Annual Net Profit)

   Therefore, Annual Net Profit =

   Annual Gross Profit - Tax =

   N58, 014,000 – (2,736,000 + 120,000)

= N58,014,00 – N2,856,000

= N55,158,000 (Annual Net Profit)

It can be seen from the above calculations that as much as fifty-five million naira is realized annually from mining business at Azara. It is interesting to note that despite this amount, the miners are still left with excess profits of seven (7) days which were deducted from thirty working days of a month (only 22 effective working days were used in the revenue calculations and part of expenses calculations).

However, artisanal miners work everyday including weekends, thus the estimated production figures are actually less than what is expected in terms of profit generated.

3.4.3 Cost of Extracting a Tonne of Azara Barytes

The following calculations show how much it costs to extract a tonne of Azara barytes per day:

Average productivity per day = 75tonnes

Labour cost per day = N18,000

Therefore, cost of mining a tonne of barytes per day is N18,000/75tonnes

= N240/tonnes/day

This shows that an approximated sum of N240 is spent to

extract a tonne of barytes from Azara deposits. The ability of the operators to minimize such cost and maximize profit to be generated it, therefore, an important consideration especially when costs of processing and beneficiation are involved.

3.5 Economics of Equipment Utilization

Adequate utilization of mining equipment safeguards economic interests limits wasteful mining and reduces environmental damages. Costing of such working equipment is, therefore, *predicated upon careful economic analysis* of certain indices that determine their use in a particular environment.

Mechanized working barytes deposits involve the use of heavy duty equipment and machineries. Nwosu (1998) opined that modern practice in surface mining witnesses a bias for semi continuous flow technology. This principle of mechanization permits systematic utilization of working equipment in accordance with orderly prescription of mine work schedule. Equipment mine design has, hence, been viewed as a way of boosting productivity and work efficiency in mining operations.

Different large equipment can be used for large scale mining while artisanal mining tools such as diggers, shovels, head pans; etc could also be optimized to some extent. This is necessary especially in a situation whereby Artisanal and small scale mining remains the only option for survival for a small mining community such as Azara in Nasarawa State. Such recommendation should be made easier by preliminary costing of mining equipment, machineries and other accessories (both mechanized and manual) used to exploit and process barytes. The correlation between the working equipment/tools and their production as well as productivity capacity is an important determinant of mine economy.

3.6 Barytes Fragmentation

The method of exploiting any mineral deposits depends on a large extent, the geology and other factors of the mineralized area. Basically, mechanized mining guarantees not only high ore recovery but also higher production rate due to the usage of machine and equipment. But in the absence of adequate capital and working equipment, manual labour through the use of simple implements generates moderate to low ore recovery and at lower production. This is especially true for artisanal mining which is prone to the application of unguided principles.

However, average output per blasting of Azara barytes depends on the following factors regardless of the mining methods used:

1. depth of drilling
2. nature of impurities

3. width of the vein

4. Number of holes (depending on the width and length of the exposed portions).

Depending on the above factors, therefore, average tonnage or output per blasting at Azara (at artisanal mining level) is put at between 5 to 7 tonnes (e.g. at vein 1). Sometimes the recovery is higher due to manual maneuvering within the pit holes.

3.7 Mining Methods and Equipment

In mechanized mining, bulldozer and scrapper are mostly employed for stripping operation, while compressor – driven drill wagon is used for primary drilling. For secondary drilling, jack hamper is most suitable. On the other hand, artisanal mining uses diggers mostly to open up the veins and load using shovels and other loading simple implements.

While mechanized blasting employs the use of explosives and accessories in suitable and measured quantity (Mallo and Nwude, 2007), artisanal mining only uses any available material (such as household electric wire) to carry out such operation; sometimes such operation (blasting) is carried out in a quite simplistic manner by artisanal miners (Amoka and Ogunbajo, 2003).

The following explosives and accessories are used in Azara for blasting operations:

- pink gelatine (for aquiver environment) due to its water resistance ability;

- ANFO (Ammonium Nitrate and Fuel Oil). This is mostly used for non-aquiver environment, especially in the dry season;
- detonating cord
- plain detonating cap or electric detonating cap
- safety fuse.

Delays are not used in Azara. Concerning spacing and burden in blasting process at Azara, two factors are normally considered. These include:

i. nature of orientation of veins;

ii. Level of inclusions (richness or poorness) of the vein portions.

Since the vein swells up and thins at intervals along its direction of occurrence, the design of spacing and burden has to be done to suit such pattern of orientation.

Also, at richer portions the rate of drilling is faster and the charging materials should be minimal to avoid over-fragmentation. At poorer portions (where there are inclusions of quartz, heamatite, magnetite, etc) rate of drilling is slower and more charging materials are required to improve fragmentation. So, due to the peculiarity of Azara vein deposits, spacing and burden should be left to the discretion of the blasting engineer, depending on the nature of orientation as well as the inclusions in the veins. Plate 3.1 below shows charging process for blasting at Emo –Ashapura Mining Company at Azara.

Plate 3.1: **Charging and Preparation for Blasting at Emo-Ashapura Mining Company, Azara**

In the rainy season when the depth of working intensifies, dewatering becomes a major operation which often leads to suspension of mining activities. Artisanal miners in Azara tackle dewatering using mostly 'Yamaha' brand water pump.

The propeller pump works spirally, suctioning or drawing water and pumping it out to the surface. Water pumped out is still used for washing barytes. In a fully mechanized mine, submersible pumps and bigger spiral pumps that use big litter engines are mostly employed (Nwude and Mallo, 1999). Such spiral pumps range from three (3) to eight (8) inches in size.

3.8 Mechanization and Artisanal Mining

Mechanization involves the use of machines and equipment whose technological complex tends to achieve the required production capacity in the working of a mine. On the other hand, artisanal mining involves manual application of techniques and implements and often without legal backing in working a mineral deposit. Nwosu (1998) opined that a mechanized equipment complex must ensure safe production, maximum extraction of ore and exploitation of all types of ores present in the deposit. These key elements are not evident in artisanal mining activities, hence inadequate working and production. At inception (in 1984), the open-cast mining of barytes at Azara was fully mechanized and this continued for almost a decade before the down-turn in operation. Major reasons for stoppage of operations by the defunct Nigerian Mining Corporation (NMC) include lack of funding by the Government and instability of barytes market. But despite the continued long-era of artisanal mining, Government's supports are still not forthcoming, even amidst relatively stable market situation. Plate 3.2 shows an abandoned Excavator used by the NMC at Azara.

Plate 3.2: A dilapidated Excavator Used by the Defunct NMC at Azara.

The following are therefore the inherent advantages derivable from mechanizing Azara barytes deposits with a particular motive of achieving optimum production:

Effective handling of the following:

- Moderate – to – high ore recovery

- pit dressing
- Dewatering
- Stability of the hanging wall
- Waste haulage
- Materials haulage
- Better work organization
- improved safety measures
- Highly reduced environmental degradation, compared to artisanal mining, etc

However, mechanization of Azara barytes veins will definitely limit the number of workers to be engaged as compared to artisanal mining which presently employs large number of people. Nonetheless, mechanizing Azara barytes has a number of advantages which will not only guarantee the required optimum barytes production but will also safeguard safety and environmental conformity. Plate 3.3 shows an excavator removing overburden at one of the veins in Azara.

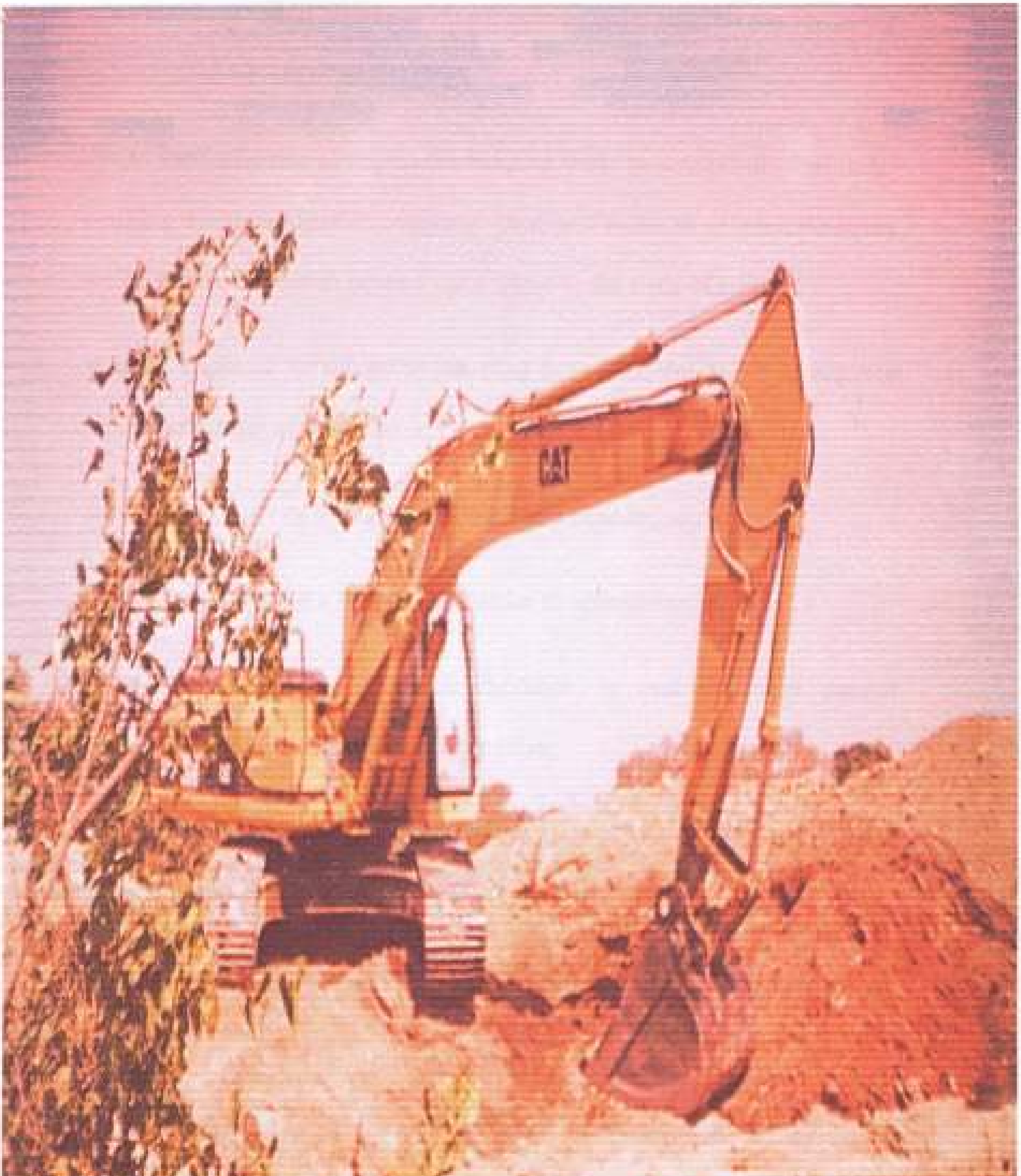


Plate 3.3: Overburden Removal in Azara

On the other hands, artisanal mining of Azara barytes veins presents the following problems associated with manual workings:

- due to vertical stress acting on the hanging walls as a result of continuous working without adequate supports, imminent collapse of such (hanging walls) is evident, which poses a great threat to the lives of miners;
- at great depth of working oxygen (O_2) is insufficient and this exposes miners to danger of suffocation;
- such mining activity is characterized by low production rate;
- insufficient capital is a continuous barrier to operational growth;
- there are no readily available facilities to tackle sudden natural occurrences, such as flooding and the likes;
- miners do not work with adequate safety gadgets and this exposes them to further operational hitches ;
- Children are used as labourers, while women are exposed to hard labour, etc.

