3D Geological Modeling for Deep Mineral Resource Assessment of the Xiongcun Cu Deposit, Tibet, China

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Abstract

Three-dimensional(3D)district-scale geoscience information for the Xiongcun Cu district was integrated for understanding the development of its regional geology and ore-forming processes and for decision-making about potential targets for mineral exploration. The methodology and datasets used were: (1) construction of an initial geological model using 1:2000 scale geological map, eight geological cross-sections, geochemical and geophysical exploration data. (2) comprehensive information deposit prediction theory were used to build a 3D digital deposit model including orebody, strata, magmatic rock and fault. (3) extraction of ore-controlling formation of the Xiongcun using the large-scale 3D models of Cu deposits and results of analysis of lithogeochemical samples from outcrops and boreholes. (4) establish the information prediction model, locate the deep resource location, and estimate the potential Cu resource amount of 0.5Mt, Au20t, Ag70t. This study provides important technical support for the evaluation of exploration mineral resource in Xiongcun copper deposit and its surrounding areas, and is conducive to the management and sustainable development of geological mineral resource.

Keywords

3D geological modeling, Information prediction model, Deep prospecting, Xiongcun Cu deposit.

1. Introduction

With the massive exploitation of surface and shallow mineral deposits, mineral resource is gradually scarce, and a large number of mines are facing a serious resource crisis. How to use new techniques and methods to discover new exploitable deposits in the depth and periphery of existing mines and obtain more reserve resource are important goals of sustainable development of geological resource. 3D modeling is developed with the continuous development of computer graphics technology, which was first proposed by Simon W Houlding, a Canadian scholar in 1993. The application of this technique in geology is of great significance for understanding geological background, mineralization and searching for mineral deposit[1-5]. The analysis and modeling of 3D-dimensional geological objects based on geophysical, geochemical and geological data can not completely eliminate the uncertainty of mineral exploration, but it provides a new perspective for the realization of exploration goals[6-7]. Compared with the previous study of spatial geological attribute information by drawing plans and sections, part of spatial information will be lost or distorted, and the reliability of prediction will be reduced. The proposal of 3D modeling theory makes up for the defects of the above method. Nowadays, 3D predictive modeling of exploration target has become desirable because it has particular advantages in extracting ore forming information from geoscience data[8].

Prediction and evaluation of deep resource is one of the key projects of the China Geology Survey in recent years, and it is also an important method to realize geological resource management and sustainable development. In this study, 3D geological modeling was conducted to assist decision-making for subsurface mineral exploration in the Xiongcun Cu district, and information model and geostatistical methods were employed to analyze and integrate geoscience information and exploration criteria from various datasets.

2. Geological setting

The Xiongcun district is located in the western segment of the Gangdese porphyry copper belt (GPCB). The No.2 deposit in the Xiongcun district hosts a measured and indicated resource of 1.34 Mt copper, 76.34 t gold, and 193.78 t silver. The copper-gold mineralization of the No.2 deposit is mainly hosted in the Early Jurassic quartz diorite porphyry which intruded volcano-sedimentary rocks of the Early Jurassic Xiongcun Formation. S and Pb isotopic compositions of the ore sulfides and Re contents of molybdenite suggest a mantle source with minor contamination of subducted sediments for the ore-forming materials. The No.2 deposit is a NW-trending, tabular body, with the dimensions of about 900 m by 500 m (Fig. 1). Veinlets and disseminated pyrite-chalcopyrite mineralization are mainly hosted within the Early Jurassic quartz diorite porphyry and the surrounding tuff. The orebody dips approximately 26°~70° to the northeast (Fig. 1). It is still open down-dip to the north and along strike to the northwest and southeast. Supergene enrichment is weakly developed in the No.2 deposits; most of the resources are hosted in the hypogene zone.

