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Influence of Construction Materials on Cut-Off Grade and Ore Reserve Determination: Case Study of Itakpe Deposit, Central Nigeria

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Abstract: *The presence construction materials in an ore deposit can add value to the deposit and affect cut-off grade. In this paper, the influence of the presence of granite and aplites on the cut-off grade and ore reserve of Itakpe Iron ore deposit has been studied. This study was carried out by converting the values and production costs of the construction stones to their main ore equivalent using some mathematical models. The study shows that by adding the value of the construction materials to the value of the iron ore, cut-off grade of Itakpe iron ore decreases from 30%Fe to 28.16%Fe. This corresponds to an increase of mineable ore reserve from 137.25mt to 151.34mt given the operating economic parameters.*

Key Words: *Ore Reserve, Cut – Off Grade, Construction Materials, Itakpe Ore Deposit, Nigeria.*

1. Introduction

The cut-off grade of an ore is the grade at which the recoverable value from a given tonnage of the ore will balance all expenditures on mining, waste removal, mineral processing and smelting, and leave the corporate outfit with at least, a minimum acceptable profit margin (Alwyu, 1991). Cut-off grade and ore reserve of a deposit are closely interrelated. When cut-off grade is raised, then ore reserve will decrease. If cut-off grade is lowered, then ore reserve increases.

Michelson and Buckley (1973) and Halodnikov (1988) have shown that the presence of secondary ores and minor metals in a deposit can significantly affect the cut-off grade and reserve of the main ore. Thus the exploitation of construction materials in Itakpe deposit will affect the cut-off grade and reserve of the iron ore.

Itakpe deposit contains 10 million tones of granite and 7 million tones of aplite (NIOMCO Project Report, 1980) which the organization is currently quarrying. The essence of this paper is to show how this quarrying operation affects the cut-of grade and reserve of Itakpe iron ore.

2. Geology of The Itakpe Area

Itakpe is located within Okene area of Kogi State in Central Nigeria. It lies within latitudes $7^{o}35'N$ – $7^{o}39'N$ and longitudes $6^{o}15'E$ – $6^{o}22'E$. The area is characterized by distinct rainy and dry seasons with the rainy season lasting from late April to October while the dry season is from November to March. Average daily temperature of $28^{o}C$ in the morning time and 37 ^{o}C from mid-day to about 4.00pm is recorded within the area.

The geology of the area is that of the basement complex rocks of Nigeria (Fig.1). It is made up of hilly plateau dipping gently. Several geological studies have been reported within and around the area. Ajibade and Woakes (1980), Akinrisola and Adekeye (1993), Nigerian Steel Development Authority (1976), Olade (1978), reported common occurrences of gneisses, migmatites and quartzite of various compositions, within the area. Low grade sediment dominated schist and ganitic rocks cut both the migmatites and schist. Biotite gneisses, migmatite gneisses, intercalations of amphibolites, tonalite gneiss are overlain by a sequence of low grade metasediments intruded by granodiorites and granitic rocks. Ferruginous and non-ferruginous quartzite occur as magnetite and hematite rich bands and lenses in alternation with the gneisses. Regional metamorphism has caused the faulting and folding of ore deposits within the area.