However, artisanal mining of barytes veins in Azara presently provides job opportunities to a vast majority of indigenes of Azara and residents of Nasarawa State. The following economic benefits are currently being enjoyed by Azara community through artisanal mining:

- the least paid mine worker earns at least seven hundred naira (N700) daily and about twenty one thousand naira (N21,000) monthly;
- There is great income realization by the community and local administration, as forty percent (40%) of the mining right of the barytes deposits is reserved for the local community.

Investigations from this study, however, reveal that if the artisanal miners in Azara are well organized and integrated into formal mining sector, total community empowerment and overall development in the study area could be attained in the nearest future.

3.9 Government's Policy on Barytes Developments

Considering the strategic role which barytes plays in the development of petroleum industry and other areas of the Nigerian economy, it has become imperative for government to ensure its orderly and accelerated exploration, exploitation, processing and marketing for local consumption and possibly exportation.

One of the general objectives of the National policy on barytes development (MSMD, 2003) is to encourage the acquisition of technology by informal or artisanal miners in the exploitation of barytes. This among other objectives is central to capacity development in barytes production in Nigeria since artisanal miners play dominant role in its exploitation. Little wonder that the National

Minerals and Metals Policy (MSMD, 2008) emphasized the need to support Artisanal and Small-Scale Mining (ASM) and encourage cordial relationship between the ASM and large scale mining operators.

The achievement of such feat, according to Eggert (2009), depends on careful design of wealth – creation and distribution opportunities associated with mineral exploitation thereby setting the pace for economic goals attainment.

In an attempt to actualize the dream of industrializing Nigeria through barytes exploitation, the present civilian administration has categorized barytes as one of the 'seven strategic minerals' whose exploitation and development is to be given priority (Ishola, 2008). This initiative is sequel to the enactment and public presentation of the Mining Act 2007 and the Nigeria's Minerals and Metals Policy in April, 2008. It is, however, hoped that such laudable policies are vigorously implemented to meet the desired objectives. One of the best ways of achieving this is to fully involve mining engineers and other related professionals in policy formulation and implementation. When this is done, barytes development and utilization in Nigeria will become a reality and will meet up with the 'Seven Point Agenda' of the present administration of creating wealth, job and foreign exchange earnings.

3.1.0 Integrating Artisanal and Small-Scale Mining through Private Investment

The only way to improve mineral production in Nigeria is to properly organize the activities of artisanal and small-scale miners, encourage them to embrace modern mining techniques and grant them incentives to reduce their financial burdens. This is because artisanal and small-scale mining (ASM) represents a large percentage of mining operations in Nigeria. Therefore, integrating their operations at the instant of private sector led mining investment will bring about the desired sanity in the solid minerals sector of the economy.

In Azara, EMO Ashapura Energy and Mining Company Limited, an Indian firm, became the first private investor to be licensed recently to exploit barytes vein deposits. The company commenced mine development operations mid September, 2007, and has since resumed full production. Plate 3.4 shows preparatory process for drilling and blasting at Emo- Ashapura Mining Company in Azara.

Plate 3.4: Drilling in Preparation for Blasting at Emo-Ashapura Mining Company, Azara.

Majority of the artisanal miners have already been engaged to fortify the labour force of the new private company, while the drilling and blasting aspects were given out to local contractors. The present composition of the workforce of the company comprising experienced indigenous mining engineers, supervisors and local contractors is a true reflection of a private sector-led investment in the mining sector. It is, therefore, hoped the company would be given all the necessary supports to enable it operate under a conducive environment in order to attain optimum barytes production.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

Results of investigations into the economic assessment of mechanized, semi mechanized and artisanal mining techniques of Azara barytes veins are as presented and discussed under the following:

4.1 Data Presentation

Figures 4.1, 4.2 and 4.3 show the three polynomial regression curves (models) built for mechanized, semi – mechanized and artisanal mining techniques used for producing barytes in Azara. Mechanized technique's model was built from equation 2, semi – mechanized from equation 3 and artisanal mining from equation 4.

As shown in Figure 4.4 the three mining techniques recorded different tonnages of barytes which represent their peak productions. The peak production for mechanized method is about 23,908 tonnes per annum. Semi-mechanization recorded about 33,500 tonnes of barytes per annum, while artisanal mining produced an estimated annual tonnage of 18,050 tonnes. Figure 4.4 also shows the trend of decline in production for each mining technique.

In Figure 4.5 the extraction cost by degree of mechanized, semi mechanized and artisanal mining are shown to be 172.8^0, 82.8^0 and 104.4^0 respectively. Figure 4.6

gives the barytes price fluctuation at Azara from about N700 in 1988 to about N4, 5000 in 2007.

In Figure 4.7 barytes importation trend grows from about 2,000 metric tones per annum in 1988 to about 20,000 metric tonnes in 2007. Figure 4.8 also shows the net profit recorded by each mining techniques. Semi-mechanized production generated highest profit margin of about N70, 000,000, while artisanal and mechanized method produced profit margins of N68, 000,000 and N21, 000,000 respectively. Figure 4.9 gives the 1999 to 2010 projection for domestic barytes demand in Nigeria.

Table 4.1 shows that the mechanized barytes production in 1987 was about 23,908 metric tonnes while between 1991 and 1997, a total of 211, 740 metric tonnes of barytes were produced in Azara, as shown in Table 4.2. However, Table 4.3 shows that between 2000-2002 barytes production was marked by glut, thereby declining to only about 10,600 metric tonnes. In 2007 artisanal barytes production was about 18,050 metric tonnes, with a shortfall of about 101,950 metric tonnes as shown in Table 4.4.

Tables 4.5 and 4.6 show that the estimated costs of working tools and accessories used by artisanal miners at veins 17 and 1 at Azara are N578,670 and N502,670 respectively.

Table 4.7 shows that the number of equipment used by the defunct Nigerian Mining Corporation (NMC) is 24. Figures 4.1, 4.2 and 4.3 below show the regression curves for the three mining techniques, while Figures 4.4 to 4.8 show the graphical representation of the economic indices upon which the three mining techniques were analyzed. Figure 4.9 show the projection for local barytes demand in Nigeria.