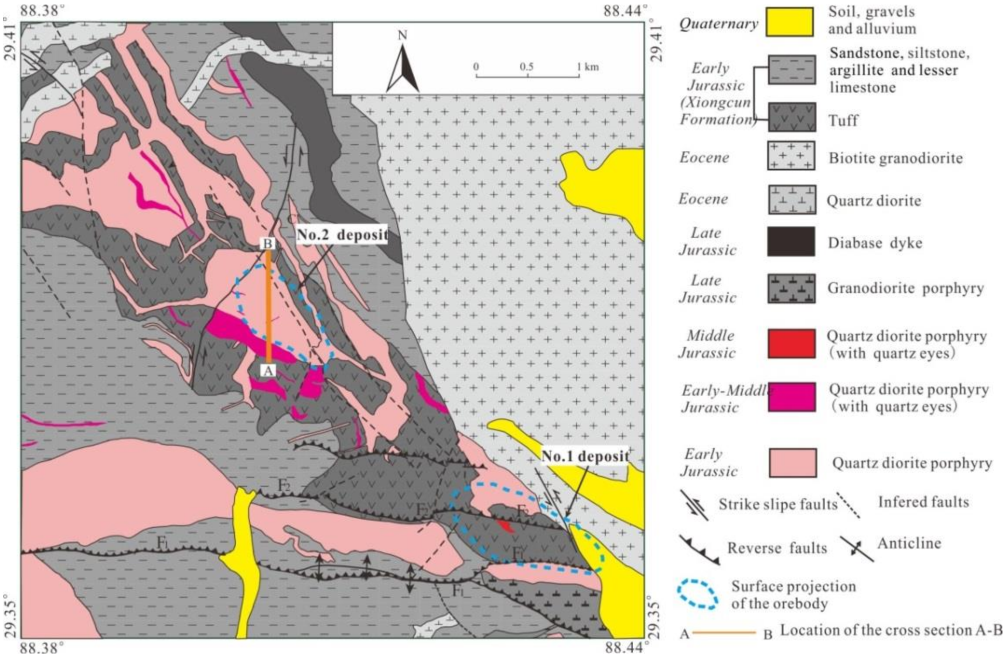

Figure 1 Simplified map of China showing the location of the Himalayan-Tibetan orogeny[9]

3. 3 D modeling

Construct a 3D model is the basis of geometric elements of building space, involving the main problem is how to use the discrete point interpolation geological borehole data level and on the basis of the geological body. This article mainly uses the TIN (Triangulated Irregular Network) to generate geological level, box line connect each observation data point, form a mutually disjoint several triangle, making each data point is one of the triangle vertices, and all of the triangles add up to form a convex polygon. The curved surface formed by these spatial triangles is the most realistic reflection of the observed data to the real situation.

In this paper, 3D modeling includes 3D digital terrain modeling, 3D modeling of orebody grade using a 3D Kriging interpolation method, and a 3D modeling of geological bodies.

3.1 3D digital terrain modeling

The 3D digital terrain model (DTM) is a digital description with spatial location characteristics and topographic attribute characteristics. It can not only show the topography and landform of the mining area above the surface, as well as the distribution of ore bodies, and dumps, but also well show the relationship between the morphology and spatial location of the structure such as ore bodies and faults under the surface(Fig.2).

Figure 2 3D digital terrain model of Xiongcun Cu deposit

3.2 3D orebody modeling

The establishment of Xiongcun No. 2 ore body model was based on the TIN surface model construction method(Fig 3), and the block model is based on interpolation method(Fig 4). Interpolation is widely used for both predictive and visualization purposes in geoscience studies[10]. A variety of algorithms have been developed to construct such interpolations, e.g., inverse distance weighting (IDW) and Kriging.

