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Assessment of Mine Plans for Production and Variations at Ibese Limestone Mines

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Abstract: *This research investigated the mine plans used for the production target and annual production of limestone for the past seven (7) years. The actual amount of limestone produced per year in tons was computed to determine the variations in the mine's production and the life span of the reserve of limestone deposits. A new mine plan was proposed, and a targeted amount of limestone production per year was suggested. The mine plans for the mine's production were generated from 2014 to 2020 using a complete data collection system for Real Time (RTK) GPS and Total Stations with in-field coordinate geometry called SurCE by Carlson Software. The total production target for the seven (7) years was 87,017,146 tons and the actual production was 76,313,056 tons. The total variations for the years under this assessment were -10,704,090 tons except for the year 2018 when the actual production was higher than the production target of 511,179 tons. The volumetric reserve estimation revealed that the total volume of the limestone reserve is 5,052,236,090.186 tons. The expected production per week was computed to be 356,400 tons/week, expected monthly production, (E_{MP}) was estimated to be 1,425,600 tons/month. The expected production year, (E_{PY}) was 17,107,200 tons/year and the life span of the limestone deposit, (L_S) was computed to be 295.34 years. It can be suggested that the company should target a production rate of 1,425,200 monthly and 17,104,200 per year. This suggestion can be achieved if there is enough investment in terms of skilled labour, heavy-duty machinery, and equipment which will cost-effectively boost production.*

Keywords: Limestone, mines, mine plan, production, SURVCE, variations.

1. INTRODUCTION

Limestone is an extremely valuable raw material and one of the most versatile industrial rocks and minerals. Its main use, however, is in the construction industry, as an essential raw material for cement manufacturing, as crushed rock aggregate, and also as a source of building and ornamental stone. The desire for developmental projects globally will continue to expand the construction industries, and subsequently increase the use and exploration of limestone deposits (Afeni *et al.*, 2021). Since limestone is widely extracted, there is a need for fairly regulated open pit quarrying in many developing countries in order to avert economic loss in terms of government revenues, demand, and supply.

There is an increasing awareness of the need for geological resource studies to guide strategic mineral planning and development plans (Exadaktylos and Saratsis, 2020). In many developing countries, there is often no factual basis to evaluate either the potential total or workable mineral resources or their life span to inform the planning processes. Ascertaining the spatial distribution of grade in the deposit as a whole and in its separate blocks and provisional determination of the economic importance of the estimated reserves are also objectives of reserve estimation (Georgios *et al.*, 2023). Dividing the ore body into different blocks with respect to the sampling locations and computing the tonnage of each block separately can give the desired accuracy (Manas *et al*., 2020). Reserve definition also takes into account the milling and extractability characteristics of the ore, and generates bulk samples for involving crushability, and other parameters (Nelson and Sampurna, 2021). The process is similar to resource evaluation, except more intensive and technical, aimed at statistically quantifying the grade continuity and mass of the deposit (Torabi and Choudhary, 2017). In many developing countries, this fundamental resource inventory has not been systematically carried out partly due to the high costs and lengthy duration of conventional and resource surveys (Geovia, 2022).

However, cement is produced by grinding cement clinker along with gypsum to a specified fitness depending on the requirements of the cement consumers. Cement clinker is produced on a large scale by heating finely pulverized calcareous and argillaceous materials at 1400 ℃ in rotary kilns.

Limestone is the main raw material of cement and is composed mainly of calcium carbonate. Limestone required for cement production is estimated at 85% (Alsop, 2007) due to various studies that were conducted to understand the potential limestone deposit.

This research was carried out to assess the seven years mine plans used for production every year and estimate the amount of targeted production and the actual amount of limestone produced per year in tons, suggest an annual production target, and determine the life span of the remaining reserve of the remaining limestone deposit.

2. METHODOLOGY

2.1 Description of the Study Area

Ibese town is about 4 km North of Ilaro town in Yewa North Local Government Area of Ogun State. The study area approximately bounded in the North by Longitude 07° 00' 14"-7° 00' 03.2" and in the East by Latitude 003° 02' 58"- 003° 02' 49.1". The topography of the area is of relatively flat to gentle slope terrain. The study area lies in Southern Nigeria, which is within the humid tropical region of the equatorial zone and is typified by two main climatic seasons, namely the wet and dry seasons. The area belongs to the tropical rainforest of southern Nigeria and is covered mainly by tall trees typical of savannah vegetation. The coastal swamp is mainly mangrove. The local geology of the study area (Figure 1) is that of Ewekoro formation.