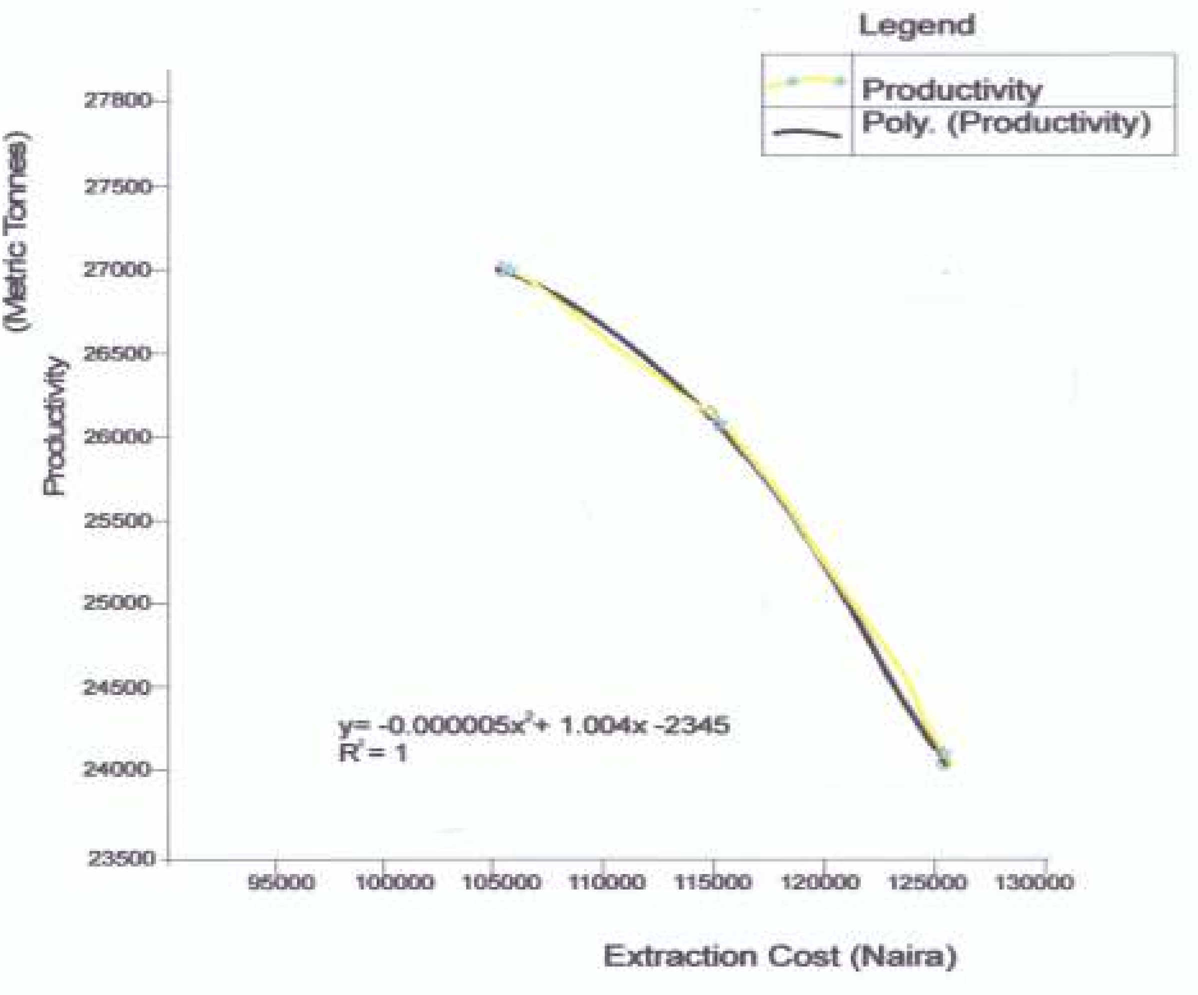


Figure 4.1: Model of Mechanized Mining Technique for Azara Barytes

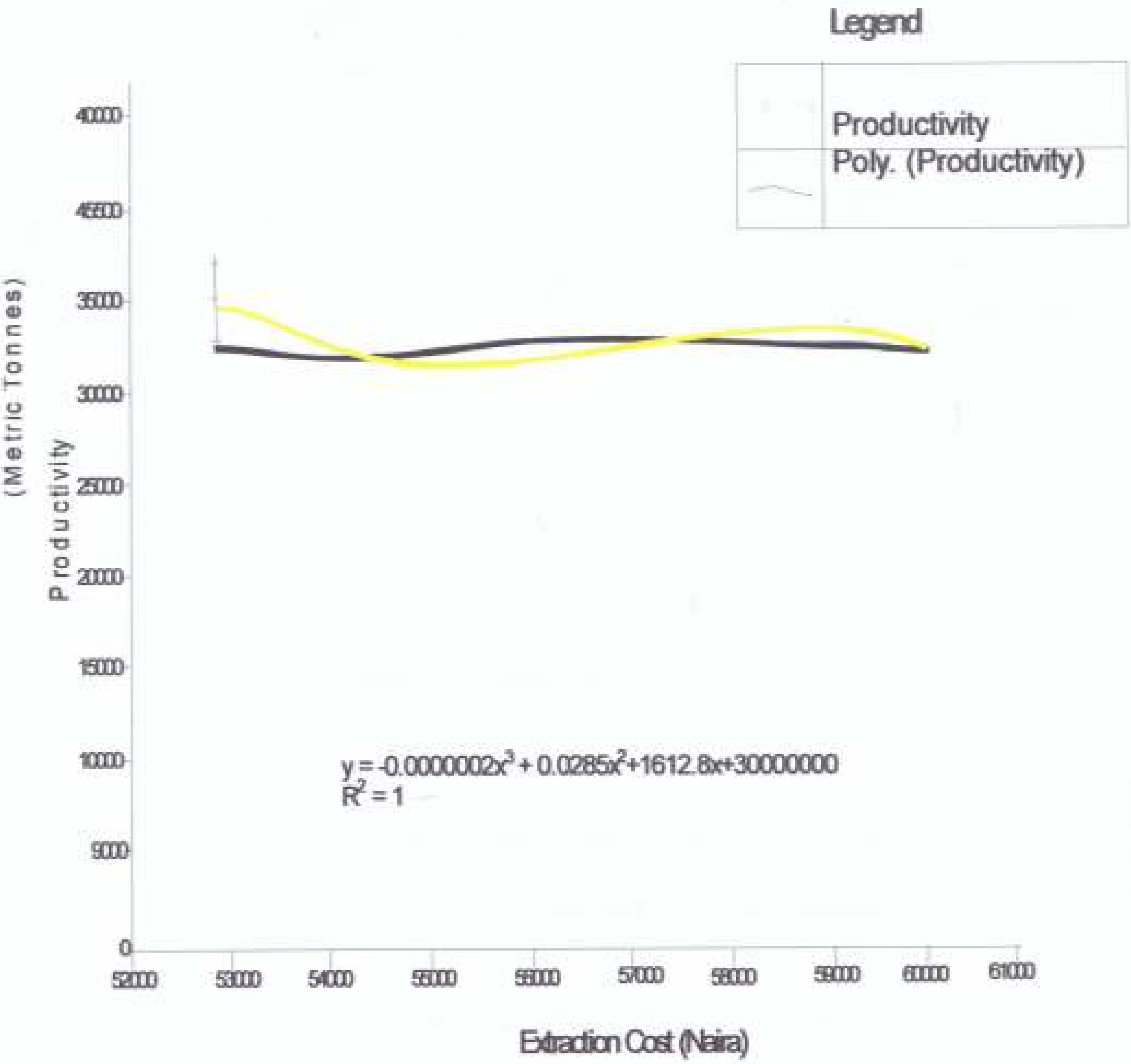


Figure 4.2: Model of Semi-Mechanized Mining Technique for Azara Barytes

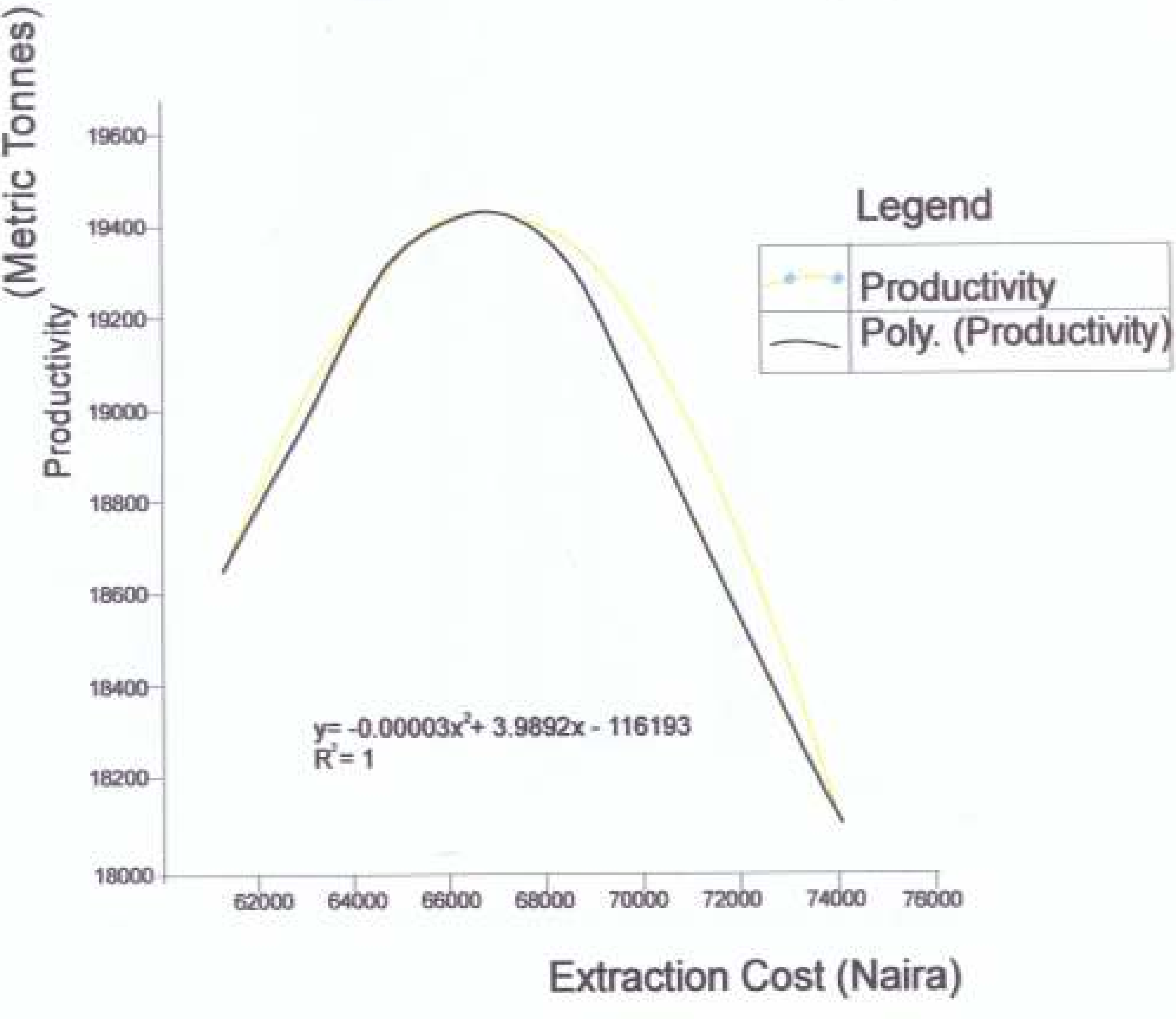


Figure 4.3: Model of Artisanal Mining Technique for Azara Barytes

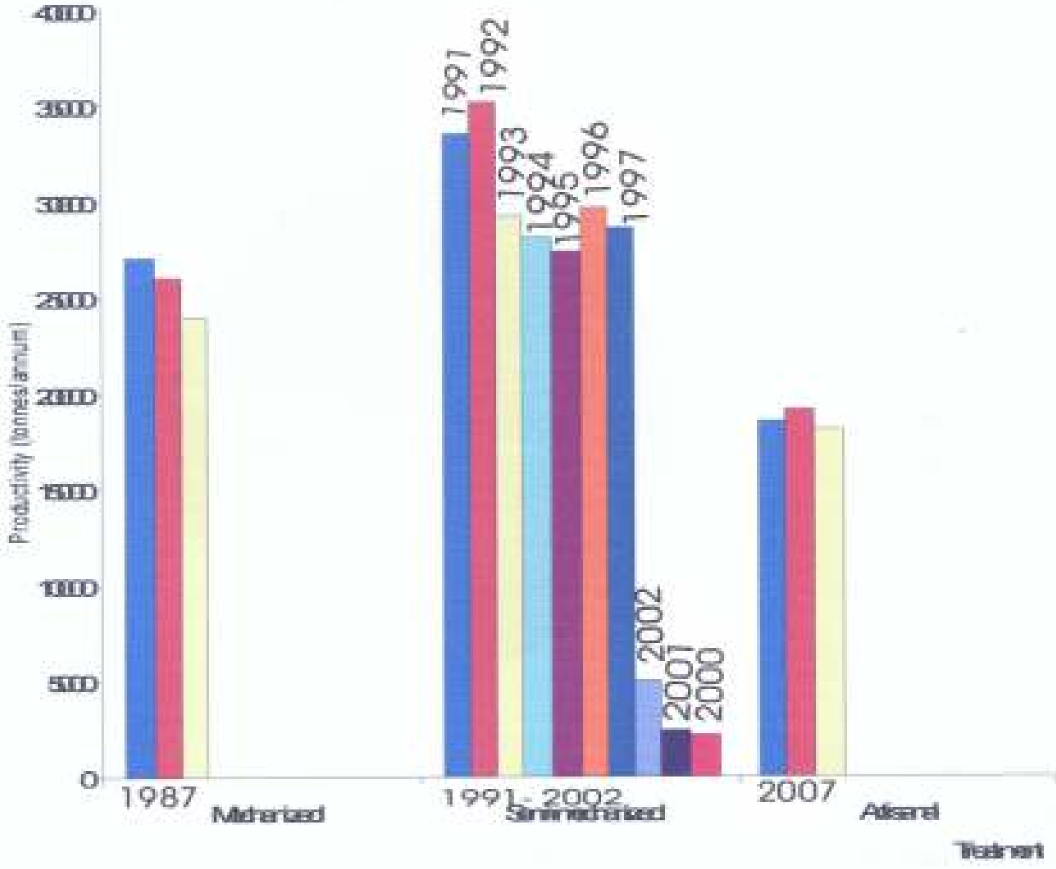


Figure 4.4: Barytes production records of mining techniques at Azara

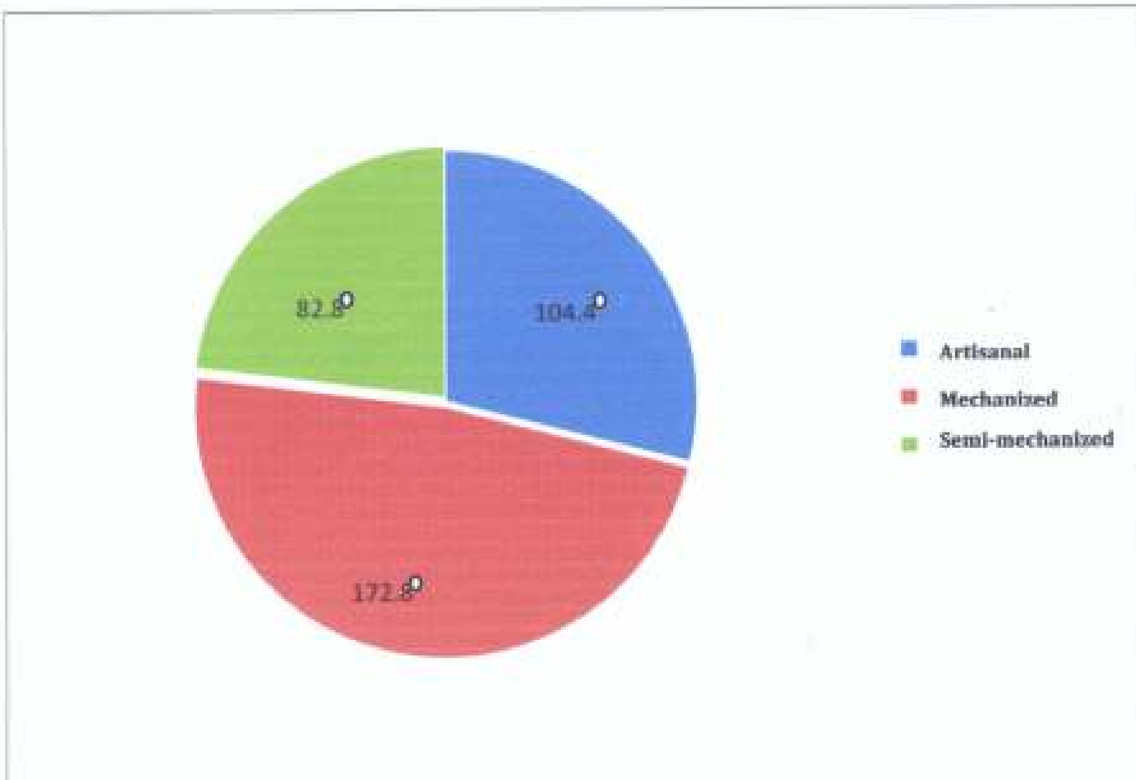


Figure 4.5: Degree Extraction Cost of Barytes Production for Mechanized, Semi-Mechanized and Artisanal Mining Techniques At Azara