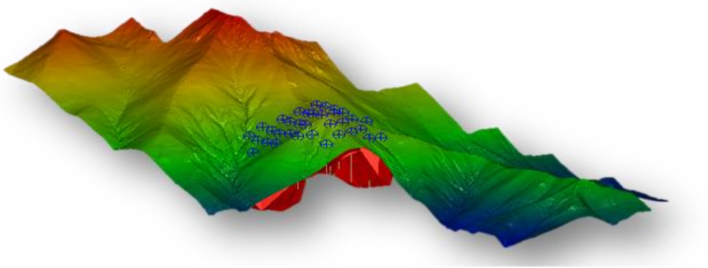

Figure 3 3D model of orebody, digital terrain model and boreholes

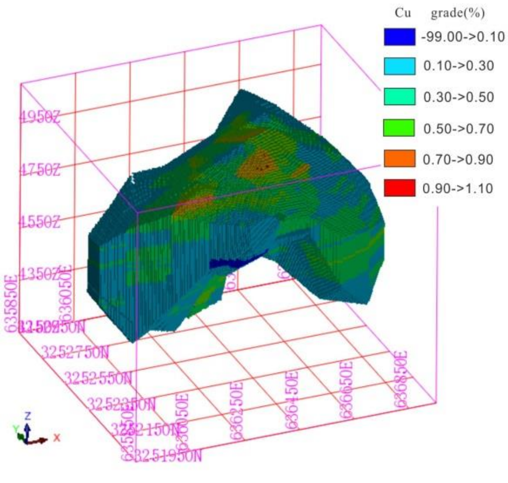

Figure 4 Grade block model of Kriging interpolation

3.3 3D geological bodies modeling

To construct an accurate 3D geological model from geological data (e.g., geological maps at different scales, cross-sections and boreholes), it was necessary to develop a methodology that also takes into account magnetic data. Geological maps synthesize geological information but they do not give a complete representation of the subsurface geology. Cross-sections and borehole logs add the third dimension to give a more detailed interpretation of subsurface structure(Fig 5). However, if geophysical information is available, a better constraint on the interpretation of structures or intrusive rocks is possible. By combining contact locations and orientation of geology and geophysical information, 3D geological models can be constructed.

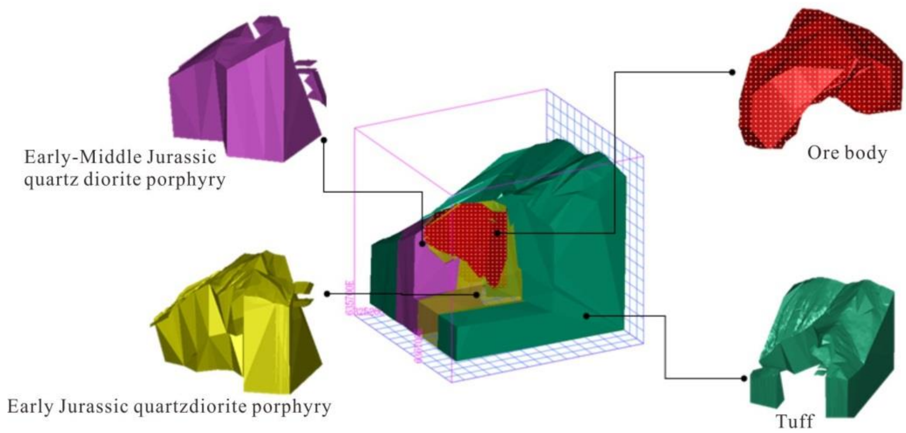

Figure 5 3D geological bodies model of Xiongcun Cu deposit

4. 3D prediction modeling

In this paper, the cube element divided by the whole 3D visualization prediction model is taken as the prediction element, and the geological information variable contained in the cube element is taken as the geological indicator for statistical analysis. Kriging is used to interpolate the whole geological model to generate grade block model(Fig.6, Fig.7). The specific steps of calculating the information of ore prospecting signs in block model are as follows:

(1) The whole 3D prediction model was taken as the prediction unit, and the geological information variables contained in the cube unit were taken as the statistical analysis variables for geological markers. Seven geological and geochemical exploration information markers favorable for mineralization were selected, and the values of each marker in the element were 1 and 0 respectively.

(2) Conditional probability is used to calculate the information of each prospecting mark(Table 1). I(A/B)indicates the amount of information that can be found for ore prospecting signs of A; P(A/B) is the probability of occurrence of ore prospecting signs of A in the presence of ore B. P(A) is the probability of occurrence of A prospecting indicator in the prediction area. In the actual prediction process, because of the difficulty of probability estimation, frequency value is often used to estimate probability value. Nj is the number of ore-bearing elements marked A in the research area; N is the number of ore-bearing elements in the research area; Sj is the number of cells with the symbol A in the research area; S is the total number of units in the study area.

$$I_{A(B)} = \lg \frac{P(A/B)}{P(A)} \tag{1}$$

$$I_{A(B)} = \lg \frac{P(N_j/N)}{S_j/S} \tag{2}$$

(3) On the basis of determining favorable prospecting indicators and their states, the information provided by these indicators is used to calculate the sum of information of each prediction unit and determine the critical value of information of the whole prediction model. (the prediction unit greater

than the critical value is regarded as the favorable ore prospecting unit).ΔI is critical value of prospecting information; K is the level of useful information; Ij is the positive information related to mineralization.

