New technology of magnetotelluric polaron exploration-taking Huashan piedmont basement fault as an example

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Abstract. Detecting the Huayin Piedmont faults and basement conditions in the Weihe Basin through magnetotelluric polaron exploration technology found that the piedmont faults in the research area are quite developed, with two stepped normal faults with larger angles, along with many small faults; From the terrestrial polarization sub-bands, it is reflected that there are many fractures in this area, and the formation energy fluctuates greatly, indicating that the energy accumulation and formation energy of the formation are discontinuous, and there is a complete anomaly of the upper and lower formation energy at a certain depth. The comparative analysis of drilling and core data believes that it is the interface between the sedimentary rock layer and the underlying Qinling piedmont basement: the overlying stratum is the Tertiary sedimentary rock, and the lower basement is the Qinling Archaean granite layer; the fault structure of the Qinling piedmont is further understood and the basement rock layer and depth also proved the accuracy and reliability of the magnetotelluric polaron exploration technology.

1. Introduction
The Weihe Basin is located in the central part of Shaanxi Province (Guanzhong Plain). It is a Cenozoic faulted basin at the junction of the Qinling orogenic belt and the Ordos Basin for two geotectonic units [1], south of the Ordos Basin, north of the Qinling Mountains, east to the Yellow River and West to Baoji Canyon; 400km from east to west, the north-south direction is about 20km wide in the west, the east is about 70km wide, and the basin area is about 2×104km² [1,2]; its stratum belong to the southern edge of the North China stratigraphic area. The research area Huayin City is located in the eastern part of the Weihe Basin, which belongs to the eastern edge of the Weihe Basin. This area is rich in a variety of resources, including Water-soluble natural gas, helium-rich water-soluble gas, and geothermal water resources, etc. [3,4]. In the process of geothermal exploration in the basin, the stratum depth, fault development and basement depth of the area are unclear [5], resulting in poor geothermal development effects, etc., Cause greater economic losses [6], through advanced magnetotelluric polaron exploration technology to carry out exploration work, to find out the development of the fault structure and the basement in the piedmont, and to guide the next step of geothermal exploration and development work.

2. Experimental area overview
The exploration area is located in Huayin County, in the eastern part of Guanzhong Basin; it from Tongguan in the east, west to Huaxian, south to Qinling Mountains and Luonan, and north to Weihe
River and Dali. The county is between 109°54'-110°12' east longitude and 34°19'-34°40' north latitude; the exploration area belongs to the Huashan piedmont structure, as shown in Figure 1.

![Location map of the research area.](image)

Huashan is the eastern section of the Qinling Mountains. The forward faults in the Huashan piedmont are very developed, forming fault triangles. The progressively decreasing fault structure and combination form are the records of the activities of different stages of the fault. The triangle surface of the entire fault shows a gentle upward and downward steep form, and the fault system is very developed, which is also in line with the wave energy display of the original section. Use magnetotelluric polaron exploration technology to conduct fault zone and base exploration in the above areas to verify the accuracy of this technology for basement exploration.

3. Experimental tasks and data collection

3.1. Principles of magnetotelluric polaron exploration

The principle of magnetotelluric polaron exploration is different from the passive source electromagnetic prospecting method based on traditional physical electromagnetic radiation. In the method of magnetotelluric polaron exploration [Bagdanov, Bavelvitch, 2008], the main body of research is natural electromagnetic Radiation, it is formed during the change of stress and strain state of the lithosphere. This kind of electromagnetic wave is different from the electromagnetic wave of fixed frequency and fixed amplitude, which is formed by the mutagenesis of magnetic field (magnetotelluric field) and atmospheric activity (thunderstorm activity field) [Baghdanov, Pavelvitch, Schumann, 2009]. Therefore, it is believed that the medium is also the most active in the formation stress and rock stress.

The rock layer is a favorable environment for electromagnetic disturbances. The nearest electromagnetic disturbance that can reach the surface of the earth forms a complex electromagnetic field structure on the earth, which opens a new channel for us to obtain information on the physical properties, structure and performance of the earth.

3.2. Implementation of exploration deployment and data collection

According to the site conditions and work purposes, deployed 3 experimental survey lines, as shown in Figure 2.

