Deep electrical structure of nailinba polymetallic mine in Balinzuo Banner, Inner Mongolia

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Abstract. The middle part of the Da hinggan mountains is an important mineral resource base in China. Since the Mesozoic, due to the uplift of the mantle, the extension of the crust, the strong intraplate volcanic eruption and magmatic intrusion, the Mesozoic magmatic tectonic belt has attracted worldwide attention. For further exploring the deep structure of this area, the final geoelectricity structure was established based on a 50-kilometer magnetotelluric sounding profile in this area. Through data acquisition, phase tensor decomposition processing, and nonlinear conjugate gradient inversion, the model reveals the main electrical structural characteristics of this area: 1. The whole has a characteristic of "longitudinal layering and horizontal block", and the shallow electrical structure is consistent with known geological conditions; 2. There is a distribution inferred that a low-resistance anomaly appears due to the fragmentation of the surface rock layer caused by the uplift of deep intrusive rocks on the surface; 3. There are three more obvious electrical gradient zones or low-resistance anomalies in the deep part, which are presumed to be fault zones or structural erosion variable zone; 4. Three electrical gradient zones in the section divide the deep structure into four large-scale and high-resistance bodies, which reflects the spatial distribution of deep concealed granite, thereby restoring the complex anticline, secondary grade anticline, oblique uplift and depression. In addition, given the electrical structural characteristics and known the mine locations and the field exploration conditions, we conclude that the location of the prospecting target should be on a belt with Shuangjianzishan Pb-Zn-Ag mine, Nailinba Cu-Ag mine, Nailinba Fe mine, and Baiyinnuoer Pb-Zn mine. Moreover, this target is further divided into the middle area of Nailinba Cu-Ag mine and Baiyinnuoer Pb-Zn mine in combination with field surveys.

1. Introduction
The southern part of the Da hinggan mountains is located in the eastern part of the Central Asian orogenic belt. It is a superposition of the Paleo-Asian Ocean, Mongolia - Okhotsk Ocean, and Paleo Pacific Tectonic-metallogenic domains. This special tectonic setting has made it rich in nonferrous metals [1]. Since the 1970s, more than 300 large, medium and small ore mines and ore spots have been discovered in the southern part of the Da hinggan mountains, which has become an important polymetallic metallic belt in northern China. Among them are the Baiyinnuoer Pb-Zn mine, the Dajing Sn-Cu polymetallic mine, the Bayenda-Villasto Ag-Pb-Zn mine, and the Haobugao polymetallic mine. Many types and high-grade mining characteristics have caused the area to attract widespread attention from many scholars.
Researches have shown that the southern Da hinggan mountains has obvious features of gravity anomalies, and the contours of the remaining gravity anomalies distribute in order of positive and negative bands. High-value negative anomalies indicate that there are a large number of granite intrusive rocks spreading, and the polymetallic mines in the southern Da hinggan mountains are distributed. The polymetallic deposits in the south part of Greater hinggan mountains all distribute in the core of Huanggangliang-Ganzhuermiao-Ulanhot negative anomaly zone, which shows that the mineralization is closely related to the deep structure [2]. At the same time, research on the regional geochemical anomaly with the scale of 1: 1 million in the Da hinggan mountains shows that the distribution patterns of Ag, Pb, and Zn anomalies in this zone are similar and the overall shape is northeastward. The south section of the Da hinggan mountains is the most important abnormal distribution area, and the high background area is distributed along the NE direction [3]. In addition, the structural characteristics of the middle and south part of the Da hinggan mountains also show excellent metallogenic potential there. It has obvious core magmatic metamorphic complex, peripheral detachment slip layer and mantle branch structure of the upper superimposed fault basin, which become an important metallogenic and ore controlling structure in the area [2]. Some scholars have refined the prospecting area in the southern part of the Da hinggan mountains. They believe that the prospecting prospects on the west slope are more extensive than those on the east slope, which is due to the subduction and ablation from southeast to northwest plate, resulting in the thickening of the crust in the west slope, which provides favorable conditions for the differentiation and storage of magma [4].

