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Integrated Geophysical and Hydrogeological Investigations for Geothermal Resources

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Abstract

In order to survey the geothermal resources in Linfen County, Shanxi Province, hydrogeological surveys, hydrological drilling, and geophysical surveys were carried out in the Yongle Palace-Dayudu area of Linfen County. The hydrogeological survey of 51.88km2 and two controllable source audio-magnetotelluric (CSAMT) profiles were obtained. The hydrogeological survey results show that the exploration area is located at the edge of the Yuncheng Basin. The tectonic movements of each phase are superimposed on each other, and a series of small faults are derived. The geological structure is intricate; the strata are mainly mud sandstones of the Quaternary and Tertiary strata, which dissipate heat It is small in nature and strong in water conductivity; the exploration area has abundant groundwater resources, which provides a material basis for the formation of underground hot water. According to the two-dimensional inversion results of the controlled source audio-frequency magnetotelluric method, it is speculated that the formation in the southeast of Linfen County (section 1-2 of line VI) is relatively stable, and the depth of the Cambrian bedrock roof is below 2600m; the northwest of Linfen county (section of line VII)) The basement Cambrian roof burial depth varies greatly, controlled by a fault developed near the location of 1600-1800m. The basement burial depth on the south side of the fault is larger, more than 2200 meters, and the basement burial depth on the north side of the fault is shallow, only a few hundred In the field survey, the fault trend is northwest-southeast, leaning southwest, the dip angle is large, the fault distance is about 1700 meters, and the length of the fault is unknown. The analysis is a secondary fault zone caused by the large fault in the southern foot of Zhongtiao Mountain, and the fault affects the bandwidth About 260-350 meters, the fault development scale is relatively large. According to drilling data, the temperature at 2100m is 67°C, and the temperature at the depth of 3500m is more than 100°C. Based on this, it is judged that the Yongle Palace-Dayudu geothermal field in Linfen County is a medium-temperature geothermal field. The electrical section and drilling results in the exploration area show that the thickness of the Quaternary and Tertiary sediments is above 2000m, and the mudstone and gravel with very low thermal conductivity are used as thermal insulation layers for thermal storage and as thick deposit caps. Provides good capping conditions for deep heat storage.

Keywords

Three-potential electrode system; Forward modeling; Least square inversion.

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1. INTRODUCTION

The high-density resistivity method is based on the difference in resistivity and solves geological problems by studying the distribution of active current fields in the underground half-space [1-2]. With the development in recent years, detection devices have been increasing, and instrument accuracy has gradually improved [3-4], and it has become one of the more effective and convenient methods in engineering geological survey, water environment monitoring, shallow mineral exploration, archaeology, and other fields [5-8]. Three-potential electrode system devices (α device, β device, and γ device) are currently one of the most widely used methods. Domestic Wang Xingtai et al. [9] studied three-potential motor system devices earlier and proposed a data processing method for ratios. Broaden the means of data processing.

However, the detection accuracy of the three devices has been disputed. Lei Wan believes that the Wenner α device is more adaptable than the β device and the γ device in undulating terrain, and the detection effect is better [10]; Ruan Baiyao [11], Luo Yanzhong [12] and M. H. Loke et al. [13] believe that the dipole-dipole device is better when detecting low-resistance anomalies; while Zheng Bing et al. [14] believe that the Wenner γ device is superior to the α device and the β device. In order to explore the detection accuracy of the three devices in karst areas, an appropriate geoelectric model is established according to the actual geological characteristics of the karst area. Through the forward calculation of the model, the detection accuracy of the three devices in the karst area is discussed and calculated based on the forward calculation. The result of the synthesis ratio parameter. According to the theory of the high-density resistivity method, the ratio parameter is defined as the ratio of the apparent resistivity of the β device and the γ device [9], which reflects the ratio of the potential difference between the two devices, which is like the characteristics of the tilter.

According to the theory of magnetotelluric sounding, the apparent tilton anomaly can reflect the horizontal non-uniformity of the geoelectric structure, and can well reflect the boundary features such as the location and scale of the anomaly [15-16]. If the ratio parameter in the high-density electrical method can also suppress the interference and reflect the boundary characteristics of the abnormal body, it is of great significance to the high-density electrical method exploration.

