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3D Geological Modelling and Prospecting Prediction of the Pulang Porphyry Copper Deposit, Yunnan Province, China

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Abstract. In this paper, we propose 3D model and prospecting application of Pulang copper deposit which is a typical super large scale porphyry copper deposit in Yunnan, southwest China. Geological, geophysical and geochemical data have been collected and integrated in a spatial database in order to model the surface and sub-surface geological bodies of the study area. 3D structure model of Pulang porphyry copper deposit (11.0 km × 5.0 km × 1.8 km) is established on the basis of these data defining temporal and spatial relationships among geological objects. The 3D grade property model of KT1 (the main orebody) is used to reflect the distribution of copper element in space and to infer or deduce the extension of orebody. In view of the nature of the mineralization, tectonism, multi-phase porphyry rocks, and wall-rock alteration, the deeper levels of KT1 at its northern and eastern limits are potential target zones for prospecting.

Introduction

In recent years, 3D geological modeling is an important method for geological visualization research, mineral exploration and resource assessment in geo-science field [1-5]. Due to the limitation of the dimension, traditional maps and sections are not easy to understand the relationships among geological bodies, like faults, folds, unconformities, and so on. 3D geological model can remedy this defect effectively with the help of computer and modeling software packages (e.g., GOCAD, 3D GeoModeller, Micromine, Earth Vision), and it is an effective method for understanding geological structures through visualization and exploring for mineral deposits [6]. Hence, the application of these 3D modeling techniques is becoming more and more convenient and useful for subsurface structure study.

The Pulang porphyry copper deposit is located in the Zhongdian island-arc zone, which makes up the south part of the Yidun island arc that was formed during Indosinian time from westward subduction of Garze-Litang ocean floor [7, 8]. Pulang copper deposit is one of the most important porphyry copper deposits found in China in recent years and proved to be a super large one. In recent years, the relevant researches have been done in Pulang copper deposit including geochemistry, geochronology, mineral deposit, etc. Nevertheless, refined 3D model of the geometry of the geological structure and property of Pulang deposit is comparatively weak. The aim of this work is to show how geological date includes geological map, topographic map, cross-sections, boreholes, copper geochemical anomalies and induced polarization anomalies data managed by geographic information system (GIS) and GOCAD technology to reconstruct 3D model. The 3D models of geometrical relationship between complicated geological bodies and regularities distribution of Cu element are created. In addition, 3D geological model is proposed by spatial logic operation and metallogenic theory to predict location of potential copper orebody and minimize exploration risks. The application of the geological modeling and Cu target prediction of Pulang porphyry copper deposit in Yunnan province, Southwest China, is then presented.

3D Geological Modeling

Structure Modeling

Geological modeling for the structure of Pulang porphyry copper deposit is carried out taking into account the database which established in GIS tools. Construction strategies of structure model vary depending on the type of geological surface characteristic and structure complexity [9]. 3D point sets are obtained by the prepared topographic map, and the topographic surface is built from the 3D point sets with elevation. After having created the topographic surface in GOCAD, geological boundaries and faults are imported with a fictitious elevation, and projected on topographic surface. Then, each single geological surface of the subsurface is built from geological occurrence and modified the constraints from induced polarization anomalies, cross-sections and boreholes, and 3D geological map is obtained after the interfaces analysis within geological environment. Finally, 3D geological bodies (regions) are created and initialized by the geological interfaces, and optimized by insertion, erosion, cross-cutting and other relationships. Using these regions, 3D structure model is obtained in the scope of 11 km NS-trending and 5 km EW-trending, and the elevation is from top surface to 2800 m horizontal plane. With the present 3D structure model, much more clear and detailed relationships among geological bodies are emerged, and spatial distribution of every geological body is showed intuitively, especially the occurrences and locations (Figure 1). It contains a total of 13 lithological surfaces and 3 fault surfaces for a total of 21 closed geological bodies (regions) formed by 55 m × 55 m × 60 m cells, creating a model with a total of 522,000 cells.