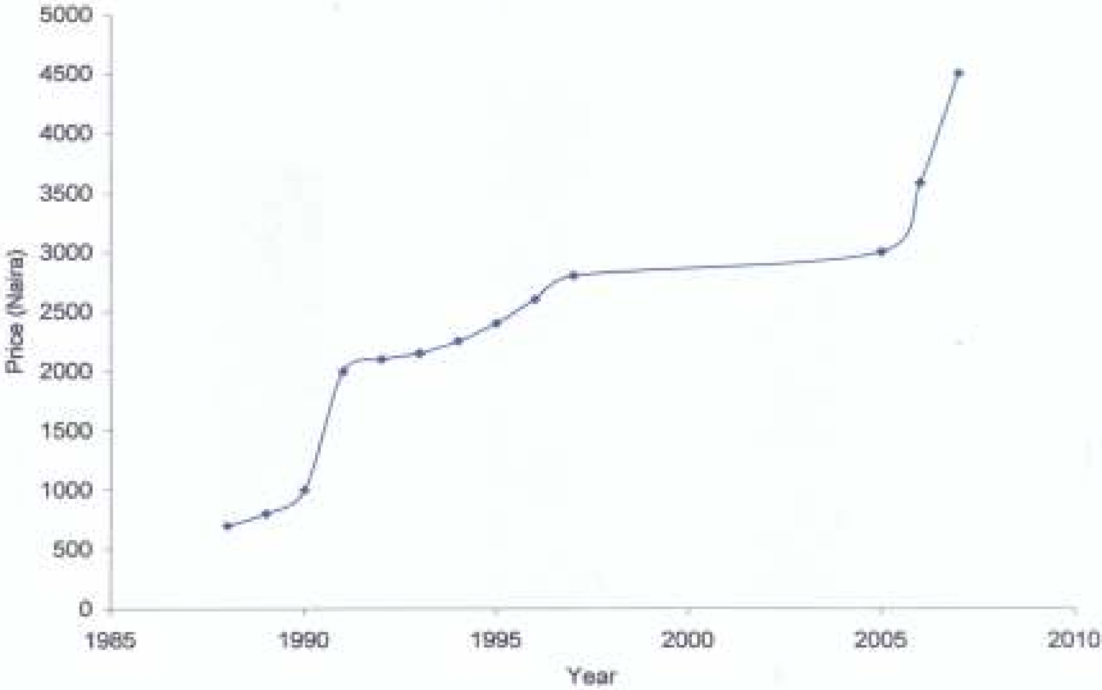


Figure 4.6: Price Fluctuation for Azara Barytes

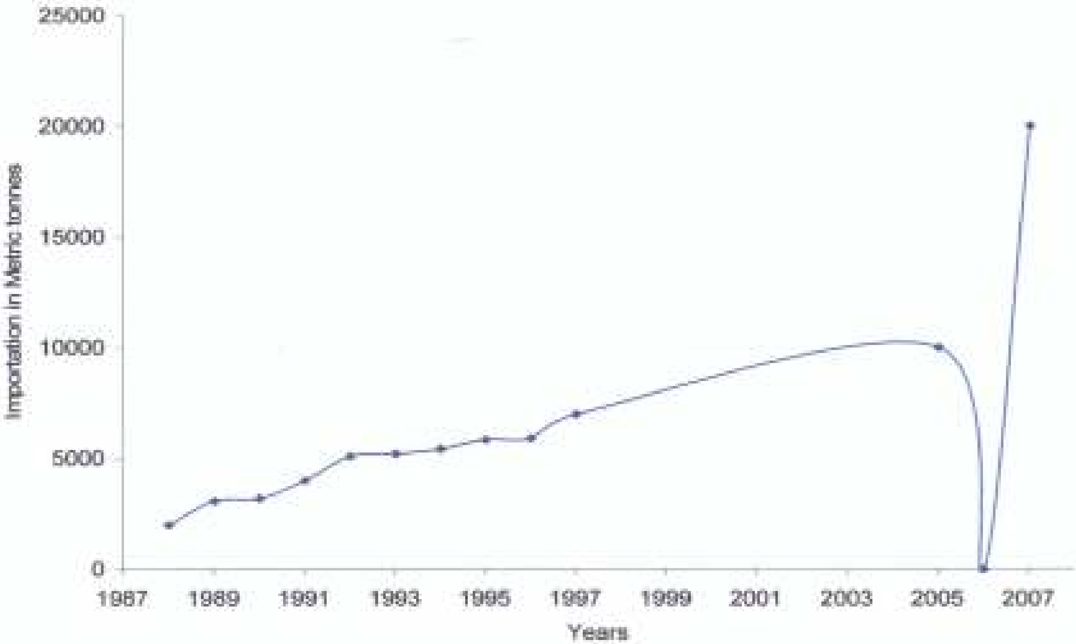


Figure 4.7: Importation Trend for Azara Barytes

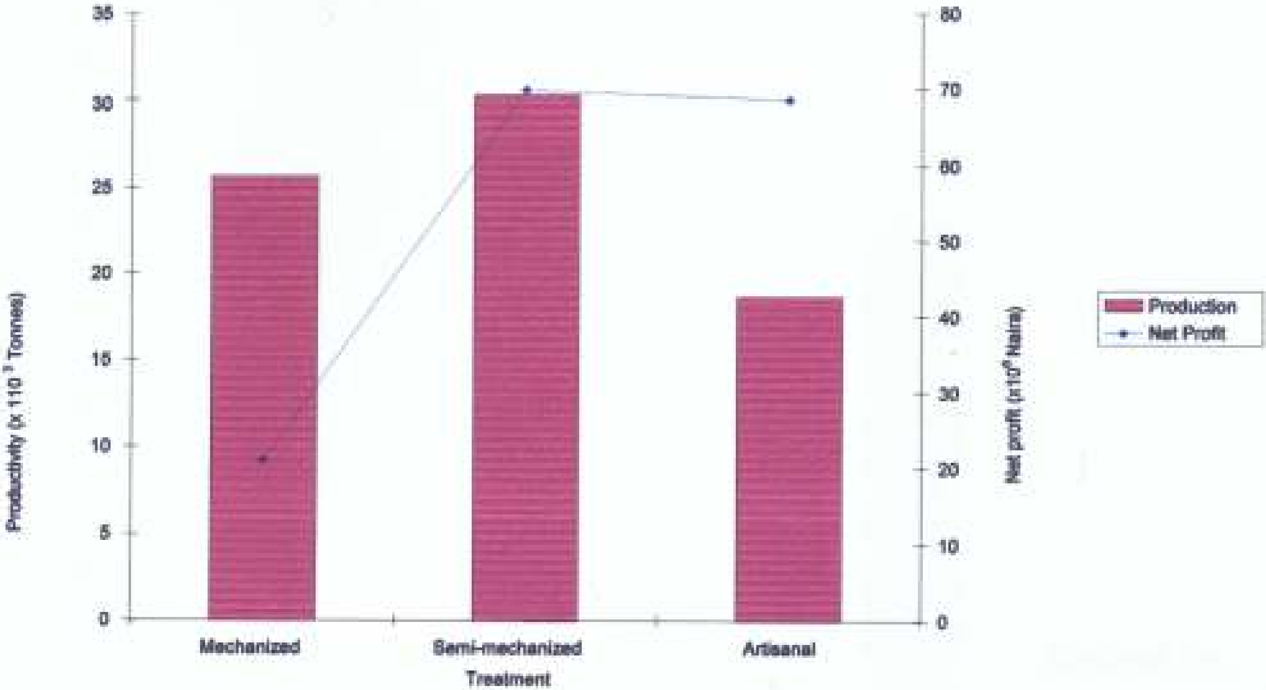


Figure 4.8: Net Profits Recorded From Barytes Production by Mining techniques at Azara.

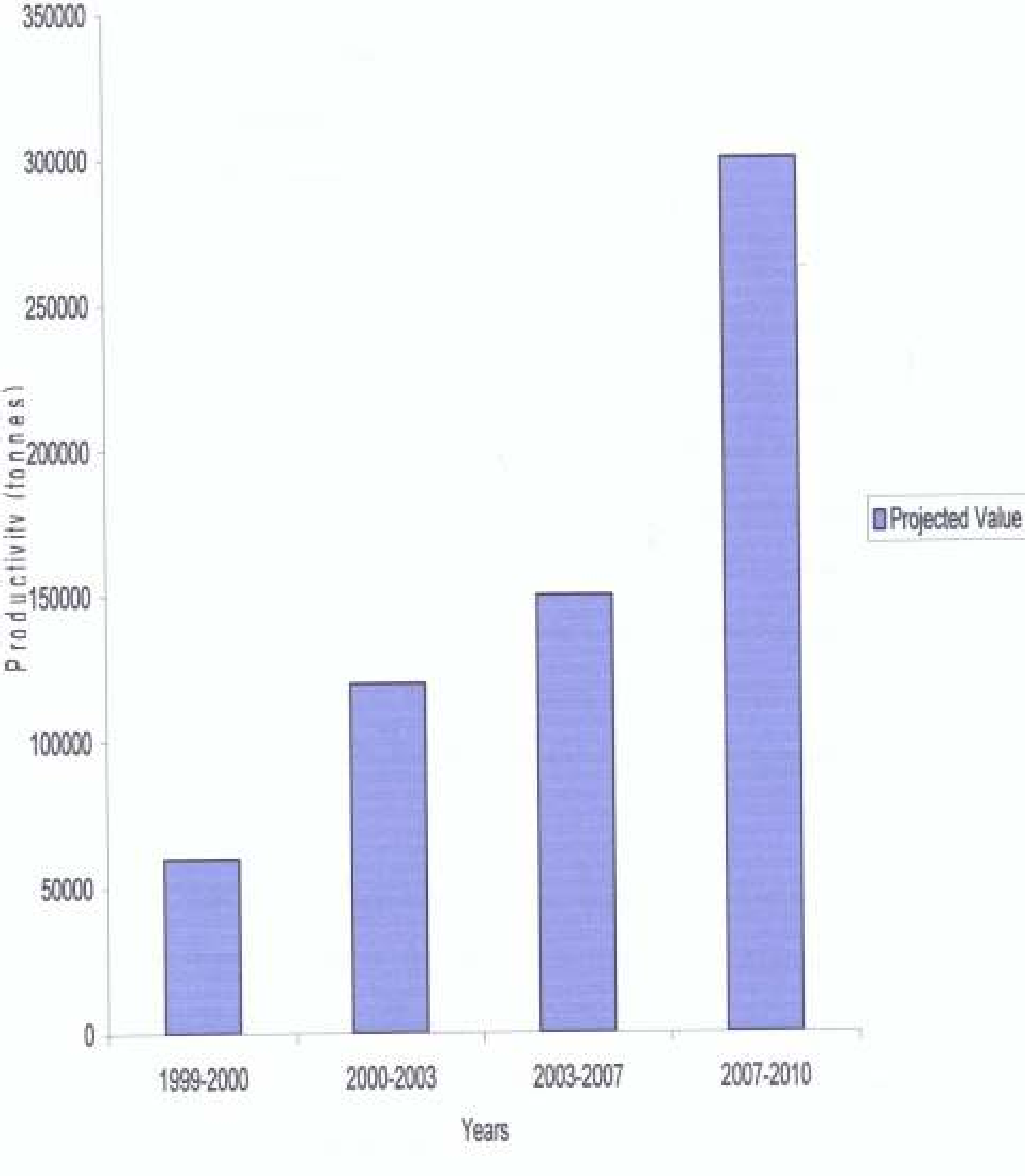


Figure 4.9: Projection for Domestic Barytes demand in Nigeria

Sources: Adegboye (2003); MSMD (2003); Umar (1999)

4.2 Data Analysis

All data collected were subjected to analysis of variance (ANOVA) at$\alpha \leq 0.05$, while Duncan's Multiple Range Test was used to verify significant differences among the treatment means at the 5% probability level.

