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Economic Evaluation of Some Feldspar Deposits in Adavi and Ajaokuta Local Government Areas, Kogi State for Investment Purposes

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ABSTRACT: *The Zango Daji, area is part of the basement complex of Nigeria and is underlain mainly by schists and intrusive granitic and pegmatitic rocks along with sediments weathered from these rocks. The granitic and pegmatitic intrusives are source of feldspar with a significant K_2O component (k-feldspar). Reconnaissance survey was conducted within the Zango Daji forest to collect relevant data and for mapping. The study of the area reveals the occurrence of feldspar deposit hosted by granitic and pegmatitic intrusives. Geographic Information System tools (GIS) was used to map the study area for primary data collection. Secondary data were obtained from relevant agencies. An analysis of the physical characteristics of the samples of feldspar deposit obtained from the study area through geological survey methods revealed the specific density of 2.56g/cm^3 and hardness of 6. on the Mohs scale. These were determined through laboratory methods. The economic analysis was carried to determine the economic viability of the deposit through net present value. The result showed that the deposit has an enormous positive socio-economic benefits as a poverty reduction means, job creation, enhanced revenue and profit maximization. Statistical analysis was then conducted by means of the Statistical Package for Social Sciences (SPSS) program to process data to develop a mining model to evaluate the economic feasibility of the project. Market analysis showed that the price of crude and processed feldspar per ton are respectively above ₦150,000.00 and ₦420,000.000 internationally, while the export price of crude feldspar is less than ₦70,000.00 per ton locally. The results of the economic analysis and evaluation showed that the mining project is economically feasible given geoscientific and economic variables used and the assumptions made.*
KEYWORDS: Zango Daji, K-feldspar, pegmatitic, intrusives, mineral resource, reserve estimation

INTRODUCTION

Reconnaissance is grass root exploration meant to identify the existence of mineral potentials. It excludes pitting, trenching, drilling or sub-surface excavation (Haldar, 2018). Exploration geology

is a complete sequence of activities between searching for a new mineral project and property evaluation (Khaled, 2019). Economic evaluation of a deposit is of a complex character and is thus referred to by scholars as geologico-economic or technical-economic evaluation. Geological exploration is a process of finding commercially viable mineral resource and the objective is to locate it in the shortest possible time and at the lowest possible cost (Gandhi and Sarkar 2016). Geologists can search for years before finding an economic mineral deposit. The deposit size, its mineral content, extracting cost and efficiency, market value of processed minerals are all factors that determine if a mineral deposit can be profitably developed. Reynolds (2011) explained that geophysical survey methods responds to the physical properties of sub-surface media, used successfully where one region differs sufficiently from another. A single geophysical method seldom yields highly reliable results because each method is specifically suitable for a particular type of mineral deposit (Narasimman, 2013). For specific geological evidences and knowledge, the location, quantity, grade, geological characteristics and continuity must be known, estimated or interpreted (Westholm and Alderton, 2015). A deposit must be evaluated using a complex of parameters since no reliable synthesizing index for determining the economic value of a deposit is available. The characteristics and modes of occurrence of a mineral specie determines if it has an economic interest, that is whether it can be profitably mined. This depends on the market demand and related to specific stage of industrial development (Lattanzi, 2022). The decline of the solid minerals industry started with the discovery of crude oil, and to an extent, Nigeria became a mono product economy and hence, vulnerable to international oil politics and its repercussions and the geopolitics of oil have played central role in international relations and it is argued that geopolitical rivalry over access to oil has been the source of much of the conflicts in the 20th century (Chatham House, 2019). Akpabio and Akpan (2010) stated that in Nigeria, oil politics partly finds expression in an unfinished nation-state project represented by a crisis of its oil dependent federalism, marked in part by the struggle of the six oil – producing states in Niger Delta region for local autonomy and control over revenues (resource control). The domineering role of oil did not allow past governments to attend to global challenges that evolved in the development of solid minerals. No doubt, the earnings from the export of petroleum denominated in United States dollars, otherwise known as “petrodollar” from these oil booms led to the neglect of these huge economic potentials.

This made Nigeria to experience the "Dutch disease" reflected by an appreciation of exchange rate, subsidize imports while discouraging non-oil exports; which in Nigeria's case includes the solid mineral sector which before the discovery of crude oil was a major contributor to economic growth. Overtime, the level of investment in solid mineral exploration and development plummeted below that of the oil and gas industry that has seen an exponential growth since Nigeria became a petrodollar state (Olumide *et al.,* 2013). While the efforts put in place by the Federal government in diversifying the economy can be said to be yielding some results, its contribution to GDP of the economy is still low. With the exit of foreign multinational mining companies, the performance of the subsector began to dwindle (Bamalli *et al*., 2011). The tempo of mining activities shifted to industrial non-metallic minerals needed for construction, building and industrial applications in domestic industries (Onah, 2005). The Federal government, through the Ministry of Mines and Steel Development has made efforts to revitalize the solid mineral sector through reforms (Ola-Omole, 2010). Oyedokun and Igonor (2013) reviewed the efforts made in the development of solid minerals in Southwest region of Nigeria is based on recent reforms targeted at sustaining possible mineral exploration. Mallo (2012) in examining the mining sector stated that the sector's contribution to gross domestic product, (GDP) was a meagre 0.3% despite its huge potential. Oscarline (2012) posited that the Nigerian mining sector's contribution might rise in coming years as a result of recent sector reforms. The global feldspar market reached a value of nearly $3,688.32 million in 2021, having increased at a Compound Annual Growth Rate (CAGR) of 6.14% since 2016. The market is expected to grow from $3,688.32 million in 2021 to $4,904.04 million in 2026 at a rate of 5.86%. The market is then expected to grow at a CAGR of 4.51% from 2026 and reach $6,113.88 million in 2031 (Businesswire, 2023). Opafunso *et al.*, (2008) in a paper titled Prospects and Challenges of Women and Children Involvement in Artisanal and Small Scale Mining in Selected African Countries opined that Small Scale Mining all over the world are structured according to access to limited finance and technical competence. He stated that informal artisanal operations are characterized by lack of capital, unsafe mining methods, environmental degradation and lack of technical competence. He further disclosed that there was lack of effective and appropriate internationally recognized policies guiding artisanal and small scale mining. These include policies guiding documentation of mining practice, code of conduct,

child labour, women miners, training and development of miners, mining research, financial guidelines and frameworks, and environmental regulations.

Significance of the Study

There is need for better understanding of the knowledge of the economic evaluation of feldspar deposits in Nigeria. The essence for an understanding of the knowledge is the bedrock of this study due to its immense economic and social benefits for the people, the government and investor. This will enable stakeholders to key into the economic diversification drive of the Federal Government to reposition the solid minerals sector as an alternative foreign exchange earner to oil.

