Application of Digital Optimum Design Technology in Mining Design of A Large Gold Mine in Ethiopia

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Abstract. In the decision-making process of mine project research, mining mode, mining method and production scale are the three core contents, which determine the investment and economic benefits of mine project. Based on the study of mining conditions, this paper establishes a digital three-dimensional geological model. By means of qualitative analysis, software optimization, man-machine interaction and multi-scheme comparison, the open-pit mining mode and mining boundary are determined, and the mining production scale is optimized. These methods take into account the influence factors of technology, economy and security, and provide reliable basis and technical guidance for project decision analysis.

1. Introduction
A gold mine project is located within northern Ethiopia, which lies in structurally weak zone that has been affected by major NW-SE trending regional compressional tectonics. The deformation has resulted dominant structural fabrics. The most prominent discontinuities in the area are joints, foliations, faults and shear zones. The presence of mineralisation zones is a northeast-southwest strike of approximately 850m length over an average of 8-12 m width, and the dip is generally between 50 to 75 degrees and the occurrence level is between 1600-1840 m.

2. Mining method selection
Open pit mining is often the preferred method of mining as less complex mine construction and mining techniques usually makes it more economic, compared to underground mining[1]. Thus, mine and infrastructure construction for open pit mining is in general less time consuming, and it is also associated with lower early stage investments, and faster return on investment. Other advantages of open pit mining include: the allowance for using larger equipment and machines, and simpler infrastructure, resulting in a higher production rate; lower rock dilution and higher ore recovery rate[2].

The main drawbacks of open pit mining are the sometimes high stripping rates; management of the sometimes large amounts of overburden and waste rock, the management of fugitive dust from for example drilling, blasting, waste rock dump, haul roads, etc. Depending on the ore body geometry and grades, mining is sometimes continued underground when open pit mining is no longer economic due to increased mining costs with depth. Underground mining may, furthermore, be particularly suitable
for mining of elongated narrow orebodies that occur at higher depths (where extensive stripping would make open pit mining uneconomic).

In summary, the advantages of the open pit mining method are fully utilizing resources, higher recovery rate, lower dilution rate, suitable for construction with large machines, faster construction of the mine project, higher production capacity, higher productivity, lower costs, better working environments and safer conditions with the comparison to the underground mining method. Comprehensive advantages and disadvantages open-pit and underground mining, according to the features of ore bodies buried shallow and poor stability of ore and rock, choose the way to open-pit mining.

3. Determination of Open Pit Limit

The locations of the holes were chosen to give a reasonably good coverage over the deposit area, thus crossing the hanging wall, ore zones, and foot wall. The Rock Quality Designation (RQD) values of the rock units from the investigated core are highly variable. However, it is apparent that intrusive rocks generally have low RQD values and thus are of comparatively poor quality, while other lithologies are classified as fair quality rocks. On the contrary, the Unconfined Compressive Strength (UCS) values indicate that the rocks have medium to very high strength, see the Table 1.

| Geological unit | Location            | TCR   | RQD    | UCS    | No. of fract. | Density |
|-----------------|---------------------|-------|--------|--------|--------------|---------|
| Silicified unit | Hanging wall        | 96.12 | 53.28  | 178.3  | 3.63         | 2.6     |
| Feldspar-chlorite schist | Hanging wall | 83.54 | 62.35  | 43.71  | 2.42         | 2.68    |
| Granite/ intrusive | Footwall           | 93.59 | 40.56  | 197    | 6.12         | 2.58    |
| Silicified chlorite schist | Footwall     | 174.9 |        | 2.83   |              |         |
| chlorite-sericite schist | Ore zone        | 191.3 |        | 2.61   |              |         |
| Siliceous chlorite-sericite schist | Ore zone | 93.78 | 65.36  | 118.4  | 3.71         | 2.65    |
| Tale-carbonate schist | Ore zone        | 29.97 |        | 2.63   |              |         |
| Siliceous chlorite-sericite schist | Ore zone | 129   |        | 2.63   |              |         |