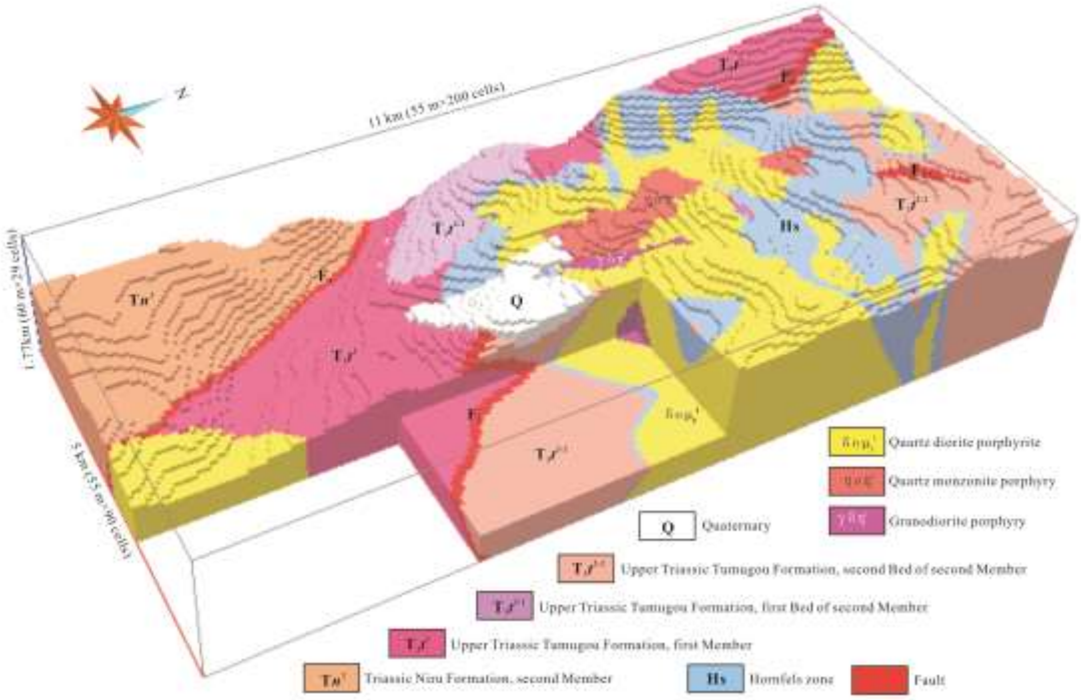

Figure 1. 3D structure model quantifying the distribution of geobodies associations in the study area.

Orebody Attribute Modeling

The structure model can only visualized observe space formation of geological bodies, lack of the property parameters (grade variation, stress field, etc.) and quantitative analysis ability, but the property model can supplement this imperfections and better reveal the characteristic of property in 3D space. The boundaries of the copper orebody outline are based on the grade data of simple test and cutoff grade of solid mineral exploration (the underground mine of copper deposit cutoff grade is no less than 0.2%). Based on the currently available database such as 19 cross-section maps of 1: 2000 scale, 72 boreholes and 7618 values of Cu-grade, 3D attribute model of KT1 is constructed feasibly and reliably. According to the cross-sections, borehole logs and characters of outcrops, a group of constraints line set is created to delineate copper orebody outlines. Then the closed surface of KT1 between exploration line 32 in northern and line 7 in southern are established through the line set. The solid model is obtained from closed surface of KT1 and divided into numerous cells which the size is 10 m × 10 m × 10 m.

On the other hand, the geological body (orebody included) has anisotropic properties in space because it may have different structures and variabilities in different directions of a certain distribution and regionalized variables. Therefore, the data of boreholes which including 7618 samples of Cu-grade information are used to calculate semi-variogram. And the semi-variogram of 2D and 3D different directions are systematically calculated after one dimension direction analysis [10]. Through the analysis, the Cu-grade data from boreholes is compliance with normal distribution. Therefore, the Cu-grade value of each cells about KT1 (between exploration line 32 and line 7) are calculated by the appropriate interpolation method which is ordinary Kriging algorithm, and the 3D attribute model of KT1 achieved (Figure 2**).** The 3D attribute model shows that the range of Cu-grade value in KT1 is from 0.2% to 2.83%, and high Cu-grade mainly concentrated in east of central KT1. The variation of copper grade is relative stability in orebody dip direction and the same characteristic in strike direction.