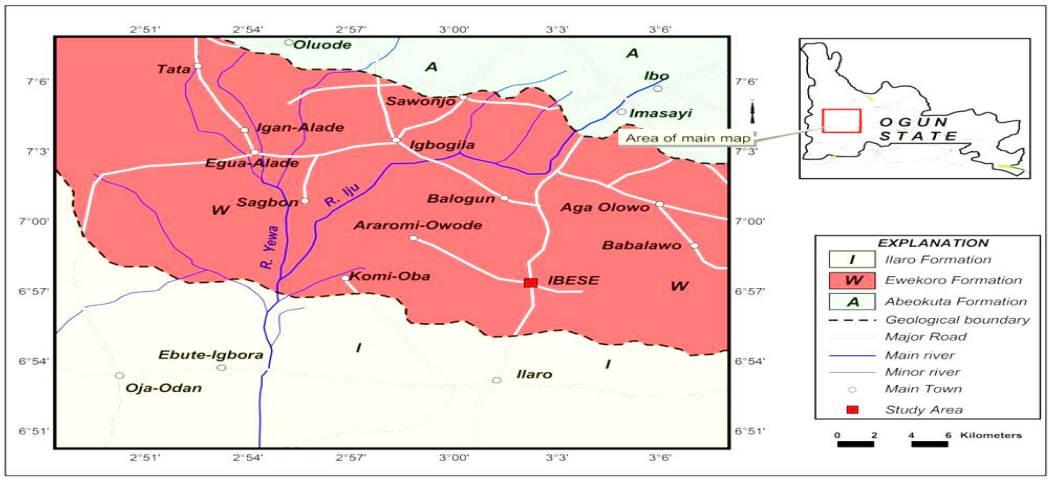

Figure 1: Geological and location map of the study area (Omoyoloye *et al.*, 2008)

2.2 Instrumentation

The instruments used for the study are:

i. Rock Physical Properties Testing Apparatus: These are the laboratory equipment used for this project. They include a measuring cylinder, weighing balance with an accuracy of 0.01 g and a range of 100 g, Sample container, Desiccator, Hammer, Venier caliper, Electric oven, Crucibles, Density bottles, and steel rule.

ii. Global Positioning System Device: The GARMIN GPS receiver was used to establish the coordinate points and height above the ordinance level of the limestone deposit.

iii. Compass – Clinometer: The instrument was used to establish geographic bearing in the study area.

iv. Arrows: metallic arrows of 3 mm thickness were used to mark points where readings were taken.

2.3 Data Collected from the Host Company

Data on limestone deposit geometry and production were collected in the form of a questionnaire from the management of Dangote cement, Ibese, Ogun state in the format stated as follows:

i. Approximate area of Limestone deposit in Ibese covered by Dangote cement;
ii. Average depth of Limestone deposit;
iii. Density of the Limestone deposit;
iv. Crusher Capacity;
v. Number of effective working hours/day;
vi. Number of working days/weeks;
vii. Number of working days/months;
viii. Number of working days/years;
ix. The life span of the reserve; and
x. Annual mining production plan in 2014, 2015, 2016, 2017, 2018, 2019 and 2020.

2.4 New Mine Plan for Production

A new mine plan was generated using SurvCE by Carlson software. SurvCE is a data collection software designed for windows mobile devices. The software features command-style data entry and a map view to

capture and stake out land survey data. It is compatible with a variety of file types, including CAD and GIS data. In the field, SurvCE features coordinate geometry, and functionality with real-time GPS, and it can switch between or simultaneously run GPS and total stations. The mining plans for the quarry sites were generated for reserve calculations.

2.5 Comparison of Targeted and Actual Limestone Production

The targeted amount of limestone production and the actual amount of limestone production were compared for error corrections using IBM SPSS Statistics Processor.

2.6 Volumetric Reserve Estimation of Limestone Deposit

The volumetric reserve estimation of limestone deposit was calculated using the following parameters and formula expressed in Equations (1) and (2) as follows:

Approximate area with quarriable limestone deposit, (Q_A) = 70% of (i) (1)

Total volume/reserve of limestone deposit, (T_V) = (Q_A * D * T) tons (2)

where: A is the total area of the limestone deposit surveyed, the average depth of limestone deposit is D and T is the tonnage factor of limestone.

2.7 Determination of the Life Span of Limestone Deposit

The life span of the limestone deposit was calculated with the following parameters and Equations (3), (4), (5) and (6).

Expected production per week, (E_P) = (Time (hrs) * Number of days * Crusher capacity (tons) * Efficiency) tons/week (3)

Expected monthly production, (E_{MP}) = (4 * E_P) tons/month (4)

Expected production year, (E_{PY}) = (12 * E_{MP}) tons/annum (5)

Life span of the limestone deposit, (L_S) = T_V / E_{PY} (6)

where total volume/reserve of the limestone deposit is T_V.