According to the detection principle, the detection depth is one-half the distance of the arrangement length, so the longer the arrangement length, the deeper the detection depth will be to receive
underground electromagnetic signals. Based on this principle, it is arranged as a double cross survey network to include the fault zone in the area and the depth range of the base.

Figure 2. Control map of exploration survey line in experimental area.

Because the experimental site is located in the suburbs of Huayin City, highways and railways are vertical and horizontal, and there are many high-voltage transmission lines in the area. These objective conditions caused stronger electromagnetic interference in many aspects to the signal acquisition of the magnetotelluric polaron exploration technology (Figure 3), has a certain impact on the exploration effect.

The experiment was started from 9:30 am and ended at 18:20 on the same day. The data collection tasks for the above three survey lines were completed, and the survey line length was 47 km in total.

Figure 3. Raw data signal curve.

4. Experimental work and results

4.1. Principles of highlight mining
There are stress and concentrated fields in the geological interface of the underground strata and the fault section, which have also become bright spots, The bright spots have high-energy electromagnetic radiation.
The method of finding bright spots can be simply stated as: two similar peaks in the original data curve, the position center of which is along the lower part of the central axis is the bright spot position, and the relationship between the depth d and the distance L between the two peaks is \( d = 0.75L \) (empirical formula, diffraction theorem) (Figure 4).

![Image](https://example.com/image1.png)

**Figure 4.** How to find highlights.

![Image](https://example.com/image2.png)

**Figure 5.** Original profile of survey line 1.

4.2. **Data processing**

Due to the small fluctuations of the ground surface in the experimental area, the ground leveling method is adopted for data processing (no ground elevation correction), and the ground is set to zero uniformly, and the longitudinal value of the profile is the vertical depth from the ground.

During the de-noising process, many random interferences were found, which affected the overall quality of the data. In contrast, survey line 1 and survey line 2 have better data quality (Figure 5, 6), and survey line 3 is because the instrument is mounted in the automobile for exploration, there is more signal interference, less effective data information (Figure 7), and the worst data quality.

It is not difficult to see from the original section that the faults are well developed.
4.3. Geological analysis
From a geophysical point of view, there must be a large difference in physical properties between the basement granite and the upper sedimentary rock. Taking the survey line 2 profile as an example (Figure 8), there are obvious differences in the energy distribution characteristics and combination characteristics of a single point in the longitudinal direction. The interface can be judged as the interface between the basement and the upper sedimentary rock (the black dashed line in Figure 8).

Combining the basic geological data of this area, through energy analysis, a more accurate basement interface depth can be obtained (Figure 9,10,11).
The structure changes drastically in this area, the buried depth of the base gradually increases from south to north, and the developed fault system is basically east-west trending.

There are two geothermal exploration wells in the exploration area, and there is a geothermal exploration well in the front of the Qinling Mountains passing through the 1 and 2 survey lines. According to on-site drilling core data and logging data, granite was drilled to the basement at 1528 meters, and a large fault was shown at about 1730 meters; According to Figure 9, the intersection of the
extension line between the fault and the basement and the well 2 basically agrees with the actual drilling data; and there is a geothermal exploration well 1 near the high-speed rail line north of the survey line 2, it encountered basement granite at about 2750 meters, which is also in good agreement with our survey line, proving that the technology has quite high accuracy and reliability (Table 1).

Table 1. Comparison of geothermal well depth and exploration effect of 2 wells in the work area.

| Geothermal exploration well | Depth (m) | Fault depth (m) | Substrate depth (m) | Relationship with survey line 2 |
|----------------------------|-----------|-----------------|---------------------|-------------------------------|
| Well 1                     | 2800      | --              | 2750                | parallel                      |
| Well 2                     | 1888      | 1730            | 1528                | intersect                     |

Through the analysis of the actual drilling data and logging data of two wells in the work area, it is proved that the magnetotelluric polaron exploration technology can distinguish the formation and the basement and fault zone accurately, it has a fairly high resolution and reliability, it also has a clearer understanding of the Qinling piedmont underground stratigraphic structure and basement rock in the Huayin Research Area, guiding the next step of geothermal exploration and development.

5. Conclusion

1. The piedmont faults in the research area