The complexity and uncertainty involved in Mine Planning and Design

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Abstract-Despite the technological advancements in the mining industry, the process of mine planning and design is still complex. In addition, mining has been and is still considered as one of the riskiest industries to invest in. These are due to the fact that it (mining) is associated with enormous uncertainties. That is, it is almost impossible to know the exact parameters of mineral deposits (mineralized zones) and the characteristics of the rocks that host the ore deposit before the actual mining is started. Even if mining has started, it is not easy to estimate the exact extends of a mineral deposit and its associated parameters. This means that designing and planning of mining activities and operations is based on estimated parameters rather the actual ones. This research paper reviews these complexities and uncertainties.

Keywords— Mine planning and design, geological model, drilling, uncertainties, parameters

I. Introduction

The process of mine planning and design is complex and full of uncertainties. This is mainly because it is impossible to know the exact parameters of mineralized zones, and the characteristics of ore hosting rocks before actual mining is started. Even if mining has started, it is not easy to estimate the exact extends of a mineral deposit and its associated parameters [1]. What this means is that designing and planning of mining activities and operations is based on estimated parameters rather than the actual ones [1]. Therefore, a mine planner must build certain level of certainty about the quality, shape and size of the ore body and ore hosting rock during mine planning [2]. This research paper, therefore, aims at reviewing these complexities and uncertainties (errors).

II. Methodology

This research mainly involves review of literatures on mine planning and design and identifying the main uncertainties facing the mine planners while designing and planning mines. These uncertainties have been identified and discussed below.

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III. Results and Discussion

A) Orebody continuity

Even though the process of orebody modeling has developed tremendously from the tedious and slow hand methods to rapid and relatively accurate computer methods, it is still practically impossible to model the exact geological parameters of an ore deposit. This is due to the fact that there are practical constraints (limits) to the amount of complexities that can be included in an ore resource model; and the geological interpretation by the mine planner or planning geologist will be constrained to critical parameters (inputs) that define the trends of mineralized zones, orebody shapes, and mineralized zone contact characteristics [1]. It is usually the decision of the planning geologist or mine planning engineer to include or reject an input based on the information available, and in most cases the available information is just an estimate rather the actual information on the ground. The use of an estimated parameter in orebody modeling may be lead to development of an inappropriate orebody. Failure to develop an appropriate geological model is one of the major reasons for large errors in ore reserve estimation [1]. As shown in the figure 1 below, a wrong geological model may lead errors that are greater than an order of magnitude.

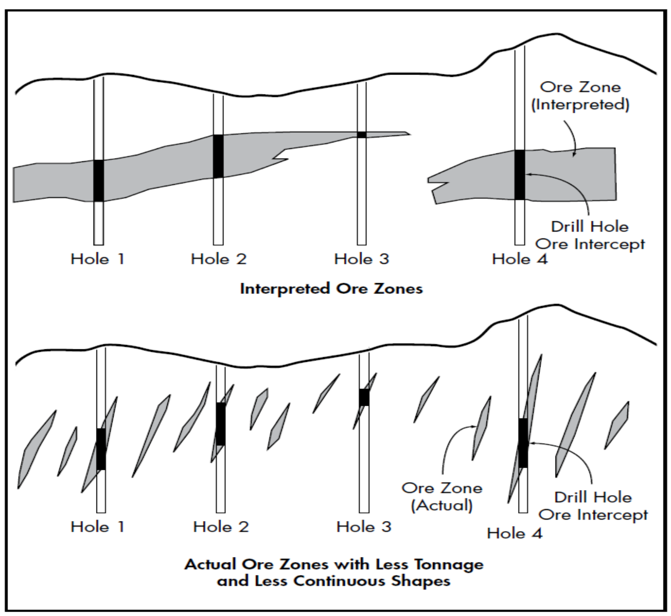

Figure 1: Overestimated orebody model that more continuous compared to actual ore zones [1]

As discussed above, the misinterpretation of geologic model is mainly because of the limitation of data at the disposal of the mine planner. The source of data for geologic modeling is drilling and sample assaying (testing). Drilling and assay sampling are usually the most expensive and slowest parts of feasibility studies, and when short cuts are done, drilling gets underdone (as shown in figure 1). Even though, the drilling programs may be expensive and slow, it is encouraged that as much drilling as practically and financially possible be done in order to get as much information as possible about the mineralized zones [2]. It is, however, important to note that not every section (part) of mineralized zone will covered by drill holes during drilling program hence it is rare to know the exact quality and full extend of an ore body until it is fully extracted (this is shown in figure 1).