This study, economic evaluation of feldspar deposits within Zango Daji in Adavi and Ajaokuta Local Government Areas in Kogi State, in addressing the gaps in the development of feldspar deposits ensures the attainment of sustainable development goals by reducing or eliminating the factors militating against the exploitation and uses of the feldspar as a mineral to reduce poverty, create employment, improve livelihoods, for improvement in revenue generation, investors' profits and the enhancement of socio-economic indices of sustainable development goals. These outcomes will result into developing a mining model which evaluates the economic feasibility of the project to attract investment.

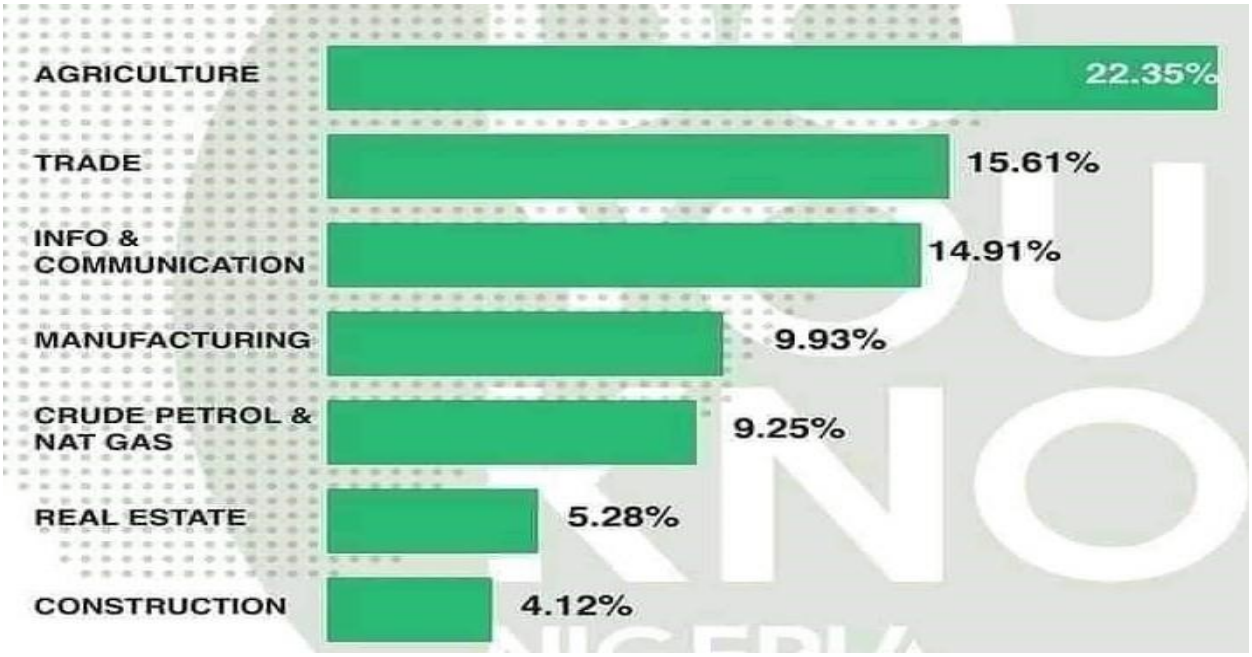
LITERATURE REVIEW

Review of Business Characteristics and Statistical Report

Mining has a combination of characteristics which differ from other types of business or industry. These characteristics have most significance for the economics of mining (Crowson, 2009) but also influence the laws and arrangements which regulate mining (Libecap, 1996). The large amounts of money needed to develop a mine, and the long time periods before any returns, means that parties providing finance to mining projects pay close attention to the planning and operation of any mine (Southlam, 2012).

According to National Bureau of Statistics (NBS) 2021 report "The Mining and Quarrying sector is crucial to growth in Nigeria considering the potential to export mineral resources to the rest of the world and the drive for diversification. Essentially, Nigeria is said to be endowed with over

forty (40) types of minerals including marble, coal, iron ore, gold, silica, lead, zinc, tin ore, manganese, granite, laterite, limestone etc" (NBS, 2021). The NBS report further states that, Value Added Tax, (VAT) revenue has been on a steady increase in the last three years when the Federal government increased VAT rate from 5% to 7.5% in a bid to increase government revenue. The mining sector is one of three sectors in Nigeria with the highest VAT remittances in the first half of 2022, jointly accounting for 62.2% of total value added tax revenue generated by the Federal Inland Revenue Services (FIRS). The manufacturing, information and communication technology (ICT) and mining sectors led the list with the highest VAT remittances in the period under review. As a constitutional requirement, the mining sector, if properly positioned, harnessed and managed could be a source of high revenue generation to the three tiers of government through VAT. (NBS, 2022). Figure 1 shows the top seven contributing sectors to the Nigerian Economy in quarter one (Q.1) of 2021 indicating the solid mineral sector as an indirect contributor to the top seven sectors.



Source: NBS (2021)

Figure 1: Top seven contributing sectors to Nigerian economy in Q.1 of 2021

Amankwah and Anim-Sackey (2004) remarked that for many centuries, mining of mineral resources has made a significant impact on the socio-economic lives of people and communities

involved directly or indirectly in the sector. Mining operations generally generate significant employment avenues, especially in remote rural areas where alternative job opportunities are scarce and low paying. Apart from the direct employment contributions of mining, it also generates a substantial number of indirect jobs in other sectors of the economy. However, production of these minerals has been at a cost to the social environment and there is the need to develop the sector in a responsible manner for sustainability.

Review of the Process of Evaluation of Feasibility

Though customary, but not mandatory, the process of evaluation of the technical feasibility and economic viability of production for a given mineral deposit pass through three stages of progressively more rigorous analysis. These are Preliminary economic assessment (PEA), Preliminary feasibility study (PFS) and Feasibility study (FS) (William, 2019a).

