3-D Modelling and Reserve Estimation for a Copper Deposit

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Abstract. Mine planning and design require large amounts of the data; these can be handled very well by the application of suitable hardware and mine planning software. These mine planning software offers a complete 3D-dimensional visualization of the deposit and mine, allowing for any orientation to be rotated, zoomed, sectioned, visualized, or sliced to better understand the metal lodes, coal, or limestone deposit, as well as for proposed or existing openings, stopes, ramps, levels, raises, and winzes. A fast-expanding area of the geological profession is the computer-assisted creation of geological models to calculate reserves, determine the best extraction method, or reflect the geometry and grade distribution within orebodies. These models are increasingly employed as a crucial foundation for figuring out whether mineral deposits are feasible in terms of real-world mine design and financial considerations. To make the job easier, old procedures like field or subsurface mapping, manually estimating grade and tonnage using geometric approaches like triangulation, as well as related tasks like interpolating cross-sections, using stereographic projections, core logging, and hand contouring, must be replaced with computerized software.

Keywords: Mine Planning · Metal Mining · Mine planning Software · Surpac · Reserve and Grade Estimation · Feasibility Study

1 Introduction

Mining is the second oldest profession in the human history after agriculture. It deals with the economical extraction of minerals from the earth's crust. As the global population grows at a faster pace than at any other time in history, so does mineral consumption, as more consumers enter the market for minerals and the global standard of living improves [1]. Due to the fact that minerals are important natural resources that serve as essential raw materials for core industries, the expansion of the mining industry is essential to a nation's industrial growth. In 2022, the worldwide copper mining production was around 22 million metric tonnes. Since 2010, the global copper output has steadily increased, from 16 million metric tonnes [2] (see Fig. 1).

India produced 41.8 thousand metric tonnes of copper in total in 2021, a significant rise over the previous year. The state of Madhya Pradesh has the greatest copper ore

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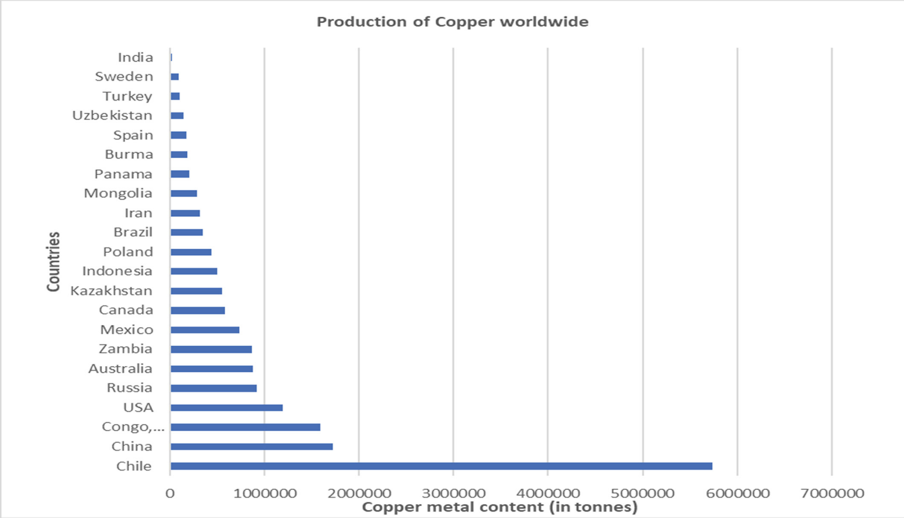

Fig. 1. Copper production worldwide (2020) [3]

resource in the nation [4]. Copper's excellent electrical and thermal conductivity have made it a crucial metal throughout history. Nowadays, over half of the copper produced globally is used by the electrical sector. India's per capita consumption is anticipated to rise from its present level of 0.6 kg to one kg in the upcoming years due to set goals of net zero by 2070. According to the coal, mining, and steel committee, which is led by Minister of Parliament Shri Rakesh Singh, the average annual global usage of the metal is currently 3.2 kg. In 2020, India used about 660,000 tonnes of refined copper in total. Interestingly, since Sterlite's 400,000 tonnes per year smelter in Tamil Nadu stopped operating in May 2008, the nation's copper production has been falling. India consequently turned into a net importer of the metal [5]. So, copper production needs to be boosted from existing mines & further increased by opening new blocks of mines.