According to Table 4.8 there exists significant difference between the three methods of extraction (i.e. mechanized, semi-mechanized and artisanal) for all the economic indices used. From the Table, in terms of productivity, semi-mechanized has the highest mean value of 30248.57 greater than that of artisanal productivity value of 8633.33. Likewise, mechanized productivity with higher value is also significantly different from that of artisanal. However, there is no significant difference between the extraction costs for semi-mechanized and artisanal methods which have the lowest mean value of N45, 627.14. This is significantly difference from that of mechanized method with mean value of N115, 010.

The three values of mining techniques are significantly different from the perspective of price of barytes. The price of barytes for artisanal method i.e. N3, 693.33 is the highest, and significantly different from that of semi-mechanized i.e. N2, 328.57 and mechanized method of N833.The same thing applies in the case of importation for the three mining techniques.

The result from the Table also shows that the net profit realized during the usage of these techniques is significantly different only between that of mechanized (i.e. N21,131,656,67) and the other two techniques (i.e. semi-mechanized and artisanal). The productivity (y) and extraction (x) for each of the techniques were plotted against each other and the regression curves between them were determined for the three mining techniques using Microsoft Excel (R).

The regression curve for mechanized technique shows a declining trend, implying that productivity is decreasing over the years with a corresponding increase in extraction cost. For the semi- mechanized, the curve shows a steady increase in productivity with a corresponding decrease in expansion cost. The regression curve for artisanal mining shows corresponding increase for both productivity and extraction cost until it reached and optimum level after when it showed a steady decrease in productivity with relative decrease in extraction cost.

4.3 Model Construction

The three economic models for Azara barytes were constructed to reflect the economic factors suggested by Labys et al (1985) which consist of the following components: demand, supply, inventories and prices.

Model equations developed for mining techniques for barytes production At Azara, Nasarawa State, Nigeria, are as follows:

Mechanized method

Model $y = -0.000005x^2 + 1.004x - 23452$ -------------------------- (2)

Correlation $R^2 = 1$

Semi mechanized method

Model $y = -0.0000002x^3 + 0.0285x^2 + 1612.8x + 30000000$ ----- (3)

Correlation $R^2 = 0.3662$

Artisanal method

Model $y = -0.00003x^2 + 3.9892x - 116193$ -------------------------- (4)

Correlation $R^2 = 1$

Where y – represents productivity (tones per annum)

And x – represents extraction cost (in naira)

The behaviour of these models is expected to consider Azara barytes development and investment decisions.

Production costs incorporated in the models will also give a specific structure to barytes mining environment, thus reflecting the opinion of Campbell (1999). Therefore, mining and processing costs incurred by mining companies in the area have already being incorporated into the price of barytes sold to other firms which use it as an income. However, under competitive conditions the price of mineral commodity equals the price of deposits, plus the unit cost of extraction:

$P_m = P_D + C$ --- (5)

Where P_m is the price of mineral commodity, P_D, price of deposits and C, is the cost. Let NC be the cost of extracting each unit of the mineral from the resource stock.

It follows from equation (1) that a change in the price of the commodity is the sum of changes in the price of deposits and the unit cost of extraction:

$dp_m = dp_D + dc$ --- (6)

Dividing both side of the equation (6) by the commodity price gives:

$Dp_m/p_m = dp_D/p_m + dc/p_m$, and this expression can be arranged to give:

$G(Pm) = b.G(pD) + (1 - b)\ G(C)$ ----------------------------- (7)

Where G (.) represents a growth rate, and $b = p_D/p_m$ is the share of the price of material deposits in the unit cost of commodity production. If the unit cost of extraction is constant G© = 0, and the growth in the price of the commodity over time is a proportion b, of the growth is the deposit price.

Regression analysis (equation), as given by Taha (2002), also estimates the time-path of barytes prices in Azara. Slade's approach (Campbell, 1999) also gives further regression equation for the commodity:

$P_t = a + b_t + c_t^2 + U_t$ -- (8)

Where P_t is the real price of barytes at time t in 2007; t is the year, U_t is a disturbance term, and a, b and c are constants. If the commodity price follows a u-shaped time-path, the fitted value of the coefficient b will be significantly different from zero and negative, and that of c positive. An insignificant value for c, together with a positive value for b would indicate that the commodity price trend is consistently positive over the period, as predicted by the simple model of equation (5). If neither b nor c were found to be significantly different from zero, then barytes price has no time trend, only cyclical fluctuations.

Considering the peculiarity of Azara barytes market structure in terms of demand, supply, prices and extraction technology, three forecasting models (equations 2, 3 and 4) earlier determined were meant to achieve the following objectives:

1. to enhance the extraction process in order to boost production and increase commodity supply;

2. to enhance mineral upgrading through balanced blending efforts to correct mis-perceptions about Azara barytes grades and attract more foreign demands;

3. To forecast short, medium and long term pricing demand and supply of Azara barytes production with a view to attaining national economic targets/goals.

Fundamentally, Azara barytes production modeling is targeted at attaining tremendous increasing production level. This is intended to match an increase in demand with the help of adequate working technology.

Locally designed technology can accommodate the artisanal and small-scale interest. In this regard, poverty will be reduced, crime rate will decline and a boost in production will be attained. This will add a positive input to the overall economy. Tables 4.1 to 4.4 below show barytes production at Azara for mechanized, semi-mechanized and artisanal mining at different periods. Table 4.5 and 4.6 also show the estimated costs of working tool and accessories used for artisanal mining at veins 17 and 1 respectively in Azara, while Table 4.7 shows the mechanized equipment used by the defunct Nigerian Mining Corporation (NMC). Table 4.8 shows the summary of statistical analysis for the three mining techniques.

Table 4.1: Mechanized Barytes Production at Azara 1987

Month	Budgeted tonnage (Metric Tonnes)	Actual tonnage realized (Metric Tonnes)	Difference (Metric Tonnes)
January	2,500	2,250	250
February	2,500	2,200	300
March	2,500	2,190	310
April	2,500	2,300	200
May	2,500	2,110	390
June	2,500	2,013	487
July	2,000	1,720	280
August	2,000	1,620	380
September	2,000	1,650	350
October	2,000	1,900	100
November	2,000	1,954	46
December	2,000	2,001	-1
Total	**27,000**	**23,908**	**3,092**

Field Data (2007)

Table 4.2: Semi mechanized Barytes Production 1991 – 1997

Year	Tonnage produced (Metric Tonnes)	Reason for increase / decrease in production
1991	33,500	High demand
1992	35,200	High demand
1993	29,230	Decline in demand
1994	28,100	Decline in demand
1995	27,410	Decline in demand
1996	29,600	Decline in demand
1997	28,700	Glut due to technical and financial problems
Total	**211,740**	

Field Data (2007)

Table 4.3: Semi-Mechanized Production of Azara Barytes During

2000 – 2002 Period of Glut

Year	Tonnage Produced (Metric Tonnes)	Reason For Increase / Decrease in Production
2000	2,200	Glut
2001	3,400	Boost in short-term programme
2002	5,000	Boost in short-term programme
Total	**10,600**	

Adapted From Bida (2004)

Table 4.4: Artisanal Barytes Production at Azara, 2007

Month	Budgeted Tonnage (Metric Tonnes)	Actual Tonnage Realized (Metric Tonnes)	Difference (Metric Tonnes)
January	10,000	1,700	8,300
February	10,000	1,730	8,270
March	10,000	1,750	8,250
April	10,000	1,750	8,250
May	10,000	1,760	8,240
June	10,000	1,760	8,240
July	10,000	1,500	8,500
August	10,000	1,250	8,750
September	10,000	1,000	9,000
October	10,000	1,000	9,000
November	10,000	1,200	8,800
December	10,000	1,650	8,350
Total	**120,000**	**18,050**	**101,950**

Modified After Adegboye (2003)

Note: Government imported 20,000 metric tonnes of barytes in 2007 to augment this low production.

Table 4.5: Estimated Cost of Working Tools and Accessories Used For Artisanal Mining at Azara (Vein 17)

S/No	Implements/Accessories	Number	Vein Location	Unit Cost (N)	Total Cost (N)
1.	Digger	60	17	1,500	90,000
2.	Hammer	60	17	1,100	66,000
3.	Chisel	120	17	400	24,000
4.	Drilling rod	30	17	6,000	180,000
5.	Shovel	90	17	300	27,000
6.	Head pan	60	17	600	36,000
7.	Blasting cable	30 rolls	17	1,250	37,500
8.	Dewatering hose and pump	A set of 3" hose/pump	17	45,000 set	45,000
9.	Sieving pan	35	17	150	5,250
10.	Wooden support	A bunch or as desired	17	15,000	15,000
11.	Cable, explosive and other accessories	A set pack	17	52,920	52,920
	Total				**N578,670**

Field Data (2007)

Table 4.6: Estimated Cost of Working Tools and Accessories used For Artisanal Mining at Azara (Vein 1)

S/No	Implements/ Accessories	Number	Vein Location	Unit Cost (N)	Total Cost (N)
1.	Digger	55	1	1,500	82,500
2.	Hammer	50	1	1,100	55,000
3.	Chisel	100	1	400	40,000
4.	Drilling rod	20	1	6,000	120,000
5.	Shovel	80	1	300	24,000
6.	Head pan	50	1	600	30,000
7.	Blasting cable	27 rolls	1	1,250	33,750
8.	Dewatering hose and pump	A set of 3"hose/pu mp	1	45,000 set	45,000
9.	Sieving pan	30	1	150	4,500
10.	Wooden support	A bunch or as desired	1	15,000	15,000
11.	Cable, explosive and other accessories	A set pack	1	52,920	52,920
	Total				**N502,670**

Field Data (2007)

Table 4.7: Equipment Used by the Defunct Nigerian Mining Corporation (NMC) During Mechanized Operation Period.

S/N	MINING EQUIPMENT/ACCESSORIES	NUMBER	EQUIPMENT TYPE
1.	Bulldozer	2	CAT D8H
2.	Wagon Drill	1	Atlas Copco
3.	Excavator	1	CAT 215
4.	Pay loader	3	CAT 922
5.	Dump truck	4	Terex
6.	Jack hammer	2	-
7.	Scrapper	1	Caterpillar
8.	Grader	2	Caterpillar
9.	Crusher (primary)	2	
10.	Jig	2	
11.	Compressor	3	Atlas Copco
12.	Generator	2	Caterpillar
		Total = 24 number	

Source: Field Data (2007)

Table 4.8: Summary of Statistical Analysis

Mining Techniques	Productivity (Metric Tonnes)	Extraction Cost (N)	Price (N)	Importation (Metric Tonnes)	Net Profit (N)
Mechanized	25683.33[b]	115010[a]	833.3333[c]	2760[b]	21131657[c]
Semi-mechanized	30248.57[a]	54627.14[b]	2328.571[b]	550.143[c]	69958730[a]
Artisanal	18633.33[c]	54627.14[b]	3693.333[a]	10000[a]	68593547[b]

*a indicates highest, b lower , and c lowest values respectively at 5% probability level.

4.4 Discussion of Results

The decline in trend witnessed in Figure 4.1 implies that decreasing production rate of barytes is glaring enough to show a correspondingly sharp increase in extraction cost. This is basically due to lack of funding which crippled operation and stifled equipment maintenance resulting in sharp drop in production. This led to major operation interruptions experienced by the defunct Nigerian Mining Corporation (NMC).

The steady increase shown in Figure 4.2 implies that semi-mechanization enjoyed technological advantage offered by the narrow nature of Azara barytes veins which mechanization did not enjoy. This gave an edge to semi-mechanization in terms of increasing productivity and decreasing extraction cost over the years until operation started experiencing decline during the period of 'glut'. The glut due to combined effects of lack of funds and flooding.