The preliminary economic assessment (PEA), often referred to as scoping study, is typically the first and least rigorous analysis of the technical feasibility and economic viability of a proposed mining project. The principal purpose of a PEA is to determine whether or not the mineral deposit in question has a reasonable prospect of being economically mineable and, if so, to make concrete recommendations as to the further work required to advance the project towards a production decision. A Pre-Feasibility Study (PFS) is a comprehensive study of a range of options for the technical and economic viability of a mineral project that has advanced to a stage where a preferred mining method, in the case of underground mining, or the pit configuration, in the case of an open pit, is established and an effective method of mineral processing is determined. It includes a financial analysis based on reasonable assumptions on mining, processing, metallurgical, economic, marketing, legal, environmental, social and governmental considerations and the evaluation of any other relevant factors which are sufficient for a Qualified Person, acting reasonably, to determine if all or part of the Mineral Resource may be classified as a Mineral Reserve (William, 2019b). A pre-feasibility study is at a lower confidence level than that of a feasibility study. The feasibility study is the final and definitive analysis of technical feasibility and economic viability. It is used as the basis for a production decision by the company owning the deposit, and also as the basis for securing funds from banks, other lending institutions or equity

investors, in order to finance construction of the project. In the feasibility study, the project and its individual components are fully defined, and sufficient engineering and design work has been completed to permit capital expenditures and operating costs to be estimated to a level of accuracy of, typically, plus or minus 15% (William, 2019c).

Swenson (2023) defined Net Present Value (NPV) as a number investors calculate to determine the profitability of a proposed project. NPV can be very useful for analyzing an investment in a company or a new project within a company. It considers all projected cash inflows and outflows and employs a concept known as time value of money to determine whether a particular investment is likely to generate gains or losses. NPV as a metric confers a few unique advantages, and it also has some disadvantages that render it irrelevant for certain investment decisions. Gladkevich and Khrushchev, (2014) expressed that an economic evaluation of mineral deposits for purposes of geographic prediction needs to be synthetic in character, incorporating the findings of special – purpose evaluations based on more narrowly defined criteria.

MATERIALS AND METHODS

Description of Study Area

The study area is located in Zango Daji forest in Adavi and Ajaokuta Local Government Areas in Kogi State, North Central Nigeria. The area comprises of ore rich deposits of feldspar and quartz and significant massive granite gneiss rock were observed. Figure 2 show the geological and mineral resources map of Kogi State.

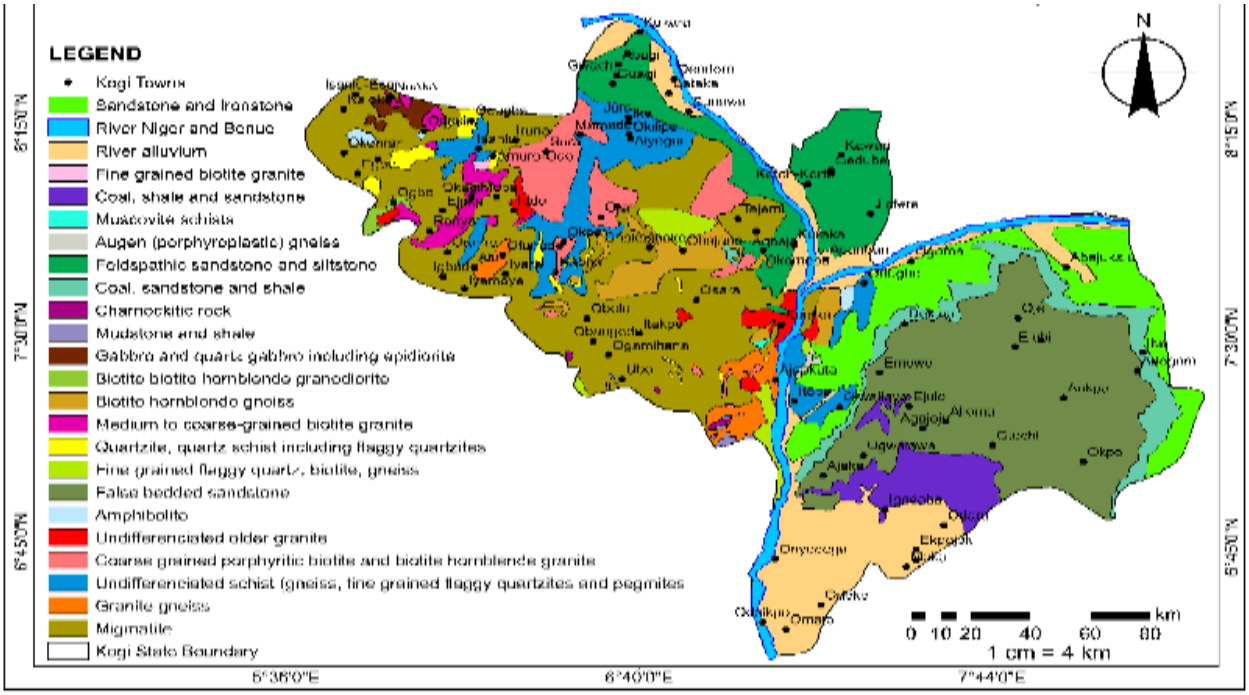


Figure 2: Geological and Mineral Resources Map of Kogi State

The primary data were collected from the selected locations through geological methods using appropriate instruments like global positioning system (GPS) and digital camera Recconnaissance survey was carried out and rock samples of the feldspar deposits were randomly collected with spades, digger and geologist hammer, stored in sample bags and carefully labelled.

Plate 1 show flakes of mined feldspar by artisanal miners in an outcrop found within block A in the study area.

Plate 1: Feldspar Flakes Mined by Artisanal Miners within Block A in the Study Area

Determination of Physical Properties

Determination of the density of the feldspar sample was carried out by Density bottle method, using Densometer while the hardness test was determined using the Mohs hardness test method. Eight (8) grams each of the feldspar rock prepared from samples collected from the three blocks were immersed separately into 90 cm^3 of water to obtain a volume increase in the water. The difference in volume was calculated and divided with the known weight of solid. The average density of the feldspar from the three blocks was determined The density of the feldspar rock was determined by using the density bottle method and calculated as summarized by Equation 1.

$$S = \frac{(M_2 - M_1)}{(M_4 - M_1) - (M_3 - M_2)} \times D_r \left(Kg / m^3\right) \quad (1)$$

Where, Dr is Density of fluid used, M_1 is Weight of empty bottle + stopper, M_2 is Weight of bottle + stopper + dry sample, M_3 is Weight of bottle + stopper + dry sample + water, M_4 is

Weight of bottle filled with water only, and S is Density of feldspar sample. The other physical properties were determined by observation under a high powered microscope.

the Exercise

Economic Analysis of the Feldspar Deposits

Economic analysis requires making forecasts and determining estimates such as production, revenue, capacity utilization etc. An oral interview was conducted to obtain some vital information. Some underlying assumptions were made to obtain profitability projections and technical specifications of equipment were obtained from manuals. Then a cash flow analysis was carried out.

