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The Terminal of Mineral System Exploration in Thick Coverage Area by Gravity and Magnetic Data—A Case Study on the Nihe Iron Deposit

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The study is concerned with the airborne magnetic and gravity data aiming at evaluating the terminal of mineral system. Nihe iron deposit, situated in the center of Luzong ore cluster area, is the case to our study. Different tectonic environments, source material, and preservation background illustrate distinct properties in the geophysical observation results. Geophysical detection applies the characteristic differences of velocity density, magnetic susceptibility, polarizability, electrical resistance (conductivity), and wave impedance to detect the deep geological union. The multi-scale mineral system detection need to analyze the source, path, accumulation, and preservation in order to delineate the deep processes in multiple scales and targets prospecting. Ore-forming material induced by the regional geodynamic movement underwent transportation, enrichment, and storage conditions changes forming the ore deposit (Lü et al., 2015, 2021; Hagemann et al., 2016). In this paper, taking Nihe iron deposit in Luzong ore cluster area as an example, the aeromagnetic and gravity methods of prospecting give a high resolution delineation of the subsurface structures. The fine processed potential data, reduced to pole (RTP) total aeromagnetic intensity map and the Bouguer anomaly map, was used to analyze the terminal of mineral system. As a result, we get the corresponding depth and the horizontal distribution characteristics of Nihe iron deposit. Our results show gravity and magnetic detection method has an important application effects in the terminal exploration of the mineral system.

The research of the terminal in mineral system focuses on three-dimensional (3D) structure of the ore-forming rock mass and the prediction of the metallogenic target area. Airborne gravity and magnetic detection has attracted much attention because of its advantages of low cost, easy operation and high proficiency to detect the terminal of mineral system in thick coverage areas. Felsic–ultrafelsic rocks show high magnetic and high gravity anomalies, so the magnetism and density differences between different ore-bearing rock can be used to delineate the boundary of the rock mass and the target area for metallogenesis. In the process of metallic enrichment, fractures are the migration path and (or) enrichment sites of ore-forming fluids. Therefore, targeting the ore-body enrichment channels and the spatial distribution of ore-forming rock bodies has become an important goal of ore deposits exploration. Modeling the results of gravity and magnetic inversion, the 3D visualization can intuitively display the distribution, occurrence, and scope of mafic ore bodies and provide support for estimating the endowment of resources (Howe et al., 2014; McCuaig and Hronsky, 2014; Luo et al., 2018; Zhou et al., 2021).

Nihe iron deposit was discovered in the middle part of the Middle and Lower Yangtze metallogenic belt, which was mainly divided into three mineral serials: the magnetite in the southwest, the pyrite in the northeast and the transitional anhydrite section in the middle. According to previous research, the proved reserves of iron ore resources were 184 million tons, pyrite resources were 140 million tons, and anhydrite resources were 13.63 million tons. The former two reaches the large scale deposit and the latter is a medium-sized deposit. Nihe Iron deposit is a major breakthrough in deep prospecting in the Middle and Lower Yangtze metallogenic belt. The predecessors have conducted detailed studies on the geological characteristics, geochemical characteristics, wall rock alteration and sulfur isotopes of the deposit, and each proposed a diagenetic and mineralization model (Zhao et al., 2011; Zhou et al., 2011; Yan et al., 2014, 2019). The technical combination of Nihe iron deposit positioning prediction methods is discussed on the basis of fully understanding the geological ore-controlling laws of the mining area and clarifying the prospecting direction. Besides, the study must combine the perspective of

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geophysical exploration with existing research results to carry out the detection of regional gravity surveys, high-precision ground magnetic surveys, and electromagnetic soundings. Further, we implement advanced processing technology and visualization technology to dissect the fine underground structure of the mining area, comprehensively explain different geophysical parameters, and make positioning predictions for terminal exploration of concealed ore bodies.

The figure of original 1:50,000 Bouguer anomaly magnitude is high in the southeast and low in the northwest, and the anomaly boundary is not clearly distinguished (Fig. 1a). The 1:50,000 raw magnetic anomaly is disordered, except for the obvious low-magnitude-value anomaly and sparsely distribution of high anomaly (Fig. 2a). After the separation of regional and residual anomaly (Fig. 1b), the high and low value area are clearly distinguished in the residual gravity anomaly. The high gravity anomaly is prominent with regular shape. In addition, it is elliptical NE spreading, and the strength is low. However, the anomalous intensity is greatly affected by the depth and scale of the causative body. The anomaly magnitude responded by the deep and large-scale geological body may be smaller than the shallow and small-scale geological body. Therefore, it is inferred that the gravity anomaly may be related to the deep mafic rock. The reduction-to-pole transformation, a standard geophysical technique used to center anomalies over their sources (Blakely, 1995), was applied to Nihe magnetic anomaly map. When it comes to the RTP magnetic anomaly (Fig. 2b), it is much more regular than before. The high anomaly is NE spreading, which is in good agreement with the gravity anomaly. The 1:50,000 scale magnetic anomaly map was used in conjunction with the digital geology data to compare magnetic highs with mapped intrusions, and then find out the possible corresponding relation with the concealed intrusions. Comparing the residual Bouguer anomaly of gravity and the RTP magnetic anomaly, we can infer that the shape of gravity and magnetic anomalies in the Nihe ore deposit are similar. So we can implement combined gravity and magnetic inversion in this area. Several implementation techniques are developed to optimize the solution. (1) GMCP method (Lu et al., 2020) is used to detect the positive and negative correlation of the potential field source, then constraint the inversion. (2) Forms of Euelr's equation for anomaly derivative signals, derivative signals can delineate the edge better than potential signals. (3) The calculating structure index (SI) during the process of Euler deconvolution, the different SI can reflect the geometric shape of the causative body.