Although the ratio parameter was proposed earlier, it was not paid too much attention in the previous work and was only used as an auxiliary parameter [17]. The reason is that the signal-to-noise ratio of the instrument is poor, and the calculated T value has a large error. With the development of digital electronic technology and the improvement of instrument sensitivity, modern high-density electrical field work can obtain high-quality electric field signals and obtain accurate potential differences [3]. The application and research of ratio parameters are also increasing [18]. Hongzhi Tang and others developed the ratio parameter software of the WGMD-1 high-density resistivity measurement system [19]; the research of Yang Runhai and Guo Xiujun showed that the ratio parameter can not only highlight low-resistance geological anomalies, but also has a certain ability to decompose complex anomalies. The abnormal structure can be intuitively expressed in the form of ratio parameters [20-21]. However, their previous researches were based on the contour map of the ratio parameter. From the electrical exploration theory, it can be known that the apparent resistivity value measured by the high-density resistivity method does not reflect the true resistivity value at that location underground [22] Therefore, the calculated ratio parameter is not the true T value of the position. At this time, the ratio parameter is used to draw contour maps to assist in the interpretation of the inversion results, and the reliability of the interpretation results is also greatly lower. in this paper, the ratio parameter synthesized by the forward calculation is used for the damping least squares inversion, and the true distribution characteristics of the ratio

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parameter in the underground and the distribution relationship with the abnormal body are verified through the inversion result.

2. MODEL FORWARD CALCULATION

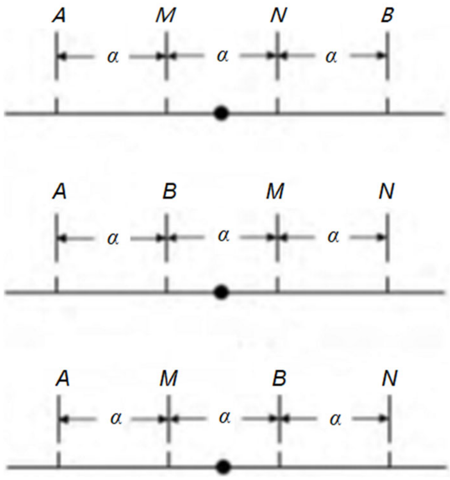

Fig 1. Schematic diagram of the arrangement of the electrodes of the Winner α, β, γ devices