B) Estimation of Metallurgical recoveries

During assaying of certain types of ore deposits such as gold, silver, tin, tungsten and vein type uranium, irregularly or discontinuously occurring high grades may encountered [2]. These high grades may occur in zones of slightly high assay values or may be encountered as a single and apparently conspicuous assay value surrounded by normal range of assay values as shown in the figure 2 below (forth column, 0.31oz Au is surrounded by assay values ranging from 0.01oz to 0.09oz). If such anomalously high assay values are not treated properly, the resulting ore reserve estimate could be seriously misleading [2]. If as mining progresses, the ore grade encountered is considerably lower than the indicated grade (non-discounted anomalous high grades) in the ore reserve estimation, serious operating losses may result [3]. However, if the actual ore grade encountered during mining is greater than the anticipated grade, all is well and good.

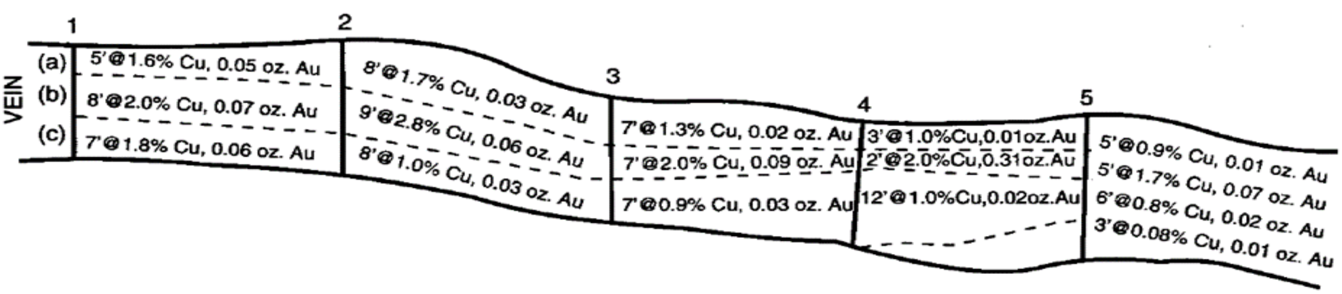

Figure 2: Discontinuously occurring high grade 0.31oz Au amongst Au of normal range assay values [2]

Generally, if there are no adjacent zones of correlatable high values, it is recommended that such anomalous be reduced to the value of the highest adjacent grade [2]. If adjacent mineralized zones have correlatable assay values on the other hand, the anomalous assay values are assigned an average of the adjacent assay values (This is shown below in the example below). From the figure 2 below,

Anomalous grade: 0.31oz Au
Adjacent grades 0.09, 0.07
Values to be assigned;

a) Discounted to the highest adjacent assay = 0.09oz Au
b) Average of the adjacent correlable assays = (0.07 + 0.09)/2= 0.08oz Au

C) *Geological and Geotechnical Uncertainties*

The geological and geotechnical uncertainties are associated with the unpredictability in the identification of rock structures and lithologies that constitute structural and geological models [3]. They (geological and geotechnical uncertainties) are also associated with relationship between and geometry of these structures and lithologies [3]. Generally, these uncertainties encompass uncertainties that may be associated with incorrect delineation of lithological boundaries, major faults and unforeseen geological conditions [4]. It is also not possible to correctly estimate the actual values of the parameters that are used in geotechnical model. This includes uncertainties that may be associated with the values of parameters used in hydrogeological model and rock mass such as cohesion, pore pressures, friction angle, deformation moduli, and so on [3]. The major source of errors associated with these parameters include:

a) Inadequate drilling to define waste rock and overburden to support the geological structure, geo-hydrological and geotechnical interpretation [5].

b) In adequate metallurgical analysis and characterization of both the ore and the hosting rock (waste rock) [5].

IV. CONCLUSION

Planning of mining activities based on the estimated parameters may lead to misunderstanding of ore body's characteristics. This misunderstanding of ore body characteristics is considered as one of the major factors that causes mining projects produce investment returns at rates lower than expected. Usually the major errors that occur during mine planning occur in estimating metallurgical recoveries, ground conditions and geological continuity. Either the orebody has unexpected geological features, it isn't continuous, the ground conditions are softer or harder than expected, or assumptions made of orebody recoveries are over optimistic. All these may result in higher production costs, and as a result, some operations may be forced to close after start up due to unexpected and unsustainable costs resulting from uncertainties (errors) in predicting these issues during mine planning.

REFERENCES

[1] P. Darling, SMA Mining Engineering Handbook, P. Darling, Ed., United States of America: Society for Mining, Metallurgy, and Exploration, Inc., 2011.

[2] C. J. Bise, Mining Engineering Analysis, Littleton, Colorado: Society for Mining, Metallurgy, and Exploration, Inc. (SME), 2010.

[3] R. E. Gertsch and R. . L. Bullock, Techniques in underground mining : selections from Underground mining methods handbook, United States of America: Society for Mining, Metallurgy, and Exploration, Inc., 1998.

[4] R. R. Tatiya, Surface and Underground: Methods,Techniques and Equipment, Leiden,The Netherlands: CRC Press/Balkema, 2013.

[5] J. Read and P. Stacey, Guidelines for open pit slope design, Australia: CSIRO Publishing, 2010.