The initial increase in productivity and decreasing extraction cost shown in Figure 4.3 is due to increasing activities triggered by large population of artisanal miners as well as increase in demand for barytes. This trend continued until production reached its peak (optimum) and started decreasing, though at reduced extraction cost. The reverse in trend is due to the inadequacy of implements used by artisanal miners (e.g shovels, diggers, e.t.c) which was responsible for low barytes production.

The declining trend in Figure 4.4 which characterizes productivity in mechanized method of extraction, which is from 23,908 tonnes in 1988 to 18,000 tonnes in

1990, is simply due to problems encountered. These include: lack of funding, mismanagement and mostly incessant flooding. Flooding was the major cause of damage to equipment used. Likewise, the sharp decrease in productivity of semi-mechanized method noticed in Figure 4.4 from 28,700 in 1997 to 2,200 in the year 2000 is due to lack of funding and partly flooding.

However, productivity level of artisanal mining method did not show much fluctuation compared to the other two techniques. This is due to relatively uniform and uninterrupted mining activities, though at lower production level, except for the slight effect of flooding.

The significant difference exhibited between the techniques according to Table 4.8 denotes that productivity due to semi-mechanization surpasses that of others due to the advantage of economics of scale. This is the combination of advantages from other two techniques. Although, this high yield of semi-mechanization is in contrast with the views of Hartman (1987), Fritts (1990) and Rzhevsky (1987) that mechanization gives maximum yield.

From Figure 4.5 the mechanized technique attracts the highest extraction cost since it is a capital intensive operation. Semi-mechanized and artisanal methods records the least extraction cost. Consequently, the statistical analysis indicates that the extraction costs of the techniques are significantly different. The low value of extraction cost for semi-mechanized and artisanal method gives them priority over mechanized method.

Figure 4.6 shows the inflation trend of barytes from N700 in 1988 to N5,500 in 2007. This is not unexpected since the inflation rate of all commodities worldwide is ever increasing. This fact is further confirmed by the statistical analysis as there exists significant difference between their prices during the usage of the three mining techniques.

The increase in importation of barytes shown in Figure 4.7 from 2,000 tonnes in 1988 to 20,000 in 2007 is due to increase in petroleum production locally and internationally, increasing price of barytes in the world market and population increase in Nigeria. From the statistical analysis, importation trend between the three techniques are significantly different. Although, the productivity of semi-mechanized is high compared to others, it does not affect importation as much. The initial drop of importation curve in Figure 4.7 is due to ban by the Federal Government in 2006.

As earlier stated, the highest productivity is noticed for semi-mechanized compared to artisanal; this high productivity corroborates the high net profit noticed for semi-mechanized. The net profit of artisanal is also high but this is only due to high price as at the time of its usage. The high price and high productivity of semi-mechanized method are the factors responsible for a higher net profit than mechanized method. From the statistical analysis, net profit between semi-mechanized and artisanal method is not significantly different as it is when compared to that for mechanized method. It could also be noticed that as the productivity is decreasing for each of the techniques, the extraction cost is increasing. The reason for this is that during the early stage of mechanized method, less money was spent on maintenance since all the equipment were new but with time, wear and tear set in and more maintenance was needed. Likewise as the depth of mining increased, depletion set in requiring additional maintenance expenditure. This is also true for semi-mechanized. For artisanal method, the increased extraction cost was due to increase in wages of workers as depth increased and economic value of money decreased. The R-square value for the correlation of the techniques is 1 for both mechanized and artisanal while that of semi-mechanized is 0.3662. This means that the models for mechanized and artisanal methods are very good for prediction compared to that of semi-mechanized.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The economic assessment of barytes exploitation techniques at Azara, Nasarawa State, has been carried out. The semi-mechanized mining technique has been identified as the most efficient for mass barytes production in the study area so far. The rating of semi-mechanization is predicated upon its satisfactory performance, as it has the highest productivity level, lowest extraction cost and highest net profit which satisfied set economic indices more than other mining methods.

Analysis of the models developed as shown that extraction cost needs to be curt down for improved productivity. This means that operators of barytes mining at Azara must minimize extraction cost for effective translation to increased productivity and eventual marginal profits. Therefore, analysis of the models has shown a strong correlation between lower extraction cost, higher productivity and higher profit margins.

The daily extraction cost per tonne for Azara barytes by artisanal miners has been calculated to be N240 Naira. This has translated to about 18,050 metric tonnes per annum and profit margin of about N68 Million Naira annually. Thus, this study has identified a lower extraction cost of between N150 and N200 Naira for higher productivity and profit margins for Azara barytes production.

The models developed were accurate for mechanized and Artisanal mining methods (with R-square = 1) compared to semi-mechanized (i.e. R-square = 0.3662) which is near accurate. Thus, the three models can be used for prediction of future production in Azara. Inadequate funding, use of crude and obsolete mining equipment and incessant flooding have also been identified as potential obstacles facing sustainable barytes production in the area.

However, artisanal mining, as currently being practiced at Azara, has being identified as an avenue for upgrading and developing the artisanal and small-scale mining (ASM) sector. Upgrading and integrating this into formal mining sector through adequate organization and funding will offer a viable alternative. Hence, poverty level will be reduced, more people at the grassroots will be empowered through massive employment and the overall economy will experience a boost.

Finally, this research work has contributed to knowledge in the following areas:

(a) profitable and virile exploitation techniques of barytes deposits have been identified in the study area, Azara; and

(b) the manifestation of socio-economic impacts of barytes mining on the artisanal miners in the area has been facilitated.

5.2 Recommendations

The following measures are herby suggested in view of the observations from the results of the research work:

i. artisanal mining sector should be developed through adequate funding and reorganization to expand the production capacity of barytes production;

ii. only a well-funded and properly managed mechanized mining operation can guarantee sustainable barytes production; all hands must, therefore, be on deck to make this a reality;

iii. based on the economic indices set in this project work, semi-mechanized technique is favourably recommended. However, the model equations developed for mechanized and artisanal mining techniques are very good for predicting sustainable barytes production in Azara and other areas. Such models can, therefore, be used for trial production to determine their efficiency;

iv. Massive exploration must be carried out urgently on the remaining thirteen (13) unexplored barytes veins in Azara to provide a reliable database of barytes potentials in the area.

REFERENCES

Adamu, B. I., (2005): Small and Medium Scale Industries Equity Investment Scheme: Pro or Anti-Industrialization? Bullion, Central Bank of Nigeria, Vol. 29 (4) pp32 – 42.

Adegboye, L., (2007): An Address at the 10th Annual General Meeting/Conference, Nigerian Society of Mining Engineers, Kaduna, 7th – 10th November, 10pp.

Adegboye, L., (2003): Mining Engineering Profession in the Nation's Economic Development: A Case Study of Iron Ore, Paper Presented at the Mining Day Symposium of the Nigerian Society of Mining Engineering Students, Federal University of Technology, Akure, 11th December, 15pp.

Aderotoye, B. O., (1998): Preliminary Returns on Barytes Occurrences in Nasarawa State, Geological Survey Department, Lafia, 6pp.

Akande, J. M., and Adebimpe, R. A., (2007): An Economic Assessment of Artisanal Small-scale Mining of Sand and Gravel in Ado-Ekiti, Paper Presented at the 43rd Annual International Conference, Nigerian Mining and Geosciences Society, Akure, 4th – 9th March, 10pp.

Akande, J. M., and Amos, T. T., (2005): Artisanal and Small-Scale Mining in Kogi, Nasarawa and Plateau States, Technical Report, Centre for Research and Development, Federal University of Technology, Akure, 24pp.

Akande, J. M. and Idris, M. A., (2006): Mechanisms of Rock Slope Failure in Selected Quarries in Oyo State Nigeria, In: Advances in Materials and Systems Technologies, Tech Publications Ltd, Switzerland, pp13 – 19.

Amoka, I. S., (1997): Investment Opportunities and Economics of the Mining Industry, Paper Presented at the Workshop on Overview of the Mining and Quarrying Industry for Financial Institutions, Zaria, 22nd – 24th September, 6pp.

Amoka, I. S., (1998): Mining in Nigerian: Constraints and Prospects, Paper Presented at the Earth Science Seminar, Nigerian Mining and Geosciences Society, Kaduna Chapter, 3rd December, 7pp.

Amoka and Ogunbajo, M.I., (2003): From Waste to Wealth: Improving the Viability of Small-Scale Mines in Nigeria, Nigerian Mining Journal, Vol. 4 (1), pp 45-51.

Barsky, J., (1999): Nigeria's Untapped Riches Invite Investment-Solid Minerals are Attracting Foreign Exploitation, The Washington times, Advertising Department, News World Communications, Inc.

Bida, G. M., (2004): A Welcome Address/Report on the Occasion of the Honourable Minister of Solid Minerals Development's Official Visit to Azara, Nigerian Barytes Mining and Processing Company Limited, Azara, 26th August, 6pp.

Brobst, D. A., (1994): Barium Minerals, Society for Mining, Metallurgy and Exploitation, Inc. Littleton, Colorado, pp125 – 132.

Campbell, H. F., (1999): An Introduction to Mineral Economics,

University of Queensland, 48pp.

Damisa, E. O. A., (2007): The Nigerian Solid Minerals Industry: Problems and Prospects, A Paper Presented at the Nigerian Mining and Geosciences Society, and Nigerian Association of Petroleum Explorationists' Day, Kaduna Polytechnic Students Chapter, Kaduna, 31st July, 13pp.

De Gregorio, J., (2004): The Role of Foreign Direct Investment and Natural Resources in Economic Development, Central Bank of Nigeria, Economic and Financial Review, Vol. 42 (1), March Edition, CBN, Abuja, pp93 – 102.

Eggert, R.G., (2009): What Sustainability and Sustainable Development Mean for Mining, In: Sustainable Management of Mining Operations, Botin (Ed), Society for Mining, Metallurgy, and Exploration, Inc., Colorado, U.S.A., pp19 – 31.

Eromosele, S., (1990): The economics Viability of Solid Minerals as a Veritable Alternative Income for Nasarawa State of Nigeria with a particular Reference to Barytes Exploration in Azara, self improvement Online, Inc, 6pp. www.selfgrowth.com . Data retrieved on 15-10- 2008.

Fritts, C. E., (1990): The Barytes Mines of Chesire, Chesire Historical Society, Chesire, 30pp. www.chesirehistory.org/index. Data Retrieved on 07-04-07.

Hartman, H. L., (1987): Introductory Mining Engineering, John Wiley, Inc., New York, 582pp.

Hendricks, D., and Dahlstrand, A., (1979): Selected Aspects of Production Planning – Berkeley Pit, In: Open Pit Mine Planning and Design, Crawford, Histrulid (Eds), American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., Maryland, USA, pp207 – 231.

Hustrulid, W., and Kuchta, M., (1998): Open Pit Mine Planning and Design, Taylor and Francis 1st Edition, Publications 1st Edition, Maryland, USA, pp836 www.google.com. Data Retrieved on 23-12-07.

Icon Group, (2007): The World Market for Natural Barium Sulphate (Barytes) and Natural Barium Carbonate (Witherite) Excluding Purified Barium Oxide: A 2007 Global Trade, ICON Group International, Inc., 100pp www.diesel-ebooks.com. Data Retrieved on 27-12-07.

Isife, A., and Adeloye, A. O., (1999): Introduction to Mining, Kenlua Paper Back and Omobala Press Ltd, Warri, Vol. 1, 272pp.

Isife, A., and Adeloye, A. O., (2001): Introduction to Mining, Omobala Educational Publishers Nigeria Ltd and Kenlua Paper Back London, Warri, Vol. 2, 196pp.

Ishola, S.T., (2008): Private Investors Needed for the Exploration of Barytes in Nigeria, Ministry of Mines and Steel Development, Abuja, Newsletter, May 2pp. www.mmsd.gov.ng/newsletter . Data Retrieved on 14-10-2008.

Labys, W. C., Field, F. R., and Clark, J., (1985): Minerals Models, In: Economics of the Mineral Industries, 4th Edition, Vogely, W. A (Ed), Seeley W. Mudd Series, American Institute of Mining, Metallurgical and Petroleum Engineers, Inc, New York, USA, pp337 – 377.