2.8 Suggestion of a Targeted Limestone Production

A targeted amount of limestone production was computed from the new mine production plan produced, based on the findings of the error corrections made from previous mine plans and the actual amount of limestone produced.

3. RESULTS AND DISCUSSION

3.1 Mine Plans Assessment

The mine plans of the Ibese mine production target were generated using a complete data collection system for Real Time (RTK) GPS and Total Stations within the field coordinate geometry called SurCE by Carlson software with data acquired from land survey work on the limestone deposits and assessed from 2014 to 2020 productions on a monthly and yearly basis for the past seven (7) years as shown in Figure 2.

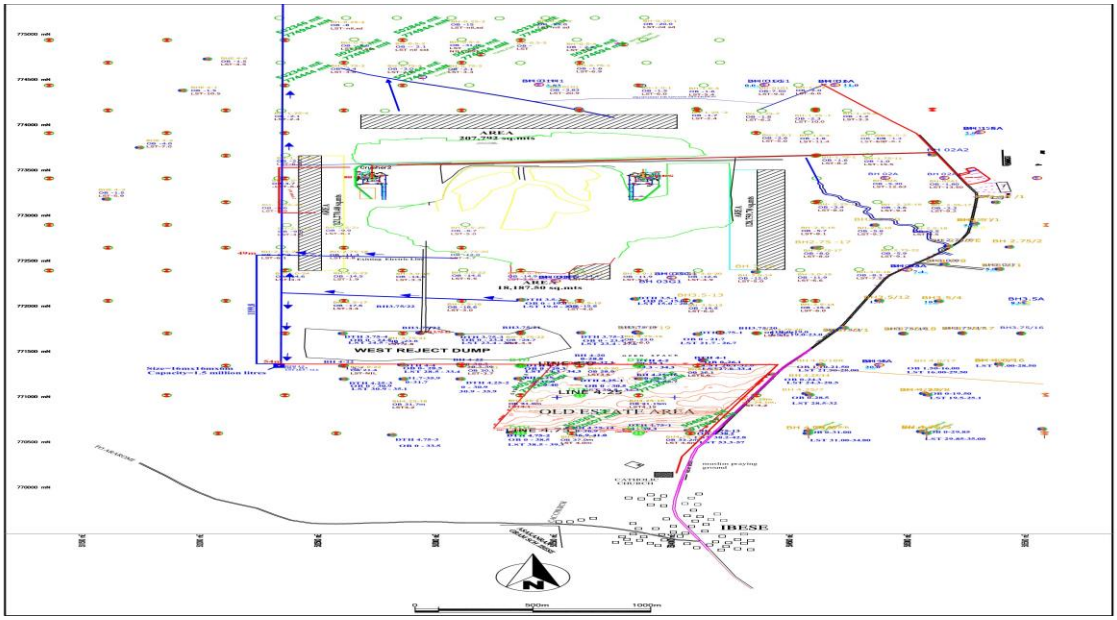

Figure 2: 2020 mine plan of Ibese limestone deposit

3.2 Estimated Production Target

The estimated amount of production targeted were computed in Table 1 from 2014 to 2020. The production was very low in year 2015 but was very high in year 2019 which can be due to staff strength, down time or availability of heavy-duty equipment.

Table 1: Estimated mines production target in tonnes from 2014 to 2020

	2014	2015	2016	2017	2018	2019	2020
JAN	644,897	686,400	1,091,418	1,114,972	1,077,264	1,376,499	1,272,310
FEB	734,047	607,200	1,021,004	1,007,071	973,013	1,243,290	1,149,183
MAR	644,897	686,400	1,091,418	1,114,972	1,077,264	1,376,499	1,272,310
APR	788,621	660,000	1,056,211	1,079,005	1,042,514	1,332,096	1,231,267
MAY	840,088	686,400	1,091,418	1,114,972	1,077,264	1,376,499	1,272,310
JUN	815,286	660,000	1,056,211	1,079,005	1,042,514	1,332,096	1,231,267
JUL	840,515	686,400	1,091,418	1,114,972	1,077,264	1,376,499	1,272,310
AUG	691,702	686,400	1,091,418	1,114,972	1,077,264	1,376,499	1,272,310
SEP	664,590	660,000	1,056,211	1,079,005	1,042,514	1,332,096	1,231,267
OCT	814,132	686,400	1,091,418	1,114,972	1,077,264	1,376,499	1,272,310
NOV	788,621	660,000	1,056,211	1,079,005	1,042,514	1,332,096	1,231,267
DEC	812,576	686,400	1,091,418	1,114,972	1,077,264	1,376,499	1,272,310
Total	**9,079,972**	**8,052,000**	**12,885,774**	**13,127,895**	**12,683,917**	**16,207,167**	**14,980,421**