Mine planning and design is a complex, iterative process comprising several inter-related and interdependent factors are considered. The technical, environmental, and commercial foundation for an investment choice is provided by the feasibility study. It employs iterative techniques to optimize each project's crucial component. It identifies the level of production, technology, investment, output, revenue from sales, expenses, and return on investment. Typically, it gives a clear explanation of the work scope and serves as a cornerstone document for advancing the project in following phases [6]. The assessment of ore reserves and their average grades is one of the most crucial aspects of a feasibility study. Methods for estimating mineral reserves may be categorized in three ways.

1. Geometric Method (Conventional Method)
2. Statistical or Geostatistical Method
3. Computer application or software

Surface and subsurface geological maps do not fulfil the requirements of current mining operations, and computer-generated geological models used on mines do not adequately depict the intricacy of the copper veins being mined. The essential premise of field mapping is to depict the real or visible geology as precisely as possible, and any slight mistake originating from data gathering compounds with each additional level of interpretation. The same holds true for the development of a computer-generated geological model. The model must be constructed with precise spatial information, regardless of whether the data represent mapped contact points, structural measurements, drillhole intersections, topo cadastral survey stations, geophysical measurements, etc. A badly prepared map is just as problematic as a poorly constructed geological model, with the exception that the latter will almost definitely have a more direct effect on estimating the size (tonnage) and grade of an ore deposit. The objective is to decrease uncertainty by incorporating as much geological data as possible during model building, and to create methods to test and quantify a model's dependability [7, 8]. Modeling rationalises the design and decision-making process when the unpredictability inherent to the mining environment is mixed with the entire system's complexity.

With computerization the historic approach of mine planning and design has changed from manual calculations to computerized operations. This change has provided speed, accuracy and practicality to the subject added with 3-dimension geometry. From exploration to mine performance evaluation, mining companies in more than 130 countries look for solutions that increase productivity and profits. For the design of underground development, several commercial software packages are available with their own merits and demerits. In this study, GEOVIA SURPAC (Version: 6.6.2. (x64)) mine planning software is used for copper sulphide ore (chalcopyrite, pyrrhotite, and pyrite) 3D-modelling. The facilities of this specific package included a geologic database capable of storing and manipulating input data from surveys as drillholes as well as gridded estimates, triangulated surfaces, polygons and volume model components. Statistical and geostatistical capabilities for data analysis and estimating grids or random point values. Gridding, triangulation and interactive graphics for modelling of geologic structures and mine openings. Specialized programs to facilitate mine design. Volumetric facilities for calculation of geologic and mining component volumes as well as volumes of intersection and reporting of geologic and mining reserves.

This research is emphasized on copper lodes, block modelling in 3D for grade and reserve tonnage calculation, also on the basis of dip and width of the different lodes the underground method of mining will be found out.

2 Research Methodology

To maintain confidentiality the whole of 1880 rows of data is not shown. There are 26 no. Drill-holes done by the second party along with that there are 34 no. Check drill-holes drilled by the third party. These are the drillholes data that are worked upon in this study.

2.1 3D Modelling Procedure

STEP 1: DEFINING THE DATABASE

SURPAC requires two types of tables for building geological database mandatory and optional tables. The mandatory tables being further divided into collar table that is the actual position of borehole in reality. Hole I'd, Y, X, RL, Maximum Depth, Survey table that is for down hole survey. Hole I'd, Depth (0 –Max.), Dip, Azimuth and translational tables this is added by SURPAC itself during the buildup process. The optional tables being is also divided further into assay tables that consists of Hole I'd, Sample I'd, To, From, Grade, Sample type and so on., Geology tables that consists of Hole I'd, To, From, Lithology 1. Lithology 2 and so on and styles table created by SURPAC itself during the buildup (color, pattern etc.). Display of drill holes with drill hole styling (see Fig. 2). As in figure less than 0.3% cu is denoted by red, more than 0.3% cu is denoted by green and waste/overburden is denoted by blue.

STEP 2: SECTIONING

Sectioning is cutting the boreholes along drillhole to see where the ore is existing. It is the mirror image of drillhole in SURPAC graphic window. Digitizing is the demarketing or outlining the orebody in a geological section and storing the information in digital form such as String or DTM. There are 17 such sections at some predefined intervals along the north direction in y-z plane (see Fig. 3).

STEP 3: SOLID MODELLING

Solid model is a 3-dimensional triangulation of data. Uses triangles to link polygonal shapes together to define a solid object or a void. A solid model file has the same extension as DTM(.dtm) but conceptualized as 3DMs.Validation of solid is extremely important in orebody modeling. Orebody models are just not used to know the physical shape and structure of orebody. It is also required for volume calculation inside a closed structure and to use as geological constraint against a block model to estimate the grade of mineral content in a structure. Estimation of volume of orebody is achieved through a simple algorithm which sums up the volume underneath each triangle in the solid. Using solid as

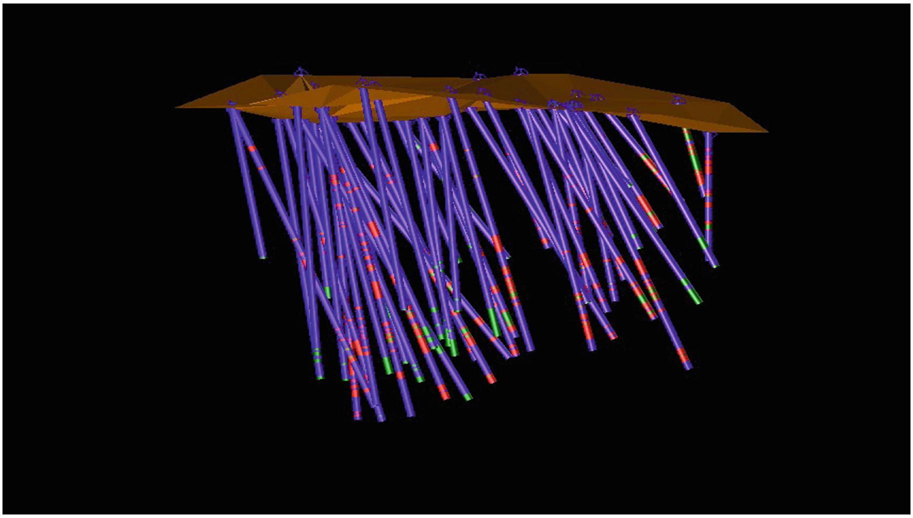

Fig. 2. Drill hole displayed with styling

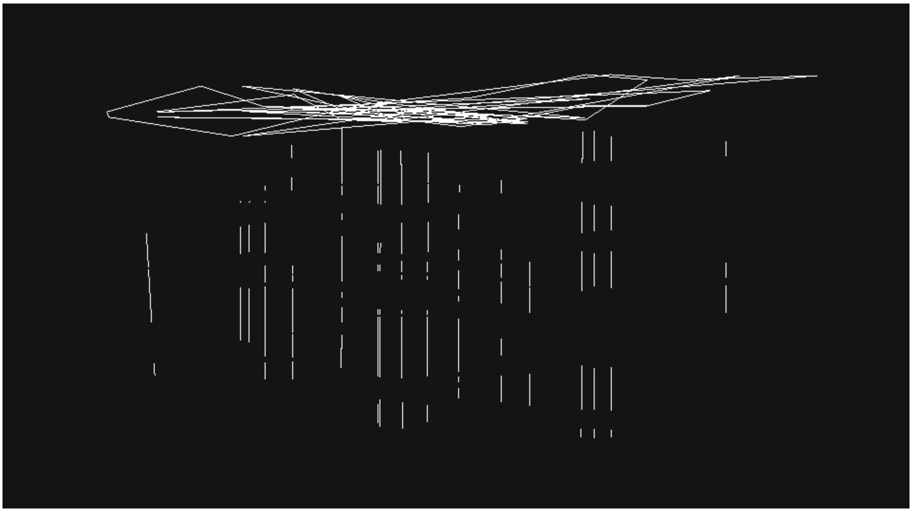

Fig. 3. Sectioning is done along 17 section planes

geological constraint for a block model relies on a test to determine if a point is inside or outside of the solid. The algorithm that does this also require a valid solid model which complies with validation criteria of SURPAC solid model. If the solid is not valid, there would be an error and the results can't be trusted. Quality of reserve estimation will not be good. This model contains all of the 5 lodes namely in their order of elevation (see Fig. 4). 1st lode (string 2) is denoted by brown, 2nd lode (string 3) is denoted by dark blue though it is not mentioned in solid model as it is insignificant. 3rd lode (string 6) is denoted by sky blue; 4th lode (string 4) is denoted by green, Local lode (string 1) is denoted by black but it is absent from the model because it is of insignificant quantity at inaccessible depth.

STEP 4: BLOCK MODELLING

The SURPAC mine planning programme generates a 3-D block model of the mineral body from an orebody arrangement with a 5m x 5m x 5m user block size. The block model was then confirmed by comparing its volume to the solid model representing the ore mass. The Inverse Distance Squared Weighting (IDSW) approach was used to estimate the grade of the attribute copper. The simplest sorts of experiments include assigning a controllable variable to a range of predetermined values and empirically measuring an experiment's observable. Thinking about linear regression facilitates a reasonably nonmathematical understanding of linear weighted averaging. In linear regression, the connection between two variables, x and y, is seen as a straight line (i.e., linear). The linear connection between y and x may be expressed as follows if the line is straight:

$$y = ax + b$$

where b represents the value of y when x equals zero and a represents the line's slope (i.e., the y-intercept). Hence, it is simple to compute the anticipated y value that corresponds to a given value of x. Linear interpolators include the Ordinary Kriging (OK) method

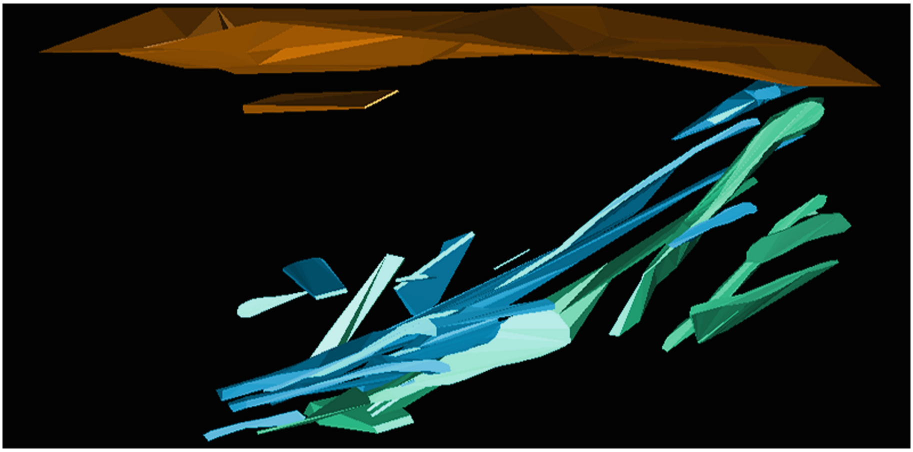

Fig. 4. Solid model containing all the lodes

and the Inverse Distance Squared Weighting (IDSW) approach. The linear interpolator assigns independent weights to individual of the N dataset sites inside our estimate neighborhood. These weights are unrelated to the exact data values at these locations. In IDSW, approximation gives a sample within the estimation neighborhood the following weight:

$$\lambda_i = \frac{1}{d_i^\alpha} / \sum_{j=1}^{N} \frac{1}{d_j^\alpha}$$

where λ are the weights, d are the separations between individual sample site and the centroid of the block to be assessed, and α is the power 2. After deciding on the power to utilize, the ith sample is given a weight that is simply based on its position (distance to the centroid). The assignment of is unaffected in any way by the sample's average or extreme value at this position [9].

STEP 5: UNDERGROUND METHODS OF STOPING

There are 3 major lodes in the deposit each with a varying inclination and thickness. So, the different methods of are employed for different lodes as well as for different parts of same lode. For flatter deposit the Room and Pillar method was used, for mildly dipping deposit we prefer Cut and Fill stoping method and for highly inclined deposit we will choose Blast Hole stoping method.

3 Results and Discussion

The specific problem of estimating recoverable resources was the origin of computer application or software and has been the main application. The following Table 1 shows the reserves, average grades of Cu and their dimensions in different lodes.

From the above table, it is concluded that the average grade of copper is 0.70% for a total reserve of 10.186 million tonnes comprising of all the three lodes. The first lode

Table 1. Details of different parameters in 1st, 2nd, 3rd lodes

Copper Lodes	Avg Thickness (m)	Reserve (Tonnes) @ Grade	Slope (in degree)
I	6.8	292000@0.28	38.5
III (Due North)			
1	13.2	140500	32.0
2	16.9	570000	23.7
3	20.0	322680	19.0
4	39.5	34934	22.3
5	15.0	7575	12.7
6	2.80	2304	24.0
7	43.5	293046	33.6
8	27.8	719628	34.0
9	7.20	240604	40.0
10	6.19	204454	33.0
11	4.56	30872	10.0
12	5.00	133090	42.0
13	12.7	166696	18.0
14	2.00	17157	34.3
15	6.50	105720	17.5
Total	14.86	2989260 @0.47	26.41
IV (Due North)			
1	23.8	676283	50.0
2	3.80	25100	21.0
3	8.00	41184	23.0
4	14.0	437454	50.0
5	8.70	310665	36.0
6	6.00	2994	52.3
7	23.6	653475	20.7
8	20.5	321708	59.0
9	9.60	156764	27.0
10	26.3	3727468	33.3
11	22.3	551763	27.0
Total	15.15	6904858 @0.81	36.30
Combined Total		10186118 @0.70	

is located around 70 m depth from surface with average grade of 0.28% and reserve of

0.29 million tonnes. The second lode consists of insignificant quantity of ore; therefore, it is eliminated. The third lode is located between depth of 32 m to 487 m from surface with an average grade of 0.47% and reserve of 2.99 million tonnes. The fourth lode is located between depth of 69 m to 437 m from surface with an average grade of 0.81% and reserve of 6.9 million tonnes. The third and fourth lode are the major lodes comprising 97% of the total minable reserve. The local lode is also eliminated from the model as it is inaccessible and of small quantity this makes it non feasible to mine.

4 Conclusions

The success of every mining operation depends on a precise estimate of both the total reserves and the grades of the various blocks. The intricate linkages and interwoven complexity of the sample data must be taken into consideration by the interpolation method. Reducing the variance of the estimator and thereby the regression effect can enhance estimation. Economic cutoffs should be set on selecting mining units rather than sample grades.

In the current work, an effort has been made to estimate the copper ore reserve utilizing linear Geo-statistical estimating techniques. At cut-off of 0.3% the total copper reserves are found out to be 10.18 million tonnes with an average grade of 0.70% from the block model developed by SURPAC mine planning software. Confidence levels in feasibility studies are found to be positively related to future project debt funding and adversely related to project failure. Mine planning software gives a feasibility study with certain high level of confidence that makes the mining of the proposed copper block feasible for the estimated grade and reserve quantity. The different underground method of stoping is proposed for different lodes with suitable slope and width as shown in Table 1. The lodes 3rd and 4th are discontinuous therefore divided into various sections. The room and pillar stoping is proposed for 3rd (2, 3, 4, 5, 6, 11, 13, 15) lodes and 4th (2, 3, 7, 9, 11) lodes. The cut and fill stoping is proposed for 1st lode, 3rd (1, 7, 8, 9, 10, 12, 14) lodes and 4th (5, 10) lodes. The blasthole stoping is proposed for 4th (1, 4, 6, 8) lodes. Considering the worldwide demand for copper and India's dependence on import of copper. This copper block is feasible to mine with the help of proposed methods of stoping for the estimated reserves and grade found through block model.

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