Mallo, S. J (2007): Mineral and Mining on the Jos Plateau, ACON Publisher, Jos, 188pp.

Mallo, S. J., and Nwude, B. O., (2007): Drilling and Blasting, YEV Superb Prints, Kaduna, 218pp.

McFadzean, A., and Tyler, I., (1990): Lakeland's Mining Heritage. www.cumbria-industries.org.uk.

MSMD, (2008): National Minerals and Metals policy; Ministry of Mines and Steel Development, Abuja, January, 46pp.

MSMD, (2007): Nigerian Minerals and Mining Act, 2007: Ministry of Mines and Steel Development, Abuja, 62pp.

MSMD, (2003): National Policy on Barytes Development in Nigeria: Ministry of Solid Minerals Development, Abuja, May, 18pp.

Nasarawa State Government, (2007): Citation on the Mineral Resources of Nasarawa State, Ministry of Commerce, Industry and Co-operative, Lafia, 20pp. www.nasarawastate.org.

Nashuni, M., (2003): Problems of Small-scale Mining in Nigeria, Nigerian Mining Journal, Vol. 4 (1), pp34 – 37.

Nwude, B. O., (2007): Investment Opportunities in Nigeria's Solid Minerals Sector, Paper Presented at the 10th Annual General Meeting/Conference of the Nigerian Society of Mining Engineers, Kaduna, 7th – 10th November, 12pp.

Nwude, B. O., and Mallo, S. J., (1999): Introducing Shaft Sinking, Waato Press and Publishers, Kaduna, 144pp.

Nwoke, M. A. U., (1997): Application of Some Nigerian Plant Oils as Fatty Acids Collectors for Recovery of Barytes from Tailing at Azara, Nigerian Mining Journal, Vol. 2 (1) pp42 – 55.

Nwoko, V.O., and Onyemaobi, O.O., (1997): Beneficiation Study on a Nigerian Baryte Ore for Industrial Use, Journal of Material Science and Technology, Vol. 13, pp76 – 78.

Nwosu, J. I., (1998): Introduction to Surface Mining Engineering, Anchor Network Publishers Ltd, Okene, 60pp.

Obaje, N., Lar, A., Azegbuna, A., Moumouni, A., Chanda, M., and Goki, N., (2006): Geology and Mineral Resource of Nasarawa State – An Investor's Guide, Nasara Scientifique Publishers, Vol. 2(1), Keffi, 33pp.

Offodile, M. E., (2002): Ground Water Study and Development in Nigeria, Mecon Geology and Engineering Services, Ltd., Jos – Nigeria, 445pp.

Popov, G., (1971): The Working of Mineral Deposits, Mir publishers, Moscow, 603pp.

Roskill Reports (2007): The Economics of Barytes, Roskill Information Services, 254pp www.diesel-ebooks.com.

Rudawsky, O., (1986): Mineral Economics - Development and Managements of Natural Resources, Elsevier Science Publishers, Inc., U.S.A, 183pp.

Rungel, I. C., (1998): Mining Economics and Strategy, Society for Mining, Metallurgy and Petroleum Engineers, Inc., Littleton, Co, USA, 316pp.

Rzhevsky, V. V., (1987): Opencast Mining Technology and Integrated Mechanization, Mir Publishers, Moscow, 490pp.

Rzhevsky, V. V., (1985): Opencast Mining Unit Operations, Mir Publishers, Moscow, 465pp.

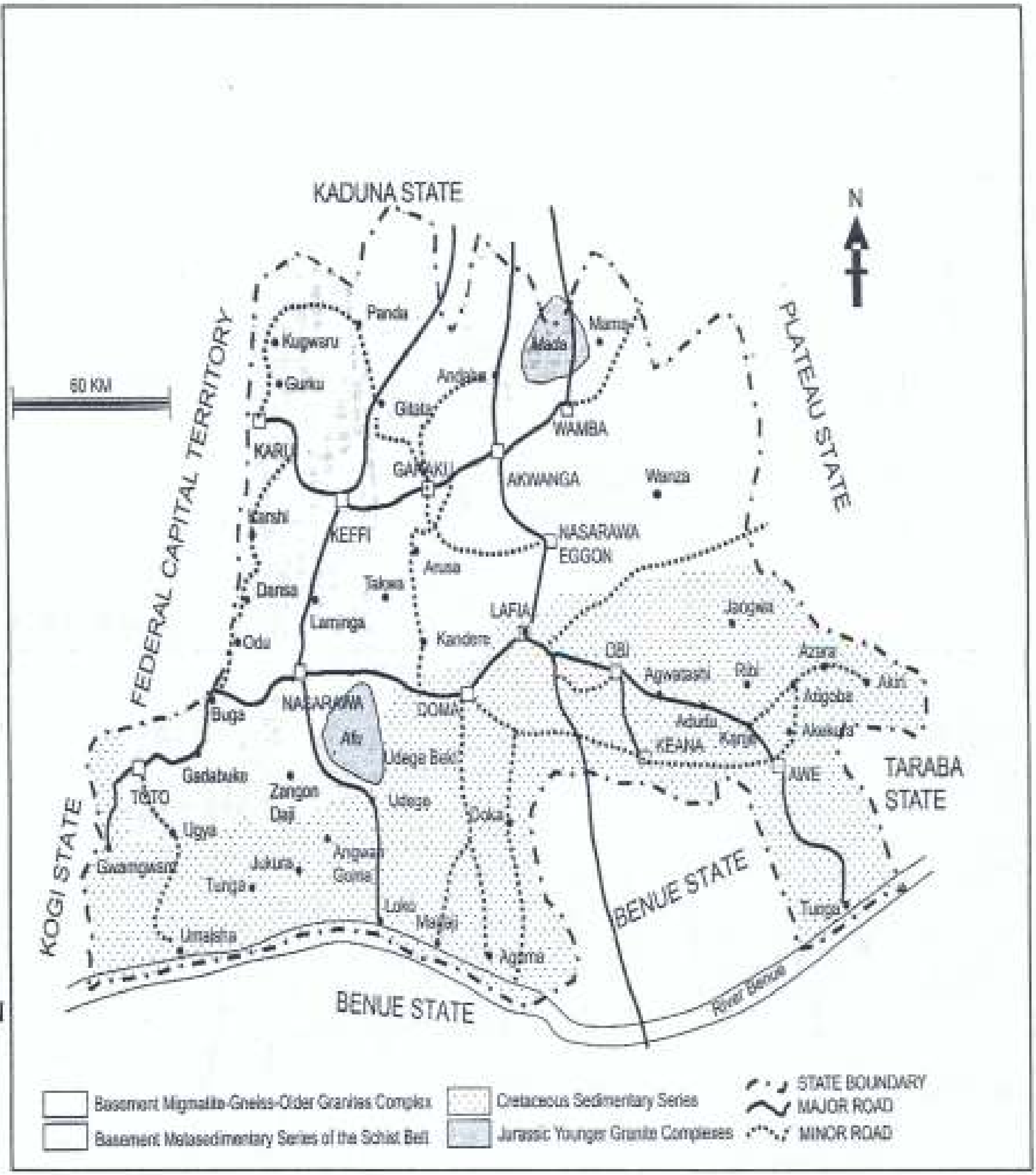
Salati, L. K., and Amoka, I. S., (2007): Artisanal Mining in Nigeria: Improving the Operational Capacity for Optimum Production, Nigerian Mining Journal, Vol. 5 (1) pp142 -151.

Taha, H. A., (2002): Operations Research: An Introducing, Pearson Education, Inc., Singapore, India, 828pp.

Umar, T. A., (1999): A Brief on the Occasion of World Bank Officials' Visit to Nigerian Barytes Mining and Processing Company Limited, Azara, 23rd December, 3pp.

Worth, D. J., (1991): Role of Canadian Chartered Banks in Financing Mining Operations, Canadian Imperial Bank of Commerce, Toronto, Canada, 6pp.

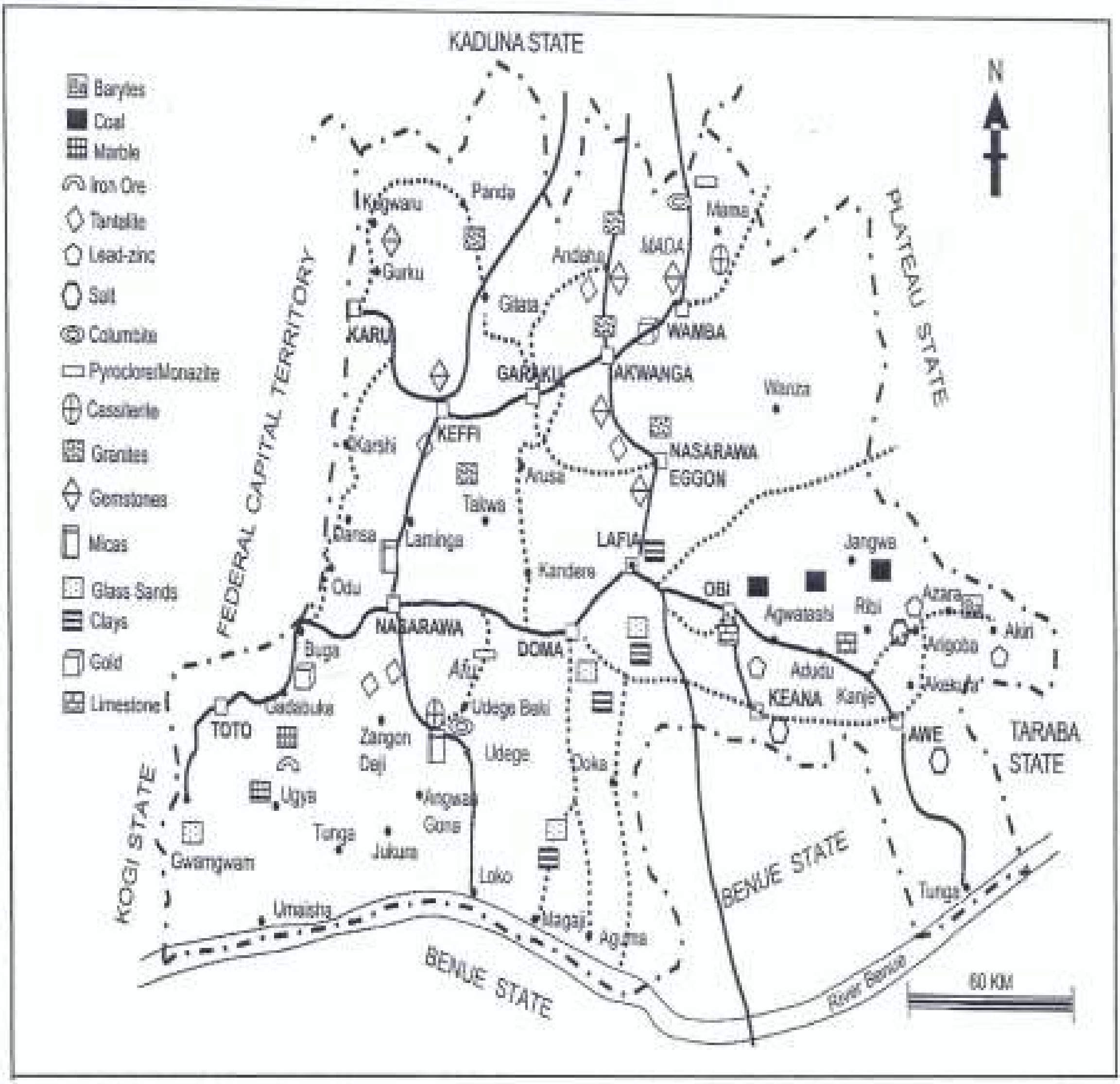
9° 14' 30E



8° 19' N

Appendix A1: Outline Geological Map of Nasarawa State (source: Nasarawa State Government, 2007).