3.3 Actual Annual Production

The actual amount of mine production per year in tons was also computed in Table 2 from 2014 to 2020. The actual production of the limestone could not meet up with the production target for 2014, 2015, 2016, 2017, 2019 and 2020 which can be caused by the shortage in workforce, down time of equipment or unfavourable climatic conditions but in 2018, the actual production was able to exceed the production target. This could be due increase in labour, pro - activeness of staff or availability of sophisticated mechanized equipment.

Table 2: Actual amount of mines production in tonnes

	2014	2015	2016	2017	2018	2019	2020
JAN	451,842	514,876	1,064,424	957,307	1,024,765	1,264,127	1,024,994
FEB	362,778	425,731	856,399	1,041,272	1,053,091	1,158,282	1,000,491
MAR	542,426	743,984	1,199,485	1,046,875	1,288,535	1,108,518	1,299,474
APR	435,779	607,404	1,264,564	1,013,838	1,217,144	1,183,236	1,031,209
MAY	584,353	646,219	981,301	819,359	1,212,649	1,206,916	1,149,859
JUN	539,947	607,381	997,214	710,650	1,003,304	1,153,908	899,950
JUL	539,402	634,728	1,072,582	869,808	1,084,036	1,318,818	1,123,632
AUG	662,156	542,324	1,046,291	861,818	1,244,357	1,465,703	1,249,789
SEP	451,580	534,986	835,794	739,746	844,489	989,240	955,787
OCT	566,714	466,533	702,328	796,716	990,687	1,001,478	1,001,070
NOV	605,360	880,615	889,837	652,370	1,010,149	1,101,543	1,012,381
DEC	647,762	740,317	1,017,888	886,110	1,221,890	1,140,100	1,218,282
Total	**6,390,099**	**7,345,098**	**11,928,107**	**10,395,869**	**13,195,096**	**14,091,869**	**12,966,918**

3.4 Determination of Variations in Mines Production

The variations in the targeted production and the actual production were determined and computed in Table 3 using the production loss and the overproduction in the actual production of the targeted production. It was observed that there were variations in all the yearly production. The variations can be tagged as production loss from years 2014, 2015, 2016, 2017, and 2019 because the production target was not achieved which can be due to some challenges encountered during production. In the year 2018, it was observed that the actual production was above the production target and the variations can be tagged as over production which can be due to the activeness of the staff and good working conditions in the mines.

Table 3: Variations in the mines production in tons

Year of Production	Production Target	Actual Production	Variations
2014	9,079,972	6,390,099	-2,689,873
2015	8,052,000	7,345,098	-706,902
2016	12,885,774	11,928,107	-957,667
2017	13,127,895	10,395,869	-2,732,026
2018	12,683,917	13,195,096	+511,179
2019	16,207,167	14,091,869	-2,115,298
2020	14,980,421	12,966,918	-2,013,503
Total	**87,017,146**	**76,313,056**	**-10,704,090**

3.5 Development of a Mine Plan to Suggest a Production Target

A new mine plan was generated using SurvCE by Carlson Software as shown in Figure 3. SurvCE is a data collection software designed for Windows Mobile devices. The software features command-style data entry and a map view to capture andstake out the land survey data.