Production estimates determination

To determine the production estimates of the feldspar deposits, the technical specifications of the crushing plants are essential. The type, model and output of the crusher, the number of working hours per day, per month and in a year was used to determine the production estimates in a year. Annual production capacity figures were determined by a product of the percentage of capacity utilization of crusher. The crusher production in tons per hour were determined from equipment specification data sheet from the manufacturer. The number of working hours in a day and the number of working days in a year were also determined statutorily.

Based on a 35% capacity utilization of the proposed 300tons/hour crusher with an annual increment of 10% shown in Table 1, and a forecasted 8 hours work per day on a single shift and 24 working days per month or 290 working days per year, the production schedule forecast is given Table 2.

Table 1: Summary of capacity utilization of proposed crusher for 10years

Year	**Yr.1**	**Yr. 2**	**Yr. 3**	**Yr.4**	**Yr. 5**	**Yr. 6**	**Yr. 7**	**Yr. 8**	**Yr. 9**	**Yr. 10**
(%)	35	45	55	65	75	85	95	95	100	100
300 tons/hr Crusher	105	105	165	195	225	235	265	265	300	300

The production forecast, based on the above capacity utilization of the crusher for ten years is also shown in Table 2.

Table 2: Production forecast based on capacity utilization of proposed crusher for 10years

Year	**Yr.1**	**Yr. 2**	**Yr. 3**	**Yr.4**	**Yr. 5**	**Yr. 6**	**Yr. 7**	**Yr. 8**	**Yr. 9**	**Yr. 10**
(000tons p.a) Feldspar Aggregate	244	313	383	452	522	592	661	661	696	696

Revenue forecast

The revenue forecast for 10 years was based on the capacity utilization of crusher and production forecast for 10 years, assuming feldspar is sold at N6,500 per ton. Sales is projected on a 15% annual increase up to 7th year of operation and cost of sales is projected on a 20% annual increase up to the 10th year of operation. Revenue projection is given in Table 3.

Table 3: The revenue projection of the feldspar project for 10 years

Year	**Yr.1**	**Yr. 2**	**Yr. 3**	**Yr.4**	**Yr. 5**	**Yr. 6**	**Yr. 7**	**Yr. 8**	**Yr. 9**	**Yr. 10**
(N'000,000) Sales	1,949	2,514	3,060	3,618	4,176	4,732	5280	5290	5290	5290
Cost of sales	440	528	634	761	913	1,096	1,315	1,578	1,894	2,273
Difference	1,509	1,986	2,426	2,857	3,263	3,636	3,975	3,715	3,396	3,017

Cash flow analysis

In order to carry out an economic analysis of the feldspar deposit, a financial analysis was conducted to obtain a cash flow analysis for the project. A cash flow analysis is an examination of cash inflows and outflows of a business. This was done using discounted rate or net present method. Through the discounted rate, which is the opportunity cost of capital, or rate of return forgone by not investing in other activities, the investor can decide whether or not to invest. The discounted rate or net present value of a stream of revenues and costs. The mathematical representation is given in Equation 2.

$$NPV = \sum_{i=1}^{n} \frac{R_t}{(1+i)^t} \qquad (2)$$

Where,

NPV is the Net present value, R_t is the Net cash flow during a single period t, i is the Discounted rate or return that could be earned in alternative investments, t is the Number of timer periods and n is the number of entities.

When evaluating a potential investment, a positive NPV indicates that expected revenues exceed expected costs after accounting for the time value of money; the investment is worth more than it costs and thus should be undertaken. A negative NPV indicates that costs exceed revenues after accounting for money's time value; a firm's money would be better spent elsewhere.

In summary, the profitability projections of the project for the first ten years were made under the following underlying assumptions shown in Table 4.

Table 4: Table of Assumptions Underlying Profitability Projections

S/No.	Activity/Item	Assumption
1.	Installed capacity	Production of approximately 600,000 tons/year
2.	Plant operation	290 days of 8 hours/day
3.	Capacity utilization	300 tons/hour crusher to work at 35%, with a 10% annual increase until the 8th year when a second crusher is added
4.	Product	Crude Feldspar
5.	Cost of sales	Ratio of price to sales
6.	Wages and salaries	20% annual increment provided
7.	Estimated selling price	₦6,500/ton
8.	Depreciation	Straight line method
9.	Interest on bank loan	21%
10.	Debt equity ratio	3.1:1

Development of Mining Model to Evaluate Economic Feasibility of the Feldspar Deposit

Multivariate Regression Model is a statistical procedure which aims at establishing the relationship between dependent and independent variables (Mertler *et al*., 2021). The established model predicts the values of a target (dependent) variable from a collection of independent variables. Generally,

Multivariate model was developed by using Equation 3.

$$\hat{Y} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n \quad (3)$$

Where,

$\beta_1, \beta_2, \ldots \beta_n$, are the coefficients of regression model, β_0 is the intercept, $\hat{Y}$ is the predictive value, X_1, X_2, …… Xn, are the independent variables.

The mining model was developed using selected variables as identified in literature (Melodi *et al*., 2023 and Mata *et al*., 2022). The input parameters considered in this study include the Operation costs (OP), Administration costs (AC), Maintenance costs (MC), Royalty (R) and Output dataset (Profit). Tables 5 – 9 gives the projected ten years fixed and variable costs used for deriving the datasets.

Table 5: Projected Administrative Cost

Item	Yr.1	Yr.2	Yr.3	Yr.4	Yr.5	Yr.6	Yr.7	Yr.8	Yr.9	Yr.10
					(₦'000,000)					
Salaries/Wages	201	241	298	347	416	499	599	719	863	1,036
General / Administrative	120	144	172	207	248	298	358	430	516	619
Furniture and Fitting	50	60	72	86.4	103.7	124.4	149.3	179.2	215	218
Building and Structure	530	50	-	-	-	-	-	-	-	-
Total Administrative Cost	901	495	545	640.4	767.7	921.4	1,106.3	1,328.2	1,592	1,873

Table 6: Projected Operating Cost

Item	Yr.1	Yr.2	Yr.3	Yr.4	Yr.5	Yr.6	Yr.7	Yr.8	Yr.9	Yr.10
					(₦'000,000)					
Utility	66	79	95	114	137	164	197	236	283	340
Raw Materials	240	276	317	365	420	483	555	638	734	844
Insurance on Fixed Assets	54	65	78	94	113	136	163	196	236	282
Total Operating Cost	360	420	490	573	670	783	915	1,070	1,253	1,466

Table 7: Projected Maintenance Cost

Item	Yr.1	Yr.2	Yr.3	Yr.4	Yr.5	Yr.6	Yr.7	Yr.8	Yr.9	Yr.10
					(₦'000,000)					
Repairs/ Maintenance	184	221	265	318	382	458	550	660	792	850

