An application of electrical resistivity tomography to investigate leakage pathways in the exploitation of IREO

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Abstract. For the mining of ionic rare earth ore (IREO) by in-situ leaching, the fracture structure, underground river and karst cave developed beneath the ore body, will become leakage pathways for the leaching liquors to escape and seriously reduce the recovery rate of IREO, in addition, the leach liquor along leakage pathways will also cause environmental pollution. Therefore, it is of great significance to study the deep structures and identify the leakage pathways. Our study area situates in Chang Ting county of Fujian province, which is an important rare earth deposit of China, in order to obtain high resolution deep electrical model, the electrical resistivity tomography based on multi-electrode resistivity method was used in this paper. First, we carried out multi-electrode resistivity method parameter experiment and select appropriate exploration parameters; Then, the Multi-electrode resistivity method data acquisition of 11 lines is completed by using ws-2 device mode; After that, the deep electrical structure model of the study area is obtained by inversion calculation and the thickness of the granite weathering layer (the layer containing rare earth ore) and the spatial distribution characteristics of the deep fracture structure are delineated by the deep electrical structure model of the study area. The interpretation results are consistent with the drilling results laid out in the study area. The exploration results provide important reference for the reserve evaluation of ion type rare earth mine, the sealing of leakage pathways and the layout of recovery pathways.

1. Introduction
Rare earth is divided into heavy rare earth and light rare earth, which are irreplaceable in the development of science and technology in the world. Heavy rare earth is not only valuable but also less in reserves, which is more valuable than light rare earth. The ionic rare earth is adsorbed on the minerals in the form of ions, and the heavy rare earth is the main one[1]. The main mining methods of ionic rare earth ores are in-situ leaching and pool leaching. Compared with Pool leaching, in-situ leaching has the advantages of environmental friendliness and low mining cost. The key steps of in-situ leaching are the recovery of leach solution and mineral leaching. But in-situ leaching, the leaching solution will escape down and out along the deep fracture structure, underground river and other leakage channels, which could reduce the recovery of rare earth resources, and cause pollution to the surrounding soil.

Multi-electrode resistivity method is an exploration method to study the distribution law of underground conductive current based on the difference of conductivity of underground medium and under the action of artificial application of stable electric field. It has the characteristics of mature interpretation technology, elevated-resolution and high working efficiency [2],[3],[4]. In this thesis, the multi-electrode resistivity method experiment and data interpretation are carried out in the C2 exploration area of Longyan Rare Earth Mine. The effective parameter combination of multi-electrode
resistivity method in the investigation of deep leakage passage of ionic rare-earth ore is analyzed and summarized. The spatial distribution characteristics of the channel can provide technical support for the efficient and green development of IREO, which has important practical significance.

2. Study Area
The exploration area is located in Zhongfang Village, Hetian Town, Changting County, Fujian Province. The faulted structure is undeveloped, and no obvious fault structure is found on the surface, the geological structure is mainly represented by joint fissure in the rock mass; the granite bedrock in the exploration area is relatively complete; bedrock is exposed in the dam valley on the south side of the exploration area; the strata in the exploration area are undeveloped, and are mainly Quaternary alluvial strata and Quaternary residual slope strata, Quaternary alluvial strata are mainly lithology clay, silty clay, fine sand and pebble; the main lithology of the Quaternary residual slope formation is residual sand (gravel) cohesive soil, which is the product of granite weathering residues, and the weathering in local areas is less complete, mainly at the ridgeline and the top of the mountain. There are many weathering residues, and the residual bedrock is mostly lenticular.

3. Line layout and data acquisition
According to the geological structure characteristics of the exploration area, 11 survey lines are arranged along the northwest 70° - southeast 70° trend, with the survey lines numbered c2-01, c2-02, c2-03, c2-04, c2-05, c2-06, c2-07, c2-08, c2-09, C2-10 and C2-11 respectively. Because of the terrain, the line C2-11 was equipped with 110 electrodes, and the other measuring lines were 600 meters in length and 5 meters in dot pitch, a total of 120 electrodes with a line spacing of 20 meters.

This data acquisition used a WS-2 device with a supply voltage of 226V stable DC voltage. Due to the local climate, the surface layer was relatively dry. In order to increase the grounding effect of the electrodes, each electrode was punched in a small pit of about 10cm, and watered in batches several times before measurement to ensure good grounding. During the data acquisition process, the preset maximum abnormal voltage was 6000mV, the minimum abnormal voltage was 3mV, the preset maximum abnormal current was 3000mA, and the minimum current abnormal value was 2mA. The abnormal data was less than 1% of the total.

![Figure 1. Schematic diagram of line layout](image-url)
The instrument used for data acquisition was the DUK-2A high-density IP instrument produced by Chongqing Geological Instrument Factory, the device was WS-2. The actual data acquisition layer was 45 layers. In the process, the distance between AM and NB changed with the change of the isolation coefficient. The distance of NM was 1 electrode distance on the first layer, and it changed every 12 layers, and it changed incrementally in the manner of 1 electrode distance, 3 electrode distance, 5 electrode distance, 7 electrode distance.

4. Data processing and interpretation
We used Res2DINV software developed by German DMT Company to carry out data preprocessing and inversion calculation. First we remove abnormal data; then perform 2D inversion calculation, the initial damping coefficient of the inversion was 0.16, and the damping coefficient increases with depth to 1.1, the vertical or horizontal smoothing filter ratio was set to 1.5, and the inversion resistivity range was limited to 1Ω.m~30000Ω.m. During the inversion process, the inversion parameters were adjusted according to the inversion results, and the resulting inversion RMS were all less than 3%. The inversion results were shown in Figure 2.

Figure 2. Contour of inversion result section
It can be seen from the inversion resistivity model that the deep electrical structure of C2-01 to C2-11 line was generally characterized by layered electrical structure, and the high resistance of the bottom layer was characterized by transverse block structure. In the longitudinal direction, it can explain the granite weathered layer and granite basement stratum, the weathering layer was longitudinally divided into high resistance surface layer of weathered laye and bedrock, the surface layer of weathered layer shows high resistance was related to the abnormal surface dryness caused by the long-term lack of rain in the survey area; The granite basement was separated by a low-resistance anomaly in the middle of the survey line. It was speculated that the low-resistance anomaly was a fault structure or a large-scale fracture structure. According to the electrical structure characteristics of 11 survey lines, the undulating form of the bottom interface of the weathering layer and the spatial distribution characteristics of the fracture or fracture structure were plotted, as shown in Figure 3. Based on the interpretation results, six verification boreholes were preliminarily arranged. The positions of the boreholes were shown in Figure 3. After the borehole verification, the results of the borehole inversion were also highly consistent.

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