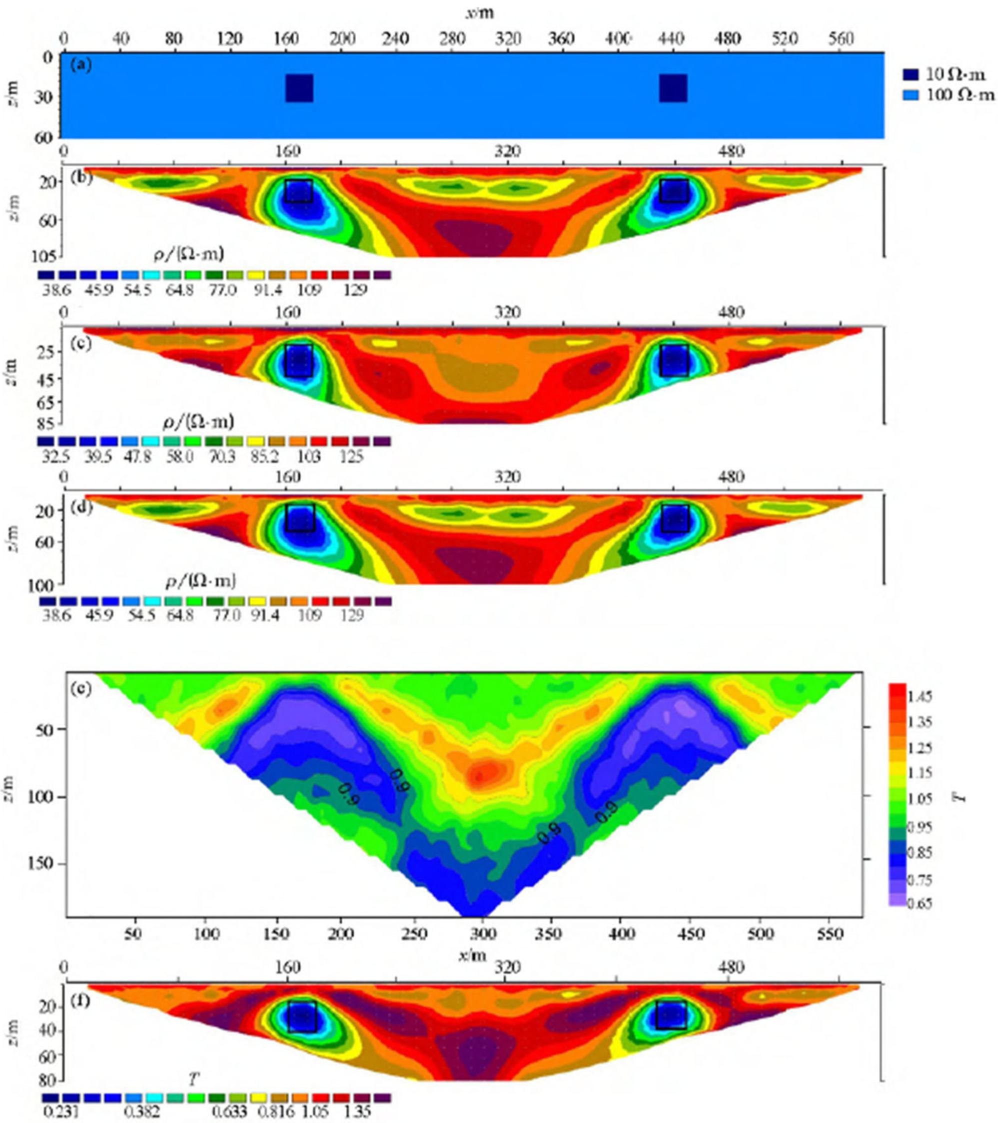

Fig 2. Low-resistance model profile and parametric profile

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Based on the forward modeling of Li Meimei and Wang Ende [23-24], according to the electrical characteristics of the karst area, a uniform half-space model with a resistivity of 100 Ω·m was constructed. There are two anomalies in the model. Among them, the two anomalies in the low-resistance model are water-containing caves with a resistivity of 10 Ω·m, and the high-resistance model is a water-free cave with a resistivity of 1,000 Ω·m. In order to better simulate the field acquisition environment, a certain Gaussian error is added to the response of the theoretical model [25], and the damping coefficient is set to 0.15 (according to the research of Huang Zhenping et al. [26], when the noise is small, 0. The damping factor of 15 has a better inversion effect), and the least square method is used to inverse the resistivity model (Figure 2, Figure 3). Comparing the results of these two simple geological models, the inversion profile of the ratio parameter is very effective in detecting simple geological bodies.