Table 8: Projected Royalty Cost

Item	Yr.1	Yr.2	Yr.3	Yr.4	Yr.5	Yr.6	Yr.7	Yr.8	Yr.9	Yr.10
					(₦'000,000)					
Royalty	121	157	191	226	261	296	331	331	331	331

Table 9: Projected Total Exploration and Mining Cost

Item	Yr.1	Yr.2	Yr.3	Yr.4	Yr.5	Yr.6	Yr.7	Yr.8	Yr.9	Yr.10
					(₦'000,000)					
AC	901	495	545	640.4	767.7	921.4	1,106.3	1,328.2	1,592	1,873
OC	360	420	490	573	670	783	915	1,070	1,253	1,466
MC	184	221	265	318	382	458	550	660	792	850
RC	121	157	191	226	261	296	331	331	331	331
Profit	**278.6**	**1,012.6**	**1,533.1**	**1,980.8**	**2,375.7**	**2,711.7**	**2,976.8**	**2,500.7**	**1,923.7**	**1,226.8**

The mining model was developed with 54 datasets from the projected fixed and variable costs, using Statistical Package for the Social Sciences (SPSS, V.16) software.

The accuracy of the model was computed using correlation coefficient (R^2), root mean square (RSME) and variance accounted for (VAF) as shown in Equations 4 – 6

.

$$R^2 = \frac{\sum_{i=1}^{r}(\alpha-\beta)^2-\sum_{i=1}^{r}(\alpha-w)^2}{\sum_{i=1}^{r}(\alpha-\beta)^2} \quad (4)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\alpha-\beta)^2} \quad (5)$$

$$VAF = \left(1-\frac{Var(\alpha-\beta)}{var(\alpha)}\right)\times 100 \quad (6)$$

Where,

α is the calculated profit in Naira, n is the number of dataset, ω is the mean value of the predicted profit, β is the predicted profit from the developed model in naira (₦).

RESULTS AND DISCUSSIONS

Site Mapping Using Geographical Information System (GIS) and Other Scientific Tools

The field exercise was performed with all geospatial readings based on the same geographic (projected) coordinate system, the Universal Transverse Mercator (UTM) and referenced to same datum (ellipsoid); the World Geodetic System (WGS) of 1984) using the Global Positioning System (GPS) locations, within a common geographic framework.

With the taken geographical coordinates of the corners of the study area, the linear dimensions of the block A which has an area of approximately 1.48 km^{2}of were drawn. This is shown in Figure 3.

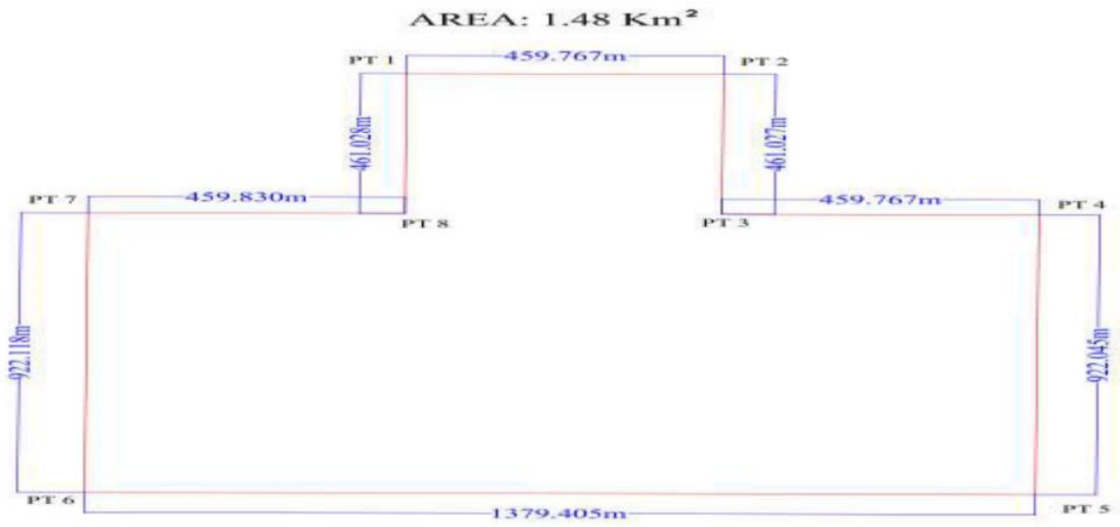


Figure 3: Linear Dimension of block A in the Study Area

The satellite imagery of the area captured showed some illegal or artisanal mining activities around the three blocks. Figures 4 and 5 were developed to show the virtual assessment of various landscapes and activities within and around the blocks in the study area. At block A, it is about 0.81 km radius from the sparsely occupied area as shown in Figure 4.

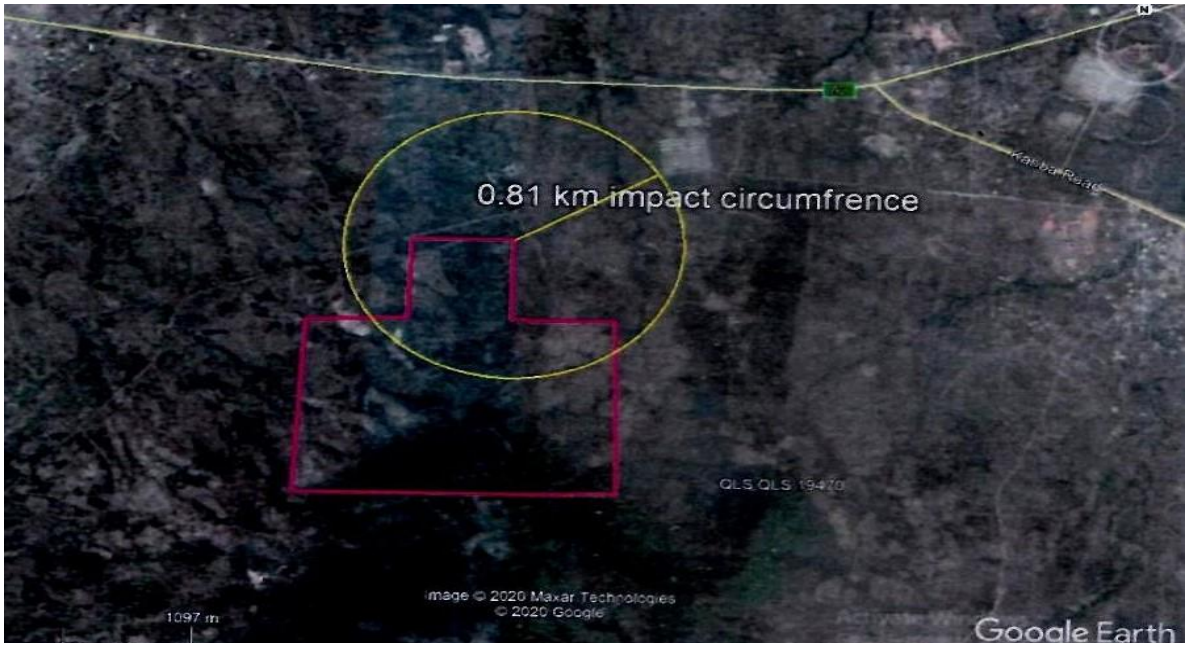


Figure 4: Estimated Minimal Distance of Likelihood Activity of Block A

It is about 9.35 km radius from the sparsely occupied area in blocks B and C as shown in Figure 5.