Prospecting Prediction

For new copper exploration, we consulted the methodology by Fallara et al. [2] and made some necessary changes. The choices of constraints used for concealed orebody prognosis in GOCAD are presented. (1) From the analysis of geological background, the copper orebodies were almost located within 1000 m of the faults, especially the intersection zone of the fault F_1 and F_2 which underwent porphyry masses emplacement. Hence, a distance of up to 1000 m to faults is the constraint to refine new potential zones. (2) The mineralization is low in the early stage porphyry rock quartz diorite, but the late intrusive rocks enriched the grade of copper. Areas of three kinds of rock masses have to be identified because they have lots of host fractures for the hydrothermal activity and deposit. Thus, the regions within the multi-period rocks are extracted. (3) The copper orebodies are located mainly within the phyllic and potassium silicate alteration zones, and not exceeding the hornfels zone. The regions within the range of hornfels zone are also extracted to refine the new orebody. (4) The continuity of mineralization is a key issue in district-scale mineral exploration of porphyry copper deposits, and it can be recognized by characterizing the horizontal and vertical distributions of geochemical data along boreholes from the 3D orebody attribute model. In conclusion, a result from the intersection of above process, potential mineralized zone is defined and the depths of northern and eastern positions of KT1 are potential targets to find new copper ore bodies (Figure 3).

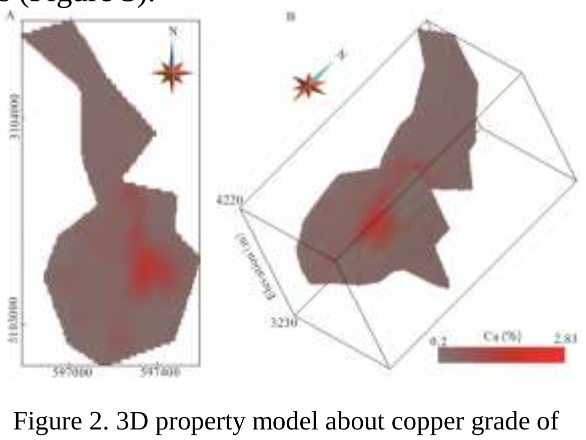

Figure 2. 3D property model about copper grade of KT1, A and B are viewed from different directions.

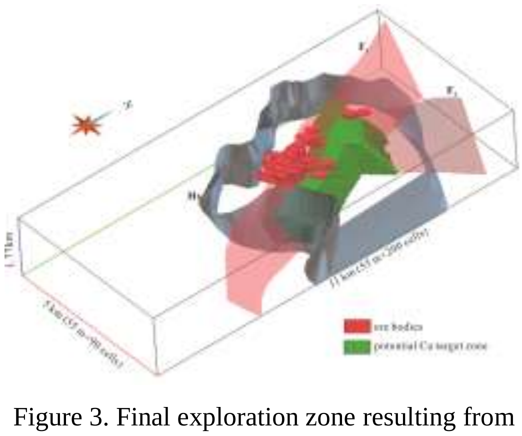

Figure 3. Final exploration zone resulting from several constraints used 3D geological model.

Conclusion

(1) The structure model shows the topography and subsurface structure of geological (such as strata, porphyry rocks, alteration zones, orebody and relationships among with each other) in 55 km^2 regional scale. The attribute model shows the distribution characteristics of copper element in 3D space and the value range of KT1 is from 0.2% to 2.83%.

(2) The analyses of the structures, multi-porphyry rocks, alteration zones and mineralization characters indicate that the sites of blind orebodies are predicted in the depths of northern and eastern positions of KT1 through 3D geological model.

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