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Quantitative analysis of intrusive body morphology and its relationship with skarn mineralization— A case study of Fenghuangshan copper deposit, Tongling, Anhui, China

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Abstract: The shapes of intrusive body and contact zone might influence the formation and distribution of orebodies in skarn deposit. By taking Xinwuli intrusive body in Fenghuangshan copper deposit, Tongling, Anhui, China, as the research object, a new method was used to obtain the quantitative relationship between intrusion morphology and skarn mineralization. The first step of the method was to extract morphological characteristic parameters based on mathematical morphology and Euclidean distance transformation; then the quantitative relationship between the parameters and orebodies was analyzed; finally correlational analyses between the parameters and mineralization indices were conducted. The results show that morphological characteristic parameters can effectively indicate the location of concealed ore bodies in skarn deposit, with the following parts as advantageous positions of skarn mineralization: (1) the parts away from the 1st trend surface in the range from −25 to 50 m; (2) the convex parts about 200 m away from the 2nd trend surface, around which the tangent plane of the intrusive body is approximately consistent with the trend surface; (3) the contact zones with angle between intrusive body original contact surface and trend contact surface ranging from 35° to 70°; (4) the parts with angle between intrusive body original contact surface and regional extruding far crustal stress ranging from 50° to 60°. These knowledge can be applied to more skarn deposits for future mineral exploration.

Key words: intrusive body morphological analysis; contact zone; mathematical morphology; skarn mineralization; Fenghuangshan copper deposit

1 Introduction

Skarn deposit has important industrial values, which is the main deposit type of rich copper deposit, rich iron deposit, tungsten deposit and tin deposit in China. The formation mechanism of skarn deposit is surrounding rock replaced by magmatic hydrothermal liquid, so the composition, formation depth, shape and scale of intrusive body have a decisive influence on the formation of skarn deposit. As the concavo−convex interface is more conducive than the smooth interface for mineralization, the shape of intrusion has certain effect on the formation and distribution of skarns and ore bodies. According to literature, the recessed parts of the intrusive body are more advantageous for mineralization than the protruding parts [1]. Thus, it is meaningful to study the occurrence and shape of the lower portion of intrusive body in the areas which have good metallogenic prospects [2]. The formation and distribution of orebody have close relationship with the complexity of the granite surface shape [3].

The skarn deposit is also controlled by contact zone between intermediate-acidic intrusive rocks and carbonate rocks [4,5]. Thus, the shape of contact zone plays an important role in metallogenic prognosis, as the more complex the contact structure morphology is, the more conducive to the mineralization [6].

In summary, analysis of the shape of intrusive body and contact zone is significant for metallogenic prognosis, exploration and exploitation of skarn deposit. However, previous studies dealing with morphology analysis are mainly based on 2D cross section maps, and the conclusions are drawn empirically by observing and comparing the relationship between the orebodies and the shape of intrusive bodies and contact zone. Many

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scholars have achieved the 3D simulation and morphological description of intrusive body and contact zone by using 3D software, and discussed the relationship between their shape and the spatial location of orebody [5,7,8]. But, the 3D quantitative morphology analysis of intrusive body and contact zone is not realized, which is not conducive for revealing the ore-controlling regularity.

Fenghuangshan copper deposit is one of the important copper deposits of Yangtze River metallogenic belt [9,10]. Many scholars believe that Fenghuangshan copper deposit is a typical skarn copper deposit after analyzing its geological characteristics, mineralization, mineralization stage and sources of metallogenic material [11,12]. Taking Xinwuli intrusive body in Fenghuangshan copper deposit as research objective, using mathematical morphology [13,14] and Euclidean distance transformation [15,16], the authors put forward a 3D morphological analysis method for intrusive body shape based on 3D raster model [17], including the hierarchical extracting and quantitative analysis of the characteristics of morphology undulance, and the geometric parameters extraction of intrusive body surface used to measure the 3D morphological features.

2 Quantitative morphological analysis method of intrusive body

Geologic bodies are discontinuous spatial entities in geological space, including sedimentary rock, intrusive body and deformation structure [18]. 3D geological model can visually demonstrate and describe the geometry and spatial distribution of geological bodies. On the basis of 3D model of the intrusive body in skarn deposit, 3D spatial analysis techniques can be used for analyzing surface morphological undulance, quantitatively extracting its geometric morphological parameters and achieving the quantification of ore-controlling indicators of intrusive body shape.

2.1 Intrusive body morphology modeling

3D geological modeling is important for understanding geological settings and spatial analysis. Considering the characteristics of spatial data model and purpose of the study, the geological body surface model based on surface representation will be firstly established, and then converted into 3D raster model based on body representation.

Based on three-dimensional computer image reconstruction technology, by combining the geological experiences, geological data and 3D modeling software, the rock borders can be delineated in 3D space by human−computer interaction, then we can generate the wireframe model and the raster model of intrusive body with the rock borders, and finally demonstrate them on the computer in order to analyze intrusive body shape.

3D structure raster model of intrusive body can be used for observation of its spatial morphology in multi-angle, and makes it easier for intuitive understanding and analysis of the internal structure and the space attribute distribution.

2.2 Intrusive body surface morphological undulance analysis

The morphological characteristics of intrusive body are important for mineralization in skarn deposit. The quantitative analysis of intrusive body surface morphological structure helps to reveal the spatial mineralization location regularity. The method of combining Trend and Remainder Analysis and structural analysis can be used for multi-level decomposition and geometrical modeling of geological body morphological undulance [19], but this method is not suitable for a complicated geologic body.

By using mathematical morphology and Euclidean distance transformation, the authors put forward 3D morphological analysis method for intrusive body shape based on 3D raster model [20]. Firstly, a spherical structure element of a certain radius is used to do morphological filtering for intrusive body in order to obtain trend morphology. Then, trend morphology set is divided, which is obtained through set operations from intrusive body voxels set, into convex peak part and concave valley part. Finally, Euclidean distance field is built in 3D space by Euclidean distance transform to measure based on trend morphology, and then the distance from voxel is obtained in the set of convex part and concave part to trend morphology outline. The local concave degree and convex degree of intrusive body surface can be quantitatively expressed by it.

Because the radius of spherical structure element decides the size of filtering-out waveform, using different radius values can extract different degrees of undulance.

2.3 Morphological parameter extraction

The shape and distribution of orebody in skarn deposit are also controlled by contact zone and related fracture, specifically manifested by the size of angle between interfaces of geologic bodies. In order to quantitatively express these ore-controlling factors, the angle between the contact surface and the trend surface as well as the angle between the contact surface and the regional stress field need to be extracted. Geologic bodies are discretely expressed in voxel raster model. The extraction issue of the angle is specified into an issue to solve the angle between tangent planes of two voxels corresponding to two spatial entities. Dealing