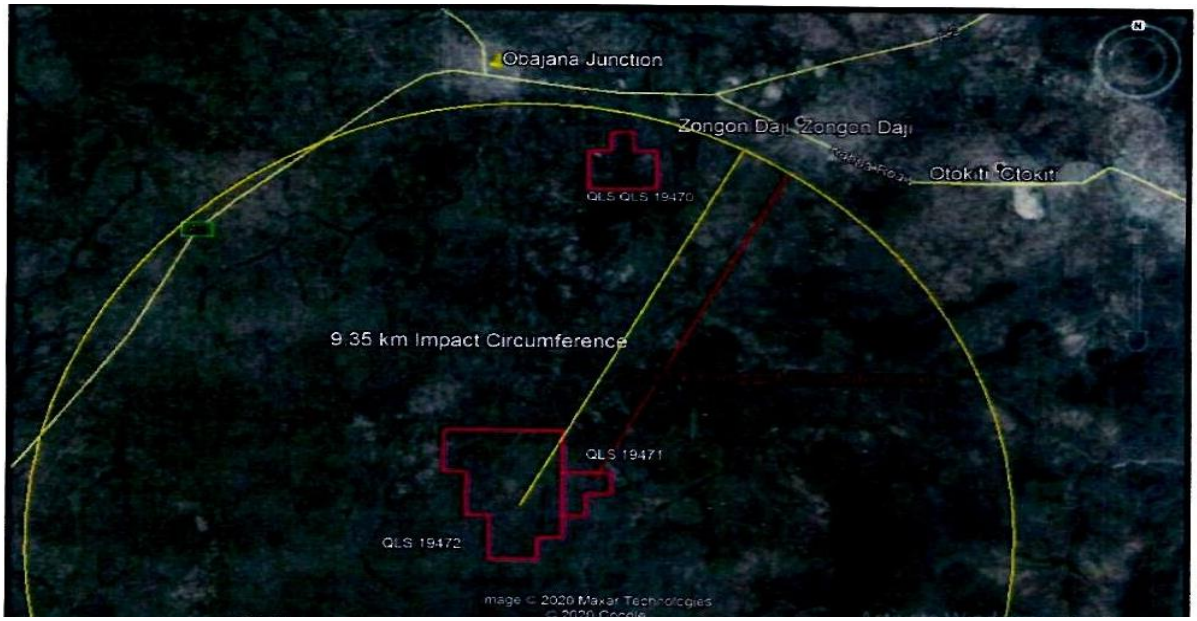


Figure 5: Estimated Minimal Distance of Likelihood Activity of Blocks B and C

Physical analysis test result

The results of rock samples taken from all three blocks, prepared into thin sections in the laboratory and analyzed for physical characteristics were processed. The summary of results is presented in Table 10.

Table 10: Results of Physical Characteristics of Feldspar Samples Taken from three Blocks

Physical Characteristics	Result Obtained
Mohs Hardness Test	6
Density	2.55 g/cm^3
Diagnostic Properties	Feldspar sample has a perfect cleavage. Cleavage faces intersecting at or close to 90˚. Consistent hardness, specific gravity, pearly lustre on cleavage faces, showing flakes of quartz (white) and muscovite (white). It is granitic and granodiorite composition.

The average density of the feldspar from the three blocks was determined to be 2.56 g/cm^3 and a hardness of 6 was obtained, using the Mohs scale

Economic Analysis for Development of Feldspar Deposit

The economic analysis is predicated on the fixed and variable costs indices. Projections were made for operational overheads, wages and salaries, royalty charges and revenue, and a profitability performance analysis of returns on sales was calculated. Table 11 shows the profitability performance analysis of returns on sales

Table 11: Returns on Sales

Yr. 1	Yr. 2	Yr. 3	Yr. 4	Yr. 5	Yr. 6	Yr. 7	Yr. 8	Yr. 9	Yr. 10
				₦(000,000)					
.-2.4	-3.91	1.5	4.9	7.8	10.6	13.2	17.3	22	27.7

Having computed all the economic parameters needed to develop a cash flow analysis and considering projections made, the cash flow economic analysis model is given in Table 12. Returns on sales (Rs) is calculated using Equation 7

$$R_S = \frac{Net\ Profit}{Sales} \times 100\% \qquad (7$$

Table 12: Economic Analysis for Development of the Feldspar Deposit Using Cash Flow Model

End of Year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
					₦(000,000)					
CASH INFLOW:										
Loan	2,435									
Sales	2,436	3,132	3,828	4,524	5,220	5,916	6,612	6,612	6,612	6,612
TOTAL CASH INFLOW	**4,871**	**3,132**	**3,828**	**4,524**	**5,220**	**5,916**	**6,612**	**6,612**	**6,612**	**6,612**
CASH OUTFLOW:										
Buildings and Structure	530	50	-	-	-	-	-	-	-	-
Machinery and Equipment	2,435	-	-	-	-	-	-	-	-	-
Raw Materials	240	276	317	365	420	483	555	638	734	844
Salaries and Wages	201	241	298	347	416	499	599	719	863	1,036
Gen/Admin Expenses	120	144	172	207	248	298	358	430	516	619
Insurance on Fixed assets	54	65	78	94	113	136	163	196	235	282
Utilities	66	79	95	114	137	164	197	236	283	340
Repairs and Maintenance	184	221	265	318	382	458	550	660	792	950
Furniture and Fittings	50	60	72	86.4	103.7	124.4	149.3	179.2	215	218
Royalty at 5% of Production	121	157	191	226	261	296	331	331	331	331
Loan Repayment	-	244	244	244	244	244	244	244	244	244
Interest on Loan at 21%	512	486	447	403	354	305	255	204	153	101
Contingency at 10%	79.4	96.4	115.9	138.8	165.6	196.9	233.9	274.1	322.3	380.2
TOTAL CASH OUTFLOW	**4,592.4**	**2,119.4**	**2,294.9**	**2,543.2**	**2,844.3**	**3,204.3**	**3,635.2**	**4,111.3**	**4,688.3**	**5,385.2**
Summary:										
Cash Inflow	**4,871**	**3,132**	**3,828**	**4,524**	**5,220**	**5,916**	**6,612**	**6,612**	**6,612**	**6,612**
Cash Outflow	**4,592.4**	**2,119.4**	**2,294.9**	**2,543.2**	**2,844.3**	**3,204.3**	**3,635.2**	**4,111.3**	**4,688.3**	**5,385.2**
Annual Cash Surplus/Deficit	**278.6**	**1,012.6**	**1,533.1**	**1,980.8**	**2,375.7**	**2,711.7**	**2,976.8**	**2,500.7**	**1,923.7**	**1,226.8**
Annual Opening Balance	-	**278.6**	**1,291.2**	**2,824.3**	**4,805.1**	**7,180.8**	**9,892.5**	**12,869.4**	**15,370.1**	**17,293.8**
Annual Closing Balance	**278.6**	**1,291.2**	**2,824.3**	**4,805.1**	**7,180.8**	**9,892.5**	**12,869.4**	**15,370.1**	**17,293.8**	**18,520.6**