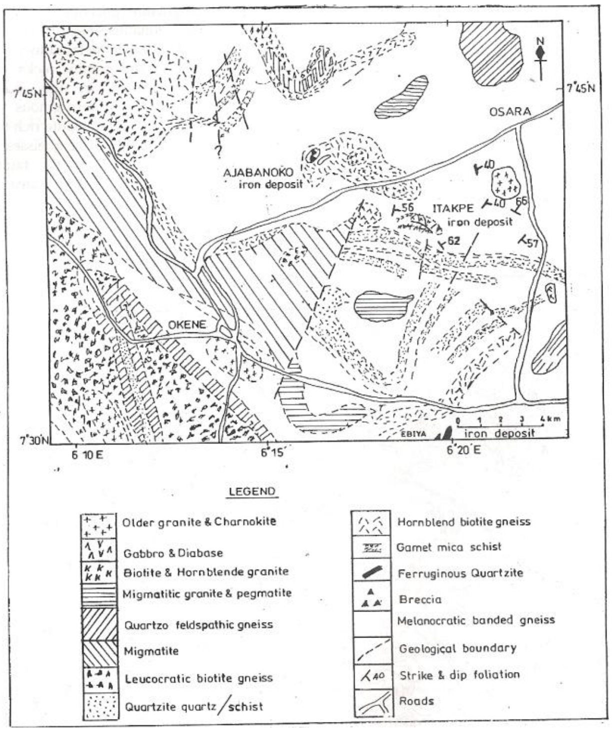

Fig1. *Geological Map of Okene Area Showing Itakpe (after Adegbuyi, 1981)*

3. METHOD OF STUDY

In order to objectively assess the influence of the construction materials on the cut-off grade and reserve of Itakpe iron ore, it is necessary to first of all estimate the cut-off grade of Itakpe iron ore without considering the influence of the construction materials and secondly to estimate the cut-off grade and reserve of the iron ore deposit considering the influence of the construction materials.

Table 1 shows the techno-economic parameters of exploitation of Itakpe iron ore while Table 2 shows the techno-economic parameters of exploitation of construction materials. Costs were estimated based on the methods recommended in Cummins and Given (1973) and Ohara (1992).

Table1. *Techno-Economic Parameters of Exploitation of Itakpe Deposit*

Parameter	Recovery R_m	Yield Y	Price per ton of Concentration P_c	Stripping Ratio S_R	Mining cost per ton, C_m	Waste Removal cost per ton, W	Processing cost per ton. C_P	Smelting cost per ton C_S
Value	0.85	.48	12000	4	300	200	280	240

Table 2: *Economic Parameters of the Construction materials*

Parameters Sec. ore	Tonnage Ma	Price per ton N	Mining cost per ton	Processing cost per ton
Granite	10	4000	290	120
Aplite	7	3500	250	115

Cut-off grade of a deposit (COG) can be estimated as:

$$\text{COG} = \frac{(Cm + (S_R\, x W) + C_P + C_S)}{Rm.Pm} = \frac{Total\ \Pr oduction\ Cost}{Rm.Pm} \qquad (1)$$

Where:

C_M - Mining cost per ton ore

S_R - Stripping ratio

W - Cost of waste removal per ton ore.

C_P - Processing cost per ton ore

C_S - Smelting cost per ton ore

R_m - Metallurgical recovery

P_m - Cost per ton of smelted ore.

If r% is taken as the minimum corporate acceptable rate of return on investment, then:

$$COG = \left(1+\frac{r}{100}\right)\frac{(C_m+(S_R\,X\,W)+C_P+C_S)}{Rm\ X\ Pm} \quad (2)$$

If the ore is not smelted by the Mining Company but beneficiated and sold to a Smelting Plant, as it is the case with Itakpe, then:

$$COG = \left(1+\frac{r}{100}\right)\frac{(C_m+(S_R\,X\,W)+C_P+C_S)}{\gamma\,X\,P_c} \quad (3)$$

Where Y and P_C are as defined in Table (1)

To consider the influence of the construction materials grade of Itakpe iron, the value of the construction materials and their cost of production will have to be converted to the main ore equivalent, (Michelson and Buckley, 1973). To do this, we recommend the following formula (approach).

(i) The value of the construction materials per ton of iron ore

$$V = \sum_{i=1}^{n}\frac{S_i.P_i}{Sm} = \frac{Total\ Value\,of\ the\,Construction\,Materials}{\mathrm{Re}\,serve\ of\ iron\ \ ore} \quad (4)$$

Where:

V - Value of the construction materials per ton of iron ore.

S_i - Reserve of the i-th type of the construction material

S_M - Reserve of iron ore.

P_i - Price per tone of processed i-th type of construction material

Then the value per ton of iron ore considering the added value from the construction material

$$V_S = \Upsilon\,P_C + V \quad (5)$$

In calculating the production cost of iron ore considering the construction material, influence of the cost of production of the construction material will also have to be transferred to the cost per ton of iron ore i.e.

$$a = \frac{S_i\,X\,B_i}{S_m} \quad (6)$$

Where:

a - Production cost of construction materials per ton of iron ore.

B_i - Cost of production per tone of i-th type of construction materials.