So far, many scholars have studied the shallow geological conditions, gravity, magnetic methods, and geochemistry of the southern part of the Da hinggan mountains, but there are very few deep explorations. So, this time, based on the full use of previous research results, the first use of broadband magnetotelluric sounding method reveals the deep structure in the southeast of Inner Mongolia to make up for the blankness of the deep tectonic pattern in the southern section of the Da hinggan mountains.

2. Regional Geological Overview

The study area is located in Balinzuo Banner, north of Chifeng City, southeast Inner Mongolia. It is located in the southern part of the Da hinggan mountains in the tectonic structure. It is the clamping area of North China plate and Siberia plate, adjacent to Songliao Basin in the East, Xing'an block in the north, and North China plate in the south. The Nenjiang fault, ErlianhotHegenenshan fault and Wenduermiao-Xilamulun fault are their east, north and south boundaries respectively.

3. Data acquisition and processing

We adopt Phoenix company's V5-2000 MT sounding instrument as the deep detection instrument and equipment. The acquisition time is 6-15 hours. The five component time series of MT sounding are recorded. The data from a total of 81 MT sounding sites have been collected. Perform phase tensor decomposition, principal axis analysis, dimensionality analysis, two-dimensional nonlinear conjugate gradient (NLCG) TE + TM joint inversion on the measurement point data, and set the inversion parameters: regularization factor $\tau = 3$, horizontal and vertical smoothness ratio $a = 1$, apparent resistivity error floor is 10%, the phase error floor is 5%, and the initial model is 100Ω·m uniform half space. The number of iterations is 200 times, and the final RMS inversion fit error is 3.48. The reliability of the inversion results is verified by forward modeling, and an electrical structure model 10km underground is established.

4. Electrical characteristics and interpretation

Judging from the result of the nonlinear conjugate gradient inversion (Figure 2), the result has a characteristic of "horizontal block and vertical layering". There are discontinuous high conductors C1 and C3 in the surface of the crust, which are buried about 1 km underground. There is a high conductor C2 at a depth of 5 kilometers underground. In addition, there are large-scale high-resistance bodies underground, such as R1, R2, R3, and R4, with resistivity as high as 10000Ω·m. The obvious electrical
gradients with F1, F2 and F3 strike nearly NE. The underground is divided into four high-resistance bodies, and the electrical gradients have resistivity of 100-1000Ω·m.

Figure 1. (a) Regional tectonic map of Northeast China and adjacent areas; (b) Regional Geological Map of Southeast Inner Mongolia. F1 is Erlianhot-Hegenshan fault, F2 is Nenjiang fault and F3 is Wenduermiao-Xilamulun fault.

Segment 1 is the southern segment of the F1 fault. From a geological point of view, a large amount of Early Cretaceous granite and Permian sedimentary rocks are distributed on the surface, leading to
high-resistance underground electrical structures. The location of the fault or tectonic alteration zone is roughly near point 34 which is the boundary between the Permian sedimentary rocks and the Quaternary.

Section II is the clamping part of the F1 and F3 faults. On the basis of the Quaternary, a large-scale middle Jurassic volcanic rock appeared in the surface strata. In the shallow part of the electrical structure, a low resistivity layer with a transverse span of 15 km and a depth of nearly 100 m appears. With the increase of the depth, the low resistivity layer gradually disappears, replaced by a large area of high resistivity anomaly of nearly 10000Ω·m, presumably due to the hidden granite at the bottom of the volcanic rock. It is worth mentioning that many mining sites are located in this section.

Section III is the northern section of the F3 fault. There are large-scale compound granites on the surface. Large-scale "bowl-shaped" high-resistance anomalies can also be seen in the electrical structure. The cretaceous intrusive body surges along the "bowl edge".