The project has a capacity of generating N1,226,800,000 over a period of ten years net all costs as shown in the cash flow analysis. The minimum cash in-flow over the first ten years is N184,100,100 and the project can still go on for more than one hundred years (100years). Equipment replacement is minimal over a long period with proper maintenance.

Mining Model Developed to Evaluate Economic Feasibility of Feldspar Deposit

The dataset statistic and the model parameters and hyperparameters for developing the mining model are presented in Tables 13 and 14 respectively.

Table 13: Parameter Statistics

Statistic	AC	OC	MC	R	Profit
Min (₦) x 10^3	450,000	360,000	184,000	121,000	278,600
Min (₦) x 10^3	7,197,767.265	5,884,361	4,516,172	1,479,752	11,263,721
Average ((₦) x 10^3	1,547,087.494	1,008,378	1,059,121	427,450.6	3,169,807
Variance	1.70983E+12	6.51E+11	8.02E+11	6.65E+10	4.05E+12
Standard Deviation	1,307,604.456	806,818.7	895,309.6	257,944.2	2,011,376
Skewness	2.898458693	4.376427	2.491334	2.282582	2.234457
Kurtosis	9.919342088	24.50572	6.748538	5.787792	5.690961

Table 14: Model Parameters and Hyperparameters

Coefficients					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig
	B		Standard Error	Beta	
Constants	-257,728	149,536	-1.724 0.091		
AC	0.005	0.038	0.003	0.137	0.891
OC	0.051	0.091	0.021	0.056	0.578
MC	-0.279	0.313	- 0.124	-0.894	0.376
R	8.571	0.967	1.099	8.862	0
Dependent Variable: Profit					

The model obtained can be tested by the mathematical formular presented in Equation 8

$$PR = (X_1AC + X_2OC + X_3MC + X_4R + K) \times 1000 \quad (8)$$

The model parameters and hyperparameters in Table 29 were extracted into the mathematical equation obtained and presented in Equation 9.

$$PR = (0.005AC + 0.051OC - 0.279MC + 8.571R - 257728) \times 1000 \quad (9)$$

Where, X_1, X_2, X_3, X_4, K are the model parameter coefficients, AC is the Administration cost, OC is the Operation cost, MC is the Maintenance cost, R is the Royalty and PR is the Profit in Naira (~~₦~~).

The model was applied to testing data and predicted result was compared with the calculated revenue. The model performance was found to have correlation coefficients of (R^2) of 0.9859 and 0.996 for both training and testing respectively as shown in Figure 6

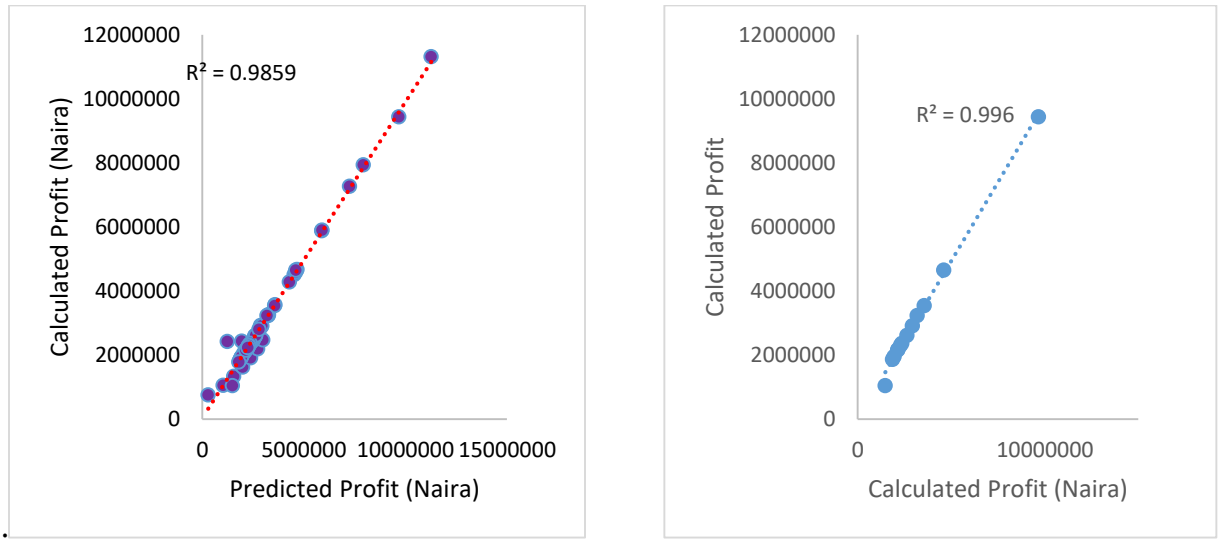


Figure 6: Relationship between Developed Model Prediction Profit and the Calculated Profit

Model error analysis

The result of the error analysis carried out on the developed mining model is presented in Figure 35. The high value of VAF and R^2 and low RSME obtained from the model revealed its degree of accuracy.

From Figure 7, it is shown that the model prediction result closely correlates with the calculated generated result as indicted by the correction coefficient >90%.