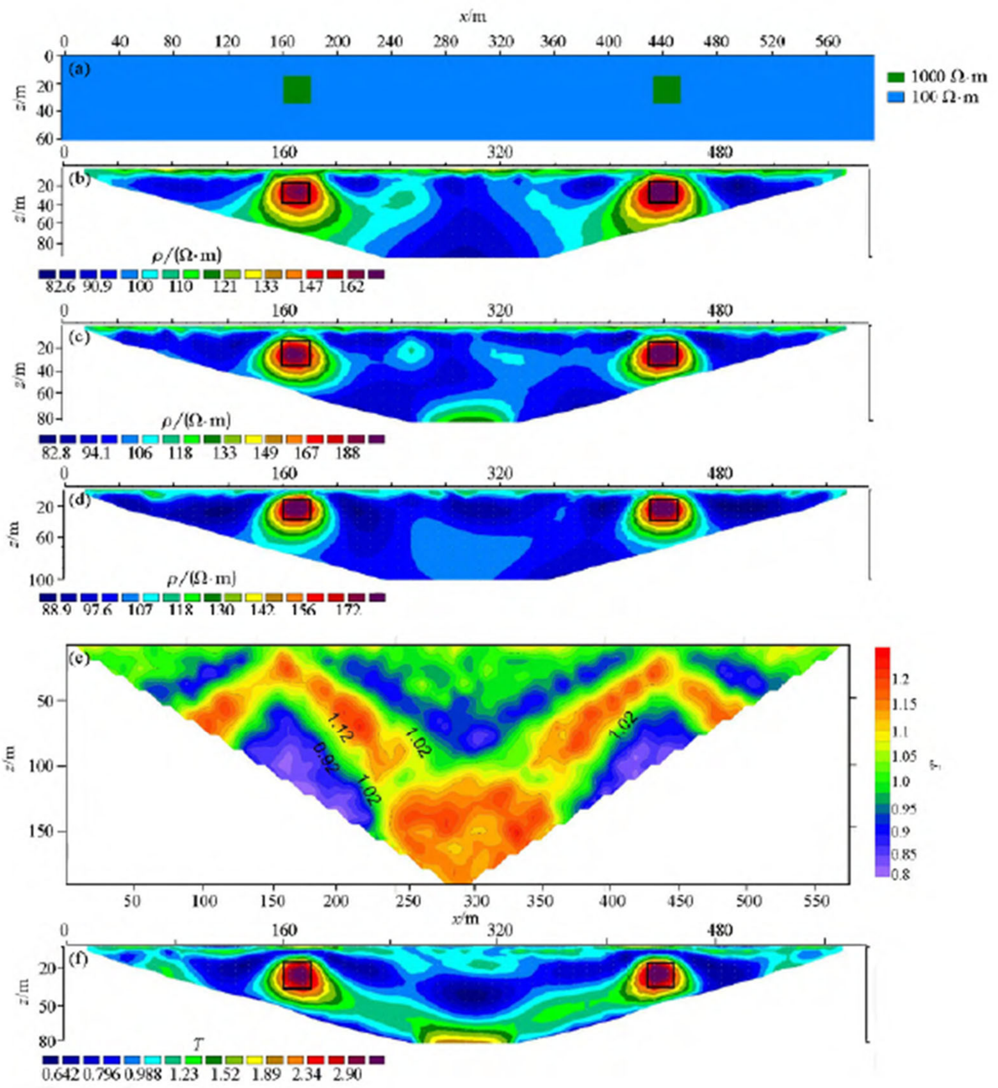

Fig 3. High-resistance model profile and parametric profile

3. PROJECT CASE ANALYSIS

Located at the core of the Mianchi syncline, Linfen is mainly composed of Mesozoic and Cenozoic strata. The faulted structure in the formation is developed, but the water content is not strong.

The Neogene marl in the aquifer is discontinuously distributed, covering the underlying strata in an angular unconformity contact manner. The caves and karst fissures are relatively

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developed, the water richness is medium, and the thickness is 0 ~ 50.8 m. Quaternary sand eggs the water richness of the gravel pore phreatic aquifer is weak to medium, and the water richness of other aquifers is weak. The hydrogeology of Linfen is of simple to medium type, belonging to Xin'an hydrogeology unit, with weak water-rich rock formations and relatively poor groundwater resources. In a limestone area in Linfen, the surface is covered by a thick layer of pebble and gravel. The surface is often exposed to bare rocks and water resources are scarce, which seriously affects the life of residents and the development of industry. In order to explore the characteristics of local groundwater resources, hydrogeologists laid out several high-density survey lines in the local area, and used Wenner α, β, and γ devices for joint detection.

After appropriately editing the measured data, use the least square method to invert to obtain the resistivity profile. Use the collected measured data to calculate the ratio parameter, draw the pseudo-cross-section diagram of the ratio parameter, and perform the least square inversion of the comparison parameter to obtain the ratio parameter cross-section diagram.

4. CONCLUSION

1) There are obvious differences in electrical properties in karst areas, and the results of forward modeling and actual measurement data show that the detection effect of the β device is good, which should be paid attention to in actual field work.

2) The inversion result of the least squares ratio parameter (T) is consistent with the anomaly of resistivity, which can be used as a reference basis for verifying the resistivity inversion result.

At present, three-dimensional high-density electrical exploration is not mature enough in practical engineering applications, and the cost is high. Improving the accuracy of two-dimensional exploration results is the focus of current research. In actual work, add data processing methods to make the processing results more abundant and diversified; before the results are interpreted, it is necessary to fully collect local geological, hydrological, drilling, geochemical, and preliminary geophysical data, and combine the results of other methods for interpretation, the accuracy of the survey will be greatly improved.

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