Electromagnetic sounding has the advantages of large detection depth and realizable area measurement. It is increasingly used in deep mineral exploration. The resistivity differences of underground media can be used to indicate structural features and locations. It provides a basis interpretation for the ore-controlling structure formed by the ore deposit and predicting the depth and shape of the buried ore body. The effective detection depth of electromagnetic sounding carried out in Nihe iron

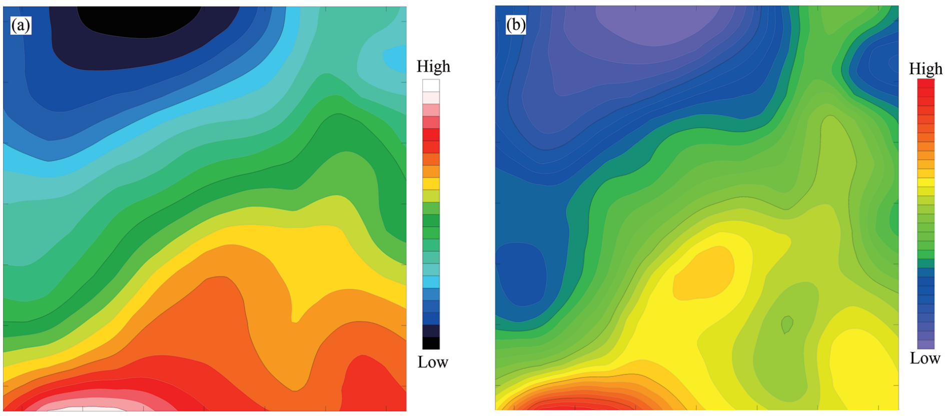

Fig. 1. Separation of gravity anomaly in Nihe iron: Bouguer gravity anomaly (a) and residual gravity anomaly (b).

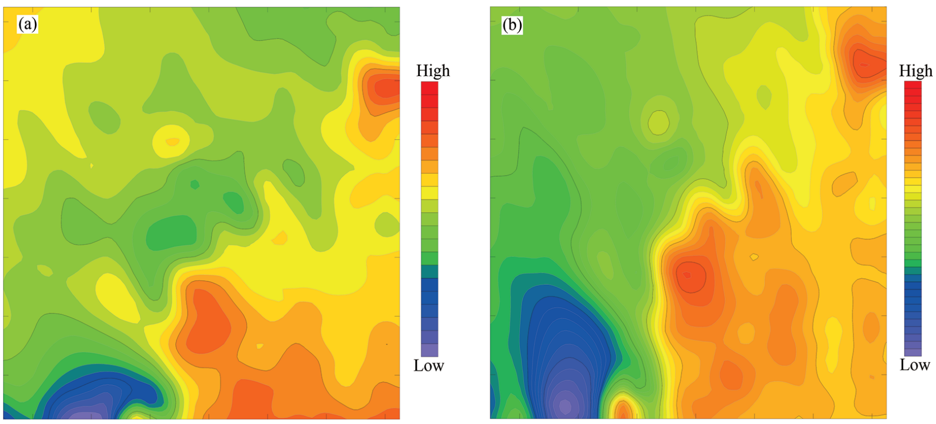

Fig. 2. The magnetic anomalies of Nihe iron deposit of original magnetic anomaly (a) and the reduced to pole magnetic anomaly (b).

deposit has reached to 1000m. The resistivity distribution characteristics of the electromagnetic sounding method reflect the distribution of volcanic rock formations. There are obvious stratigraphic boundaries at 500–800m, and the high-resistivity anomaly patterns corresponding to the gravity and magnetic high value anomalies are upwardly bulging, implying the stratum distribution of Zhuanqiao volcanic rock and subvolcanic rock, which indicates the intrusive position and shape of diorite porphyry. It is predicted that the favorable location for the occurrence of the ore body is the diorite porphyry body at the top of the dome or the volcanic rock strata of the lower section of Zhuanqiao Formation (Kuang et al., 2012). After drilling verification, the predicted ore bodies spread as thick lenticular magnetite bodies, layered and lenticular pyrite bodies. The lithology of the subvolcanic rock body is pyroxene diorite porphyrite. It shows that the combination of geophysical methods of gravity and magnetic joint interpretation for precise positioning and prediction has achieved good results in the prediction of mineral system “terminal” in this area.

The exploration of deep concealed minerals needs to be based on a correct understanding of the ore-forming law to comprehensively analyze the characteristics of the geophysical field. Different geophysical methods were expected to obtain different physical property parameters, whilst the interpretation of physical property anomalies often has multiple solutions, especially the ore body was located deeply, the observed anomalies usually contain the shallow non-mineral anomalies. Therefore, it is particularly important to use multiple geophysical methods for detection and comprehensive interpretation. What we want to emphasize is gravity and magnetic exploration method takes an important role in the process of locating the terminal of the mineral system. The multi-scale geophysical data of the RTP aeromagnetic anomaly, Bouguer anomaly, and their derivatives were used to prospect the Nihe ore deposit, which is a successful case for the terminal of mineral system exploration.

Key words: mineral system, gravity and magnetic exploration, ore deposit

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