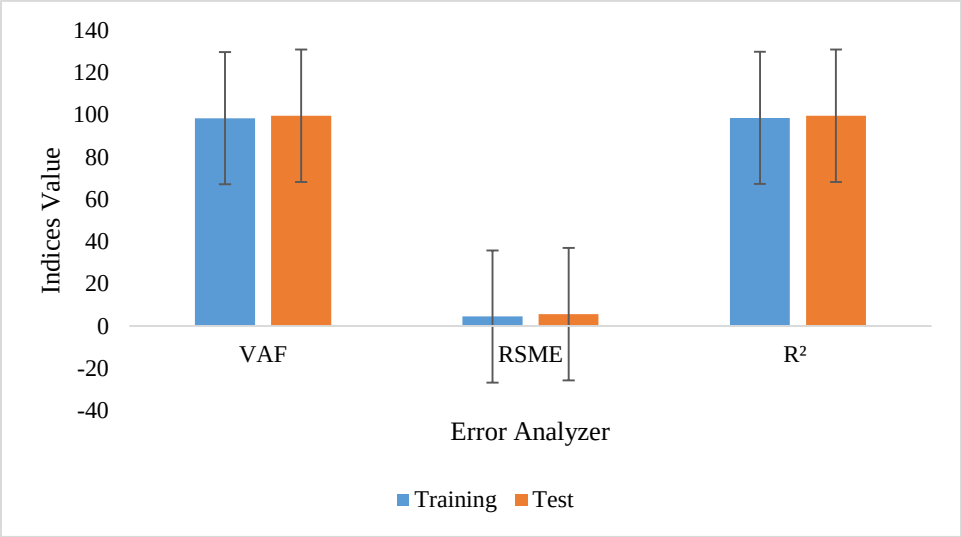


Figure 7: Model Error Analysis Result

These indicates that the performances of the proposed model are satisfactory and it can be used for the practical purposes and for decision making.

The developed model in Equation 10 was tested by running data from the economic variables derived for each year used in developing the model as shown in Table 15. It was also observed that the calculated profits and predicted profits are closely correlated.

Table 15: Tested Economic Variables on Developed Model

AC	OC	MC	RC	Profit	Predicted
883297.1	698166.4	1197907	477968	3549081	3544743
578716.2	466075.7	799687.8	357745.8	2623261	2612061
744398.9	592325.9	925681.5	395783.2	2916184	2910196
2405038	707545	685032.2	323131.2	2356698	2368816
2114016	485786.2	470329.4	258312.4	1857535	1860391
2604060	859199.7	654984.1	314059.7	2286839	2308177
7197767	1359605	1036452	429224.9	3173715	3237317
6877602	5884361	4485760	1237931	9664884	9435540
3759162	1260613	960988.9	173802.5	1470139	1046905
2345700	662329.4	504906.2	268751.2	1937923	1950377
1355741	2158169	1645213	613009.7	4589023	4654209
2507879	785909.8	599113.9	297192.5	2156947	2174977
2491509	773435.8	589604.7	294321.7	2134839	2152306

CONCLUSIONS

The economic evaluation of feldspar deposits in Adavi and Ajaokuta local governments in Kogi state was carried out. The economic evaluation involved both an economic analysis and economic feasibility. The following findings and conclusion were drawn
from the study;

i. The economic analysis carried out on the feldspar deposit using the derived parameters. The net present value was used to determine the economic and financial analysis. The outcome showed that the project, if embarked upon has a life span of 117.8 years or more at an average daily production capacity of 5000 tons should it be embarked upon and a loan payback period ten years. Therefore, there is need for more exploration to acquire more reserves of feldspar.

ii. A mining model was developed and the developed model's prediction performance is appropriate to evaluate the economic feasibility of the feldspar deposit with associated financial benefits.

iii. The assessment further showed that of the three mapped out block of feldspar, block A, based on its level of economic evaluation has the largest deposit of feldspar followed by block B, and then block C.

iv. The preference for the development of the three mapped out blocks of feldspar would be based on the both the economic evaluation and the level of geoscientific information of the deposit.

RECOMMENDATIONS

Based on the economic analysis carried out and mining model developed, the project has a capacity of generating a net profit of close to a billion naira without any liability after the loan payback period of ten years net all costs and is viable. The cash flow analysis shows a positive net present value of the project and the mining model showed the viability of the project given the technical and managerial skills of the mangers of the project.

i. With an estimated reserve of 113.3million metric tons, it is expected that the project will last for 117.8 years with an estimated production of 600,000 metric tons per annum. With the abundance of feldspar and a whole lot of other minerals in the Nigeria,

investing in the solid mineral sector will yield higher returns and improve the country's wealth.

ii. In addition, the proposed project site location is hereby recommended in view of the following favorable attributes:

a. Its nearness to Lokoja, the capital of Kogi State

This is an historic town with an history of settlement of the British colonial government dating back to several years. It is also known as a trade route for the miners who use the navigable port in the State to transport their mining products. This will provide means of transporting the mineral products to several parts of the country through the River Niger.

b. Nearness to Military Formation

There is also a Maimaleri Military barracks located about ten minutes away from Zango and less than fifteen minutes' drive to Lokoja. This facility is expected to provide security support to the proposed Feldspar Quarry, especially in security prone Kogi State.

c. Kogi is a Gateway State

Kogi State, where the project is located is a gateway to the Nation's Federal Capital Territory, (FCT) Abuja and also to the Eastern and Southern parts of Nigeria. The Federal Express road, which also run from Lokoja to other parts of Nigeria makes the project site accessible to Northern, Southern and Western parts of Nigeria. Also, the Itakpe-Warri standard gauge rail lines which has just been completed, will soon be extended to FCT. These different modes of transportation will also make the haulage of mined Feldspar to other parts of Nigeria easy and economical. Nearness of Lokoja to FCT and neighboring States is a guarantee for adequate supply of skilled and cheap manpower.

d. Abundance of Mineral Deposit

The abundance of the mineral deposit in Kogi State attracts the presence of other extractive industries to the State. This includes Ajaokuta Steel Plant about to be resuscitated by the Federal government. It also includes Royal Ceramic Company, Lokoja and West Africa Ceramic Industries Limited, Ajaokuta, which use Feldspar as

one of their major raw materials. Also, Dangote Industries Limited, Obajana, which uses Limestone as basic raw material is not far from Lokoja.

e. Presence of Educational Institutions

The presence of the following higher institutions near the project site will enhance the settlement of workers to the environment: Kogi State Polytechnic - Lokoja, Osara and Itakpe campuses; Federal University, Lokoja, Kogi State University, Ayangba, Salem University, Lokoja and Federal College of Education, Okene.

f. Presence of Electricity Infrastructure.

The presence of Geregu Power Plant in the Ajaokuta area which is close to the project site will provide needed electricity to the project.

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