Then the total production cost considering the influence of the construction material will be

$$T_s = T + \propto \alpha \quad (7)$$

Where T is the total production cost per ton ore including beneficiation costs and return on investment i.e

$$T = (1 + r/100)\,(C_m + C_P + (S_R \times W)) \quad (8)$$

Cost of production of the construction material B_i equals cost of mining and cost of processing at Crushing Plant. Since the construction materials are located within the pit contour and would have been removed at cost if they were not useful, then cost of mining the construction material is the difference between the actual cost of mining the construction material and cost of waste removal. In other words, if the cost of mining the construction material were the same as cost of waste removal, then cost of production of the construction material would have been equal to the cost of their processing at crushing plant. But waste materials at Itakpe are simply thrown down-slope whereas the granite and aplite need to be hauled to the crushing plant a distance of 3km from the mine. Consequently, the net cost of mining:

$$C = C_i - W \quad (9)$$

Where:

C - Net cost of mining i.e the difference between actual cost mining and cost of their removal as waste

C_i - Actual cost of mining i-th type of construction material.

Therefore, cost of production per ton of the construction material

$$B_i = C_i - W + X_p \quad (10)$$

Where:

X_p - Cost of processing pr ton of construction material

4. RESULTS AND DISCUSSIONS

Given a 25% minimum corporate acceptable rate of return, cut-off grade of Itakpe iron are (in %) without the influence of construction materials:

$$COG = \frac{\left(1+\frac{25}{100}\right)(300+280+(4x200)}{0.48x12000} X \frac{100}{1}$$

$$= 30\%$$

Table 3 shows the ore reserve that can be generated from Itakpe deposit at various cut-off grades.

Table3. *Ore reserve of Itakpe at various cut-off grades.*

Fc%	34.19	29.88	29.5	28. 6	25.3	24.4	20.8	20.6	20.5	18.7	18.2	17.8	15.8	14.8
Ore reserve mt	137.25	146.79	147.74	151.34	155.14	159.94	162.54	166.14	168.41	74.01	177.81	185.41	190.71	196.31

From the Table 3, the ore reserve corresponding to a cut-off grade of 30% Fe is the reserve of the next higher cut-off grade which is 137.25mt s

Considering the influence of construction material

(i) The value of granite per ton of iron ore:

$$V_1 = \frac{20mt\ x\ 4000}{137.25} = N291.44$$

This means that for every 1ton of iron ore, there is N291.44 increase in its value coming from the quarry plant as a result of granite exploitation and processing.

(ii) The value of aplite per ton of concentrate

$V_2 \quad \frac{7mt\,x3500}{137.25} = N178.5$

Then value per ton of iron ore considering the added value from the exploitation of construction material

V_s = 0.48 x N12, 000 + N291.44 + N188.5

=N6229.94

4.1. Production Cost

(i) Granite

Mining cost = N290-N200 = N90

Production per ton of granite = N90 + N120

(ii) Aplite = 210.

Mining cost = N250-N200 = N50

Production cost per ton of aplite = N50 + N115

= 165

Therefore, cost of production of the construction material per ton of concentrate:

(i) Granite = $\frac{10mt\,x220}{137.25}$ = N15.3

(ii) Aplite = $\frac{7mt\,x165}{137.25}$ = N8.42

Therefore, production cost of the construction material per ton of iron ore

= N15.3 + N8.42 = N23.72

Therefore, total production cost per ton of iron ore including its construction material equivalent and return on investment

= N1.25 (300 + 280 + (4 x 200) + 23.72)

= N1754.63

Therefore, cut-off grade considering the influence of the construction material.

$$COG = \frac{1754.63}{6229.94} X \frac{100}{1}$$

= 28.16% Fe.

Consequently, because of the influence of the construction material, the cut-off grade lowers from 30% Fe to 28.16% Fe.

The ore reserve corresponding to the cut-off grade of 28.16% Fe is 151.34mt. Thus, because of the presence of aplite and granite in Itakpe deposit, the mineable iron ore reserve increases from 137.25mt to 151.34mt.

5. CONCLUSION

This study has revealed that a proper consideration of the influence of the construction material at Itakpe in the evaluation of the economic viability of the deposit can cushion the effect of high stripping ratio of the deposit and present the picture of a more viable venture than what is presently available. This will increase the investors' confidence in coming into partnership with the Government in the project.

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