$$\Delta I = K\sum_{j=1}^{n} I_j \tag{3}$$

Table 1 Statistical results of prospecting information

Information	Nj	Sj	Ij
Tuff	9537	162567	-0.49
Early-Middle Jurassic quartz diorite porphyry	102	22834	-1.6
Early Jurassic quartz diorite porphyry	42584	102237	0.36
Cu Geochemical anomaly	45695	103002	0.39
Au Geochemical anomaly	38284	75643	0.45
Ag Geochemical anomaly	15733	27015	0.51
Fault	11501	12523	0.70

(4) By extracting prediction units whose total amount of information is greater than the critical value under constraints, and combining the statistics of known orebodies, the amount of deep prediction resource can be obtained(Fig.7).

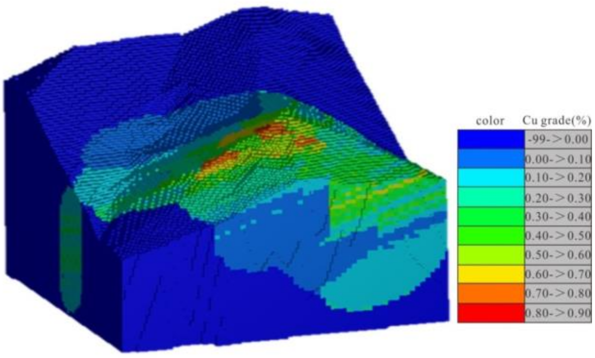

Figure 6 The result of interpolation of the whole prediction model by Kriging

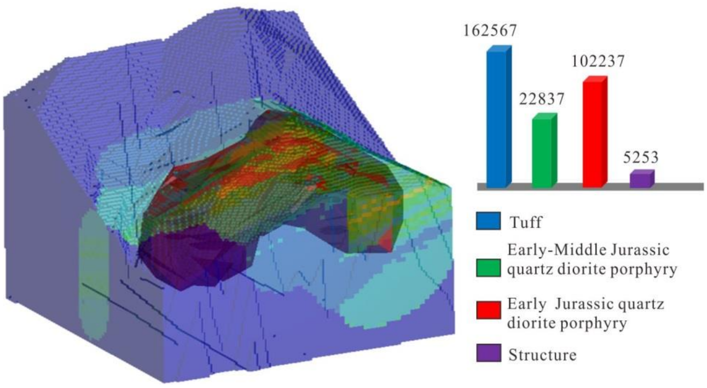

Figure 7 Statistical analysis results of geological information variables contained in cube elements

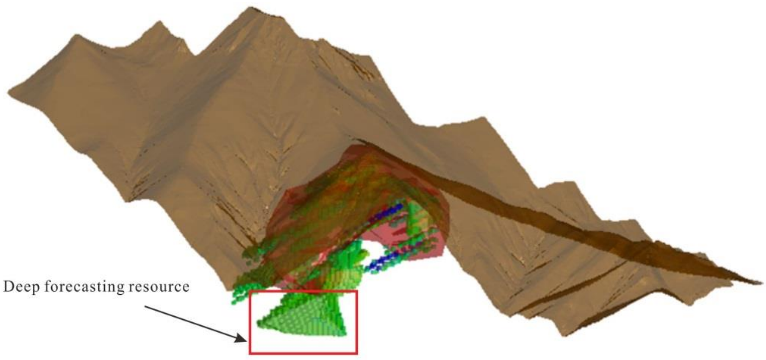

Figure 8 Prediction results of Xiongcun No. 2 orebody

5. Conclusion

In this paper, the surface and underground geological model of Xiongcun Cu deposit is established by using 3D modeling technology, which clearly shows the spatial distribution between strata and structure in this district. The ore body model of Xiongcun was delineated by boreholes, and the ore body grade block model was obtained by Kriging.

Then guide by prospecting model, the paper selects favorable ore-forming strata, fault buffer, early Jurassic quartz diorite porphyry as evidence factors. On the basis of establishing the three-dimensional digital research area and relying on geologic setting, it adds geophysical and geochemical information to the geological model and predicts the deep concealed orebody by making full use of the geophysical and geochemical exploration indication so as to realize geophysical and geological combination forecast. Prediction shows that there may be Cu0.5Mt, Au20t and Ag70t in Xiongcun II orebody below 900m depth.

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