The granite was exposed in a large area in the surface layer of section I and section III, but disappeared in section II. It can be seen from the geoelectric structure that there is hidden granite in the lower part of the sedimentary rock of section II, so it can be inferred that the outline of the whole complex anticline is secondary anticline in the section I and section III, and secondary Syncline in the section II. The data show that the Huanggangliang-Ganzhuermiao complex anticline strikes the northeast as a whole, and its southeast wing secondary anticline core (Section I) is invaded by Cretaceous rocks, resulting in the core part of the syncline in the southeast wing forming a Mesozoic sedimentary basin and depositing a large number of Mesozoic volcanic rocks, confirming the correctness of the fold shape inferred from the geoelectric structure.

In summary, the shallow part is characterized by low and medium resistance, and the resistivity value is between 10-1000Ω·m. It is presumed that the sedimentary cap rock consists of the Paleozoic, Mesozoic, and Quaternary, and the thickness of the sedimentary cap rock is less than 1km. The deep part is dominated by medium and high resistance, and the resistivity value is generally greater than 1000Ω·m, which is presumed to be a reflection of the Mesozoic intrusion into the rock mass or the old crystalline basement. There are obvious electrical gradient bands between the intrusive rocks formed in different periods, which represent the existence of phase transition or fragmentation of the rocks. Therefore, it is speculated that this area may reflect the basement fault zone. Polymetallic mines such as Baiyinnuoer and Shuangjianzishan are located near the deep anomaly zone, indicating that the formation of the ore body is not only controlled by the fault zone, but also closely related to the deep magmatic activity.

Ore mines and ore spots are generally distributed on high gravity zones [5]. Metal mines are often distributed near magnetic anomaly interfaces and where multiple groups of magnetic anomaly interfaces meet, reflecting the characteristics of different levels of structure controlling the mineral classification [6]. According to the local gravity and magnetic anomaly maps, we can know the structure of the study area in the southern part of the Da hinggan mountains, in which the Shuangjianzishan mining area, Nailinba mining area and Baiyinnuoer mining area belong to the same high Bouguer gravity anomaly belt and magnetic anomaly gradient belt. So the prospecting target in this area should form a mineralized belt with the Shuangjianzishan Pb-Zn-Ag mine, Nailinba Cu-Ag mine and Fe ore, and Baiyinnuoer Pb-Zn mine. In fact, Mineral debris has been found in this area. Thus, the key prospecting target can be further divided into the middle area of Nailinba Cu-Ag mine and Baiyinnuoer Pb-Zn mine.

5. Conclusions
(1) Three faults are identified in this section, all of which are controlled by the main Huanggangliang-Ganzhuermiao fault and head northeast. F1 fault zone is located at the boundary between the Permian sedimentary rocks and the Quaternary; F2 fault zone divides the Shuangjianzishan mining area and the Nailinba mining area; F3 fault zone is located in the compound granite area.

(2) The granite was exposed in a large area in the surface layer of section I and section III, and disappeared in section II. It can be seen from the geoelectric structure that there is hidden granite in the
lower part of the sedimentary rock of section II, and the entire anticline can be inferred from the contour. Sections I and III are secondary anticlines, and section II is a secondary syncline.

Figure 2. Interpretation of electrical structure of MT profile. Mine 1 is Shuangjianzishan Ag Mine, Mine 2 is Nalimba Cu-Ag Mine and Mine 3 is Nalimba Fe Mine.

Figure 3. Local Bouguer gravity anomaly map in southeastern Inner Mongolia.

Figure 4. Local magnetic anomaly map in southeastern Inner Mongolia.

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(3) Fracture rock at the fault zone provide a channel for magma upwelling, while alteration zones are often associated with ore bodies and their distribution range is generally wider than deposit bodies. Both
alteration zones and its range are important indicators for ore prospecting. The alteration zones or fracture locations corresponding to No.34, No.66, and No. 98 of this section are presumed to be prospected targets. From the geological study and geophysical prospecting, the middle area of the Nailinba Cu-Ag Mine and Baiyinnuoer Pb-Zn Mine is the best target area to finding mine.

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