9⁰ 14¹ 30E



8⁰ 19¹ N

Appendix A2: Major Mineral Resources Map of Nasarawa Stat (source: Nasarawa State Government, 2007).

Appendix B1: Rating of Mining Techniques for Azara Barytes Production Based on Revenue Potentials

MINING TECHNIQUE	RATE OF RECOVERY	PRODUCTION RATE	REVENUE POTENTIAL	REMARKS
Mechanized	Moderate to high	High	High	Recommended, provided competent management team and adequate funding are available
Semi-mechanized	Very high	Very high	Highest	Suitable, highly recommended but with full support
Artisanal mining	High	Low	Moderate to high	Recommended for grassroots mining but with better organization and support

Appendix B2: Estimated Revenue Potentials of Mining Techniques for Azara Barytes Production at Different Selling Prices

	Mining Technique	Revenue/ Day (N)	Revenue/ Month	Revenue/ Annum	Year in Focus	Price/Tonne (N)
1.	Mechanized	71,590	15,750,00	16,735,600	1987	700
2.	Semi-mechanized	-	-	* 70,400,000	1993	2,000
3.	Artisanal	347,727	7,650,000	81,450,000	2007	4,500

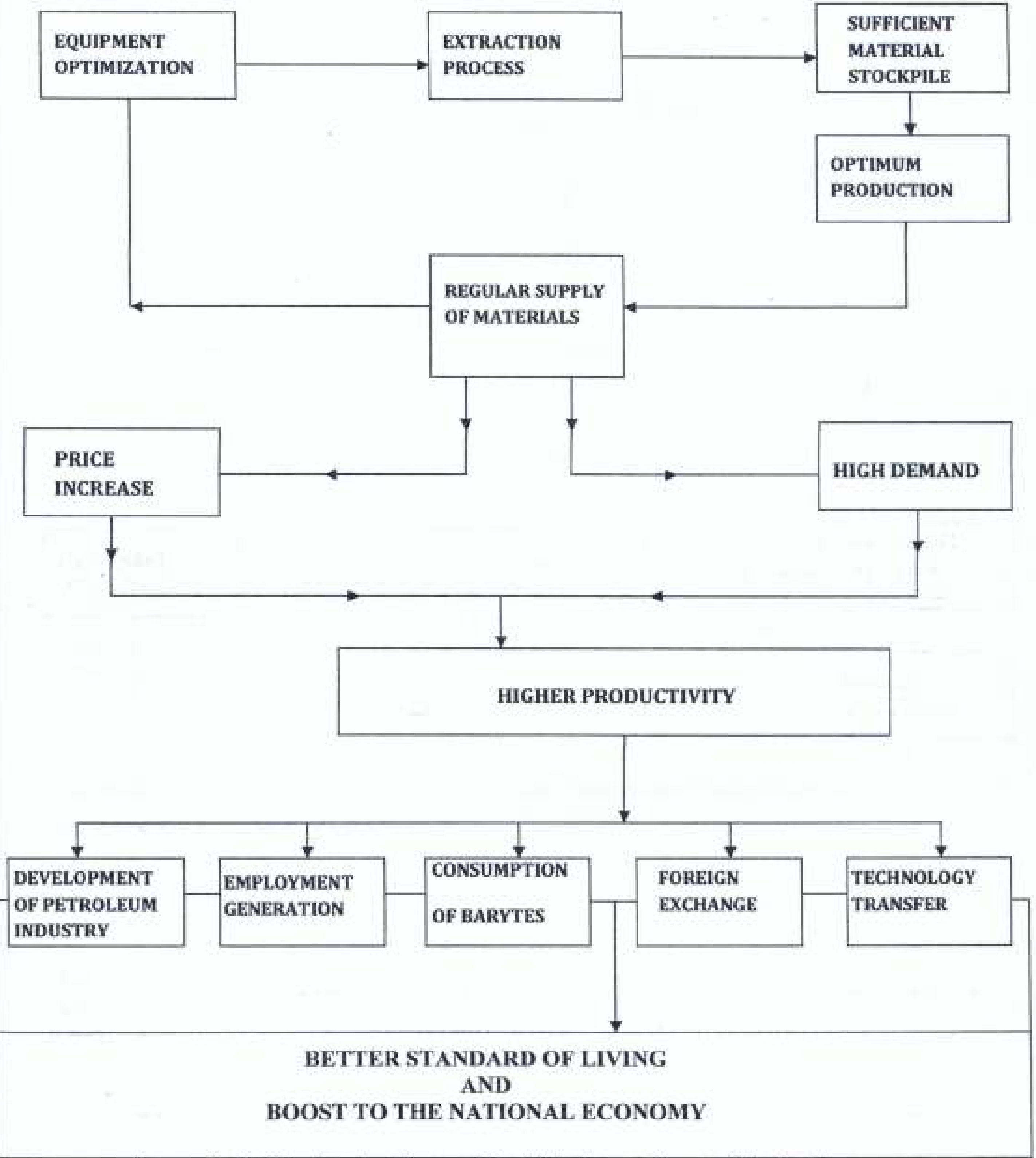
(Modified after Bida, 2004 and Umar, 1999).

- means information not available

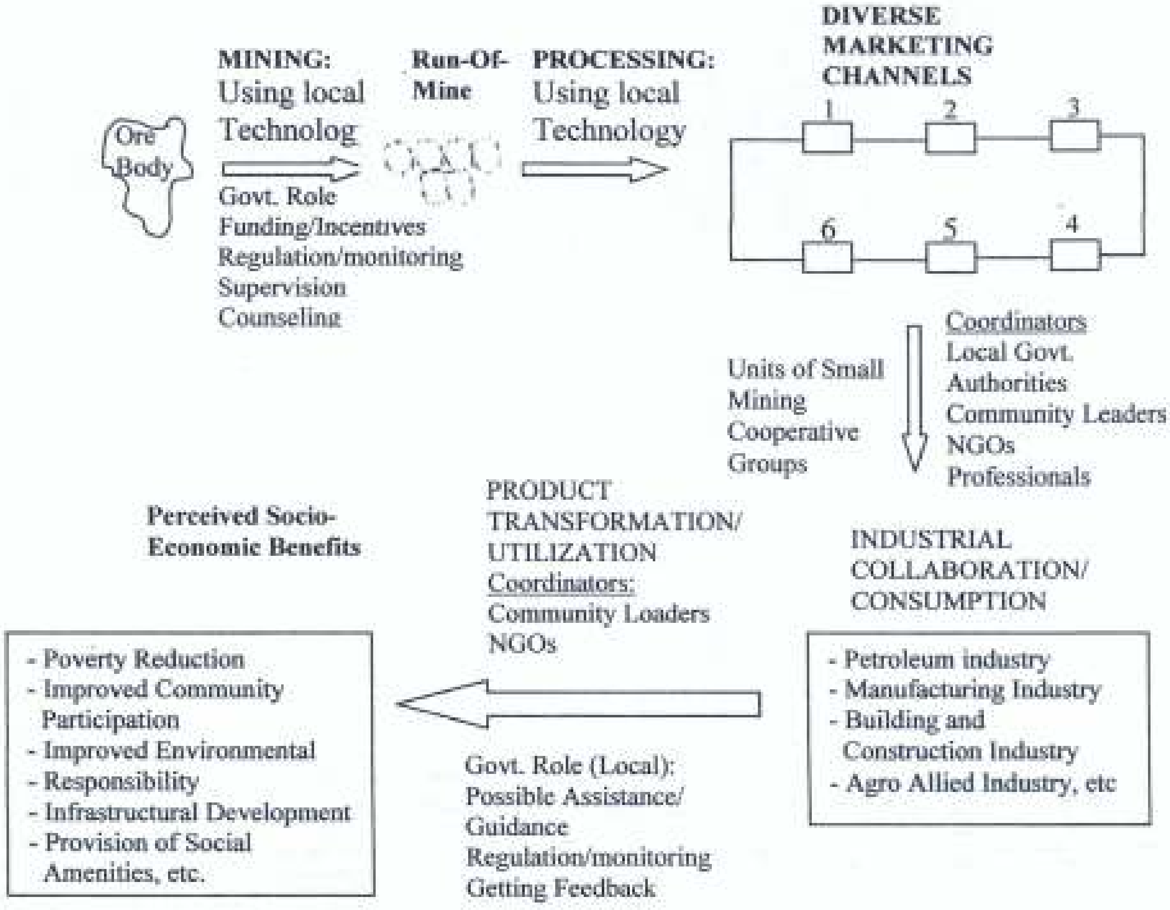
* **NOTE:** Revenue generated by semi-mechanized mining was till higher, despite a low price/tonne of ₦2,000 in 1993, compared to a selling price of ₦4,500 to N5,000, in 2007.

Appendix C: Artisanal Barytes Production 2005 – 2007

YEAR	TONNAGE PRODUCED (mt)	TONNAGE OF BARYTES/BENTONITE IMPORTED BY THE GOVERNMENT (mt)
2005	18,600	10,000
2006	19,200	-
2007	18,100	20,000
	Total: 55,900	**30,000**



Appendix D: Engineering Process Model for Azara Barytes Production



Appendix E: Community-Oriented Artisanal and Small-Scale Mining/Marketing Model (After Salati and Amoka, 2007).

APPENDIX F: SOME SUGGESTED MECHANIZED MINING EQUIPMENT/ACCESSORIES FOR AZARA BARYTES WORKING

s/ no.	Equipment	Model	Manufacturer/supplier	Year of manufacture	Price	Function	Rated capacity	Status	Available hour	Other remarks
1.	Bulldozer	Caterpillar 82AC SP core	Hoss equipment company	2008	$259,500	Over burden removal	Maximum	New	0	-fast fuel system - 29.5 x 2.5tires system
2.	Drill wagon	Atlas copco AB/long hole drill wagon	Atlas copco	2000-2004	$135,000-145,000	Drilling	Operating width = 2.0m Operating height = 12.om hole diameter = 110-125mm	New	0	
3.	Jack hammer	MTX subwoofer jack hammer	MTX subwoofer inc.		$399.99	Drilling	1600W peak power	New	0	
4.	Dump truck	Atlas copco E120	Atlas copco	1981	$35,000	Loading Hauling Dumping	120 ton capacity	New	0	Designed for CAT 777, etc
5.	Excavator/shovel	CAT bucket excavator, shovel	Hoss equipment company	2001	$255,000-300,000	Overburden removal, loading etc	6-10metric tones capacity	New	0	22' fair to good
6.	Pay loader	CAT 928G wheel loaders	Hoss equipment company	1998	$69,500	Loading Dumping Hauling	6-10metric tones capacity	Rebuilt	7,661	Tires at 95%
7.	Scrapper	CAT DIIR	Roupe equipment company inc.	2001	$170,500	Loading Overburden removal Ripping Scraping	Over 15000W peak power	New	0	Diffs 16K
8.	Grader	CAT 160H VHP motor grader	Hoss equipment company	2001	%169,500	Road grading etc	VHP engine – 180/200 HP	Rebuilt	10,332	17.5 x 25itres at 65%
9.	Crusher	12 x 36 universal jaw crusher	Hoss equipment company	-	$12,500	Crushing	-	New	0	Excellent condition
10.	Compressor	Kaeser ASD 25 rotary compressor	Dudley, punnysl, Versailles inc., etc	-	$13,832-$30,000	Powering drills and kacj hammer	120gallon capacity, over 10 HP cap.			-
11.	Jig									
12.	Generator	Caterpillar 3406 DITA Gen Set	Hoss equipment company	1991		Power generation	400KW and above	New	0	

Sources: www.heavy-equipment-types.dozenet.com;
www.caterpillar.doznet.com;
www.bizrate.com; www.our.bargain.com/products.asp.com; www.atlascopco.com;
www.infomine.com/equipment/sellers.roupe.html; www.minmine.com