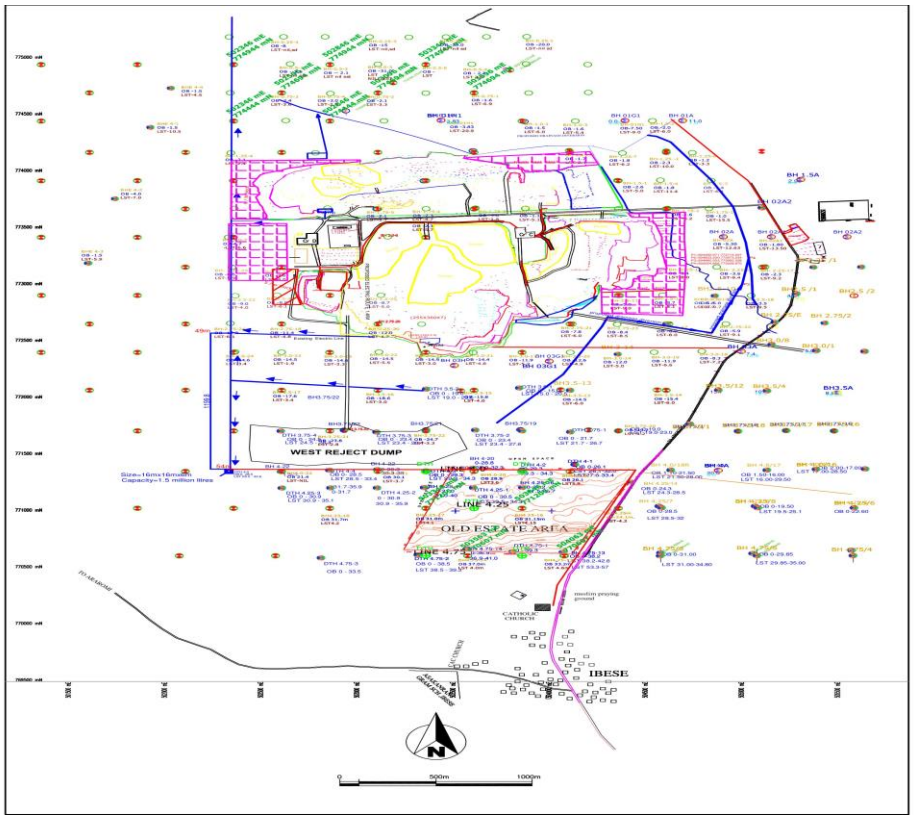

Figure 3: A new mine plan for Ibese limestone deposit

3.6 Volumetric Reserve Estimation of Limestone Deposit

The volumetric reserve estimation of limestone deposits was calculated using the following parameters and Equations (1) and (2).

i. The total area of the limestone deposit surveyed, (A) was calculated in square units of 25, 566 by 15,342.18 (392,254,354.828 sq. units) on the ground which was scaled on the map to be 1 square unit to represent 100 m. The total area of the limestone deposit surveyed was 392,254,354.828 sq. units.

ii. Approximate area with quarriable limestone deposit, (Q_A) = 70% of 392,254,354.828 = 274,578,048.3796 sq. units.

iii. The average depth of limestone deposit, (D) = 8 m.

iv. Tonnage Factor of limestone, (T) = 2.3

v. Total volume/reserve of limestone deposit, (T_V) = (274,578,048.3796 * 8 * 2.3) tons = 5,052,236,090.186 tons.

3.7 Determination of the Life Span of Limestone Deposit

The life span of the limestone deposit was calculated with the following parameters and Equations (3), (4), (5), and (6).

i. Total volume/reserve of the limestone deposit, (T_V) = 5,052,236,090.186 tons.
ii. Expected production per week, (E_P) = 16 (4) * 5.5 * 1350 * 0.75 tons/week = 356,400 tons/week.
iii. Expected monthly production, (E_{MP}) = (4 * 356,400) tons/month = 1,425,600
iv. Expected production year, (E_{PY}) = (12 * 1,425,600) tons/annum = 17,107,200
v. Life span of the limestone deposit, (L_S) = 5,052,236,090.186 / 17,107,200 = 295.34 years

It can be suggested that the company should target a production rate of 1,425,600 monthly and 17,107,200 per year.

4. CONCLUSION

This research work assessed variations in the mine production plans for future investments at the Ibese limestone deposit to assess the mine plans used for production every year for the past seven (7) years and estimate the amount of targeted production and the actual amount of limestone produced per year in tons, determine the variations in the production of the mine, propose a new mine, determine the life span of the reserve of limestone deposit and suggest a targeted amount of limestone production per year. The total production target for the seven (7) years was 87,017,146 tons and the actual production was 76,313,056 tons. The total variations for the years under assessment were -10,704,090 tons except for the year 2018 when the actual production was higher than the production target of 511,179 tons. The volumetric reserve estimation shows that the total volume of the limestone reserve is 5,052,236,090.186 tons. The expected production per week was computed to be 356,400 tons/week, expected monthly production, (E_{MP}) was estimated to be 1,425,600 tons/month. The expected production year, (E_{PY}) was 17,107,200 and the life span of the limestone deposit, (L_S) was computed to be 295.34 years. It can be suggested that the company should target a production rate of 1,425,600 monthly and 17,107,200 per year. The mine plans for the mine's production were generated from 2014 to 2020 using SurCE by Carlson Software. Based on the findings from this research work, it can be recommended that the investor should focus on automated equipment and machinery to have optimum performance to actualize the production target. The operators should reduce or block all loopholes (like downtime for machinery), which can lead to production loss in the mines during production.

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