Datamine NPV Scheduler software was used for optimal delineation of the open pit limit directly. Lerchs-Grossmann method was applied for the pit optimization, in short, i.e. graph theoretic algorithm, which is the rigid mathematical logic method for the final pit optimization. The ultimate pit limit within which extracting mineral ores with maximum total value can be found by the given value model, which aims to maximize the Net Present Value (NPV). The height of the bench was set to 10 m, based on the production capacity of the mine and technical specification of the mining equipment. The block model created in Datamine NPV Scheduler is shown in Figure 1.
and bench on which purpose for cleaning up etc constraints need to be taken into consideration for the actual operating process, thus the secondary optimization of the ultimate pit outline needs to be done. The reserve of mineral ores delineated in the secondary optimization of the pit limit via human-computer interaction method reduces by comparison with the preliminary delineation of the pit limit, while the stripping ratio increases correspondingly. The secondary optimization of the ultimate pit limit is more reasonable with comprehensive consideration of the open pit feasibility. The final open pit design is based on the parameters described below, and the model for the ultimate open pit is shown in Figure 2 and Figure 3.

4. Study on Mining Scheme
The material handling procedure of drilling, blasting, loading and hauling for stripping and mining process is designed according to the environmental conditions, occurrence features of the ore body and physical & mechanics performance in the mine area. American B Cavender put forwarded that the defined mine life or production capacity shall maximize the cumulative net present value or internal rate of return, thus the corresponding mine life and production capacity design are appropriate[4]. For a mine enterprise competing alone in the market, which major goal for the mine operation is to obtain the maximum economic benefits. The maximum net present value i.e.NPV or internal rate of return i.e.IRR, which are usually used to estimate the mine enterprise benefits from the view of dynamic and economic aspects.

The production capacity is determined with obtaining the best economic benefits after analyzing and comparing the several different production capacity plans which are come out based on the experiences during the planning process of the mine project[5]. Four feasible production scale plans are put forwarded in this paper, for the comparisons from the point on the NPV and IRR respectively, see the following Table 2.

| Item                                      | Plan I | Plan II | Plan III | Plan IV |
|-------------------------------------------|--------|---------|----------|---------|
| Production capacity (Mt / year)           | 0.6    | 0.8     | 1.0      | 1.2     |
| Operating infrastructure investment (thousand USD) | 95,250 | 105,830 | 114,655 | 122,300 |
| Time for meeting the maximum production output (years) | 1      | 2       | 2        | 3       |
| Life of mining operation (years)          | 17     | 13      | 10       | 7       |
| Steady-state production (years)           | 15     | 11      | 9        | 5       |
Rock stripping method with forming steeper pit wall by combined benches is used to reduce the stripping volume of the infrastructure construction and balance the operating stripping ratio. Pre-split blasting needs to be fired at the platform which is formed by combining several benches into one bench before the final pit slope of the pit is formed. Both the average dilution ratio and loss ratio of the mining are defined as 5% based on the ore body occurrence.

The selection of the development and transportation plan shall focus on the economic benefits, select the plan with less investment and better economic benefits, shorten the infrastructure construction time of the mine, to put the mine into production and achieve the maximum production capacity as soon as possible. The development and transportation system pursues the simple, reliable and technology advanced production flow sheet, low operation cost. The system shall coordinate mutually with other engineering facilities to occupy less space and increase the overall economic benefits of the mine.

The location of the waste dump is determined close to the open pit based on above calculation results and combining the perimeter geological terrain information of the pit, the south area close to the pit is designed as the waste dump, which can receive the dumping waste with short hauling distance and decrease the mine operating cost. The 3D design of waste dump is shown in Figure 4. The schedule of construction and mining, including amounts of the ore and waste is shown in Figure 5.

In order to effectively postpone the peak of stripping, reduce the amount of capital stripping and initial production stripping ratio, and reduce investment and initial mining cost, short-stage mining is designed. Within the whole mining boundary, there are several temporary mining boundaries, which are gradually mined from the temporary boundary to the final boundary and divided into six short-term stages, see the Figure 6.
5. **Conclusion**

(1) Lerchs-Grossmann method was applied for the pit optimization, for short, i.e. graph theoretic algorithm, which is the rigid mathematical logic method for the final pit optimization, the ultimate pit limit within which extracting mineral ores with maximum total value can be found by the given value model, which aims to maximize the Net Present Value (NPV).

(2) The material handling procedure of drilling, blasting, loading and hauling for stripping and mining process is designed according to the environmental conditions. The working bench is arranged parallels to the ore body strike based on the strike, dip, geological, terrain and other information of the ore body, development & transportation system and ultimate pit limits. The stripping and mining benches are dug with the sequence from the highwall to footwall to gain the best economic benefits.

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