Preliminary application of grade equivalent theory in a local section of a mine and economic estimation of the deposit

Guan Wang [1], Huaqiang Song [1], Zongda Yang [1], Lize Wang [2], Pei Xue[1], Jingyuan Xu [1], Wei Jiang [1]

[1] Norin Mining Limited, Beijing 100053, China
[2] NORINCO International Cooperation Ltd, Beijing 100000, China

Abstract. By introducing the practical application of grade equivalent theory in a copper -cobalt mine, it can show the maximum economic value of the individual ore block and the mine, maximize the comprehensive utilization of limited resources and contains positive significance for extending the service life of the mine. Briefly introducing the steps of Micromine software in the process of reserve estimation and the feasibility of displaying the economic value of individual ore blocks. Estimation of reserve can be completed objectively and scientifically by Micromine software, grade and economic value of ore blocks can be displayed in three-dimensional image.

Keyword: Grade Equivalent; Economic Value of Ore Blocks; Micromine Software; Copper -Cobalt Mine in Drc.

1. Introduction

Head grade of a single metal element determined by the geological and reserve management departments was used for poly-metallic open pit mines during feasibility stage, mining and metallurgical circuit. However with variety of metal price, the improvement of mining and processing technology and other factors, it is necessary to consider the value of associated component elements which is the integrated economic value to estimate the value of mineral deposit, maximize the recovery of mineral resources, it is essential to determine the combined grade of polymetal which is so-called grade equivalent.

2. Methodology of Grade Equivalent Calculation

According to the definition of integrated grade of polymetallic ore, the integrated grade equivalent is calculated as follows:

$$g_z = g_0 + \sum_{i=1}^{n} g_{0i} = g_0 + \sum_{i=1}^{n} (f_i, g_i)$$

gz: integrated grade equivalent; g0: grade of primary metal; g0i is the e grade quivalent of the ith associated component converted to the main component; gi is the grade of the ith associated component; fi is the equivalent factor of the ith component converted to the grade of the main component.

Grade information of components which are required to calculate integrated grade can be provided by geological data. Calculation of the equivalent factor requires consideration of the economic value of ore mined. Profitability method and price method are two general methods for calculating the equivalent factor.

2.1 Profitability Method

$$f_i = \frac{(k_i - r_i) \cdot \alpha_i \beta_i}{(k_0 - r_0) \cdot \alpha_0 \beta_0}$$

fi is the equivalent factor of conversion of the ith component into primary component; ki is price of the ith associated component; ri is smelting cost of the ith associated component; αi is processing recovery of the ith associated component; βi is the smelting recovery of the ith associated component; k0 is price of the primary component in the ore; r0 is smelting cost of primary component in the ore; α0 is processing recovery of primary component in the ore; β0 is the smelting recovery of the primary component in the ore.

2.2 Price Method

$$f_i = \frac{k_i \cdot g_i}{k_0 \cdot g_0}$$

fi is the equivalent factor of conversion of the ith component into primary component; ki is price of the ith associated component; gi is the average grade of the ith associated component; k0 is price of primary component in the ore; g0 is the average grade of primary component in the ore.

3. Appilication

A copper-cobalt mine, situated in the northern parts of the Central Africa Copperbelt(CACB) which primary metal is copper with cobalt as associated element. It is necessary to improve utilization of cobalt metal as the price of cobalt surged in recent years and there is a downward tendency reflected in copper price. Grade equivalent theory is applied at this specific mine to enhance the economic efficiency of the mine while effectively extracting natural resources to maximize the comprehensive utilization of limited resources and avoid depletion of resources. The operation of optimization of the orebody and the display of the individual ore block values was made by mining software Micromine.

3.1 Collection of Drilling Data

Drilling data is collected from exploration line 23 to 47 of western main ore body. All drilling data in the area were electronically organized into four Micromine database format files which are Collar, Survey, Lithology and Assay in order to establish the drilling database.

Table 1 Drilling Database Format

Collar						
Hole _ID	East	North	Elevat ion	Depth		
Survey						
Hole _ID	Depth	Angle of dip	Azim uth			
Lithology						
Hole _ID	From	To	Litho	Rock type		
Assay						
Hole _ID	Sample num	From	To	Lengt h	C u	

3.2 Establishment of Drilling Database

The main steps to build the drilling database are as follows: ①Data import. Drilling data is imported into Micromine software to generate "dat" format file. ②Verification of data. Micromine software seeks errors automatically in the drilling data and modify them with verification function. ③Database generation. Generating database through data which is verified with steps above.

3.3 Generation of Ore Body Wireframe

Display drill hole information including drill hole trajectory, lithology, grade distribution of sample within Micromine software. A string of sections is generated along exploration lines, ore body is interpreted according to geology and assay information, wireframe or three-dimensional solid model which is used to describe the outline of the ore body is created as follow criteria: ①cut-off: 0.5% cu; ②exploitable thickness: 2m; ③permissible maximum thickness of gangue parting: 2m.

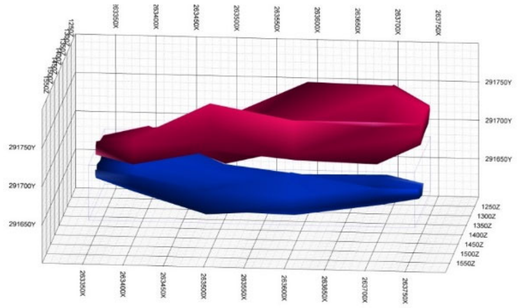

Figure1 wireframe of ore body

3.4 Block Model

After creating the block model which is used to estimate the resource by using the inverse distance weighted(IDW) interpolation. The interpolation should be restricted to a space where the ore grade are correlated and block within the ore body should be identified using a wireframe ore body, then the identified blcok should be used as the basis for statistical analysis and interpolation. Dividing whole block into numerous sub-blocks with same size which requires a comprehensive consideration of the morphology, complexity and drill hole spacing. Complete block model is comprises of each individual block that is interpolated by data adjacent. Drill hold spacing for resource estimation is 100m×50m, sample composite is 1m, morphological complexity of the ore body is medium and the block size is determined as 10m×2m×5m. Edge blocks are divided using sub-block factor to ensure the accuracy of the solid model boundaries. Radius of the search ellipsoid is set to 50m. Three-dimensional morphology of the ellipsoid is consistent with the morphology of the ore body basically, the long-axis azimuth is consistent with strike of the ore body and the sub-axis azimuth is consistent with angle of dip of ore body. To reduce the interpolation bias from the high-density sample point area, it is necessary to disperse the cluster samples and limit the minimum maximum number of sample points in each quadrant of the search ellipsoid to enable unbiased search for ellipsoidal valuation. In order to interpolate all empty blocks, interpolation process has been run three times with increased radius of search ellipsoid at a time. Block model is examined in each run until every block in the model has been interpolated a grade.

3.5 Report of Resource Estimation

Result of resource and average grade estimation is as follow

Table 2 Result of resource estimation

Ore body	Volume m^3	Tonnage t	Density m^3/t	Cu grade %	Contained Cu t
upper	1253962	3134905	2.5	1.67	52445.02
lower	1790627	4476567	2.5	2.30	102794.57
total	3044589	7611472	2.5	2.04	155239.59

3.6 Update of Block Model

Equivalent factor is determined combined by price and recovery rate of each component metal. Copper and cobalt prices are based on three-month average bid price of US$4,750/t and US$26,500/t on LME respectively. Average grade of copper and cobalt are 2.04% and 0.116% respectively. Copper to cobalt equivalent factor is 0.317. Partial integrated grade is calculated and shown as follow.

Table 3 Integrated grade information

Name or ore body	Sample number	from	to	litho	Cu %	Co %	EqCu %
ZKPW31-2	H26	86.6	87.6	RSC	0.752	0.481	0.904
ZKPW31-2	H31	91.6	92.6	RSC	1.180	0.378	1.300
ZKPW31-2	H34	92.6	93.6	RSC	3.890	0.553	4.065
ZKPW31-2	H39	97.6	98.6	SDB	5.200	0.440	5.339
ZKPW31-2	H100	156.7	157.7	CMN	4.410	0.358	4.523
ZKPW31-2	H102	157.7	158.7	CMN	7.130	0.465	7.277

Updated wireframe is created by applying integrated grade and cut-off is EqCu 0.5%. Optimized block mode and result of resource are shown as follow. Copper grade and metal contained are increased slightly mainly caused by low cobalt grade overall which has minor influence converted to integrated grade.

Table 4 Result of resource estimated by EqCu

Ore body	Volume m^3	Tonnage t	Density m^3/t	EqCu grade %	Contained Cu t
upper	1254522	3136306	2.5	1.71	53765
lower	1793313	4483284	2.5	2.32	104230
total	3046907	7619590	2.5	2.07	157995

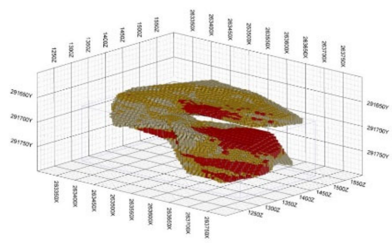

Figure 2 Block Model of EqCu

3.7 Economic Value Evaluation

Economic value or profit of the ore blocks is remaining value of revenue contained in each block minus mining cost, processing & smelting cost and sales cost value (Table 5). Construction infrastructure investment and cash flow during the operation period are not included.

Table 5 Economic Value of Block

Num of block	Sub-block factor	Orebody	Cu %	Cu metal t	Block value $	Mining cost $	P&S cost $	Sales cost $	Block profit $
1	0.03	lower	1.28	0.08	335.1	102.4	180.3	54.9	-2.5
2	1.00	lower	3.57	8.56	36594.3	4000.0	19688.2	5992.1	6914.1
3	0.99	lower	2.36	5.67	24231.8	3999.6	13037.0	3967.8	3227.4
4	1.00	upper	2.41	5.79	24747.8	4000.0	13314.6	4052.3	3380.9
5	1.00	upper	upper	2.96	12653.5	4000.0	6807.7	2071.9	-226.2
6	0.82	upper	upper	2.21	9462.0	3272.0	5090.7	1549.3	-450.0

Block value is the copper contained in individual block times copper price. Copper price is based on three-month average bid price of US$4,750/t on LME. Mining cost is unit cost of individual block which size is 10m x 2m x 5m and volume is 100m^3. Unit integrated mining cost in which contained mining, striping, drilling and blasting is 8$/$m^3$ referenced to the Comica mine and other mines located adjacent of Likasi. Strip radio is 4:1; Density of ore is 2.5t/m^3; Processing and Smelting(crush, mill, leach and SX-EW) cost 2300$/t copper which is referenced to average cost of mining company in DRC. Recovery rate is 90% from actual data. Sales cost 700$/t copper which is referenced to average cost of mining company in DRC. Profit Model and value can be displayed by Mircromine software as follow(partial). Profit value of upper and lower ore body is $15627787 and $55723125 respectively.

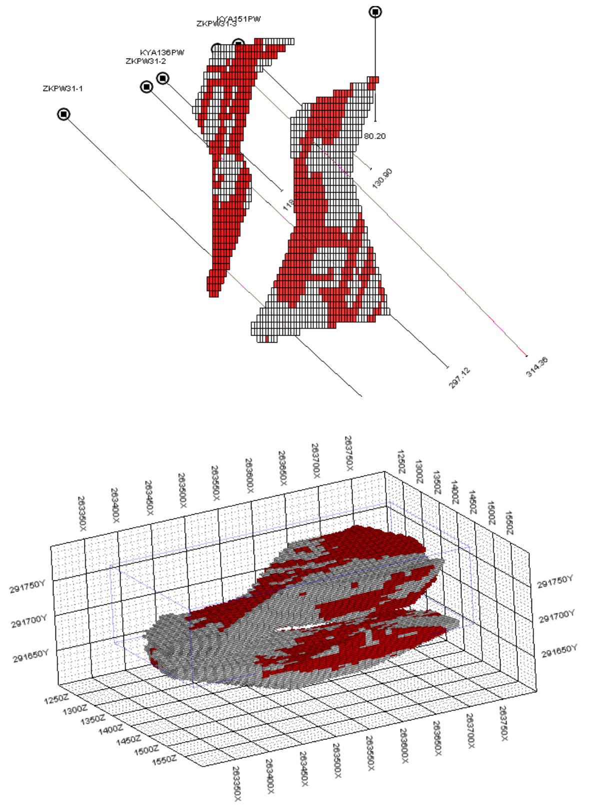

Figure 3 Profit Model of ore body

note: profit block is shown on red color; loss block is shown on white color

4. Conclusion

Comprehensive evaluation of the economic value of individual block by using grade equivalent is beneficial to maximize utilization of resources and contribute to postpone the depletion of resources as well as extend life of mine. Given mining, processing, smelting and sales costs are basically stable while metal prices keep volatile, updated integrated grade and profit value can be generated according to metal prices volatility. Visibility and rapid interpretation of Micromine software enables continuous update and optimization of block model as well as estimation of economic profit value of resource. It provides actual direction for mine operation. Comprehensive evaluation of resouce with grade equivalent enable rational exploitation of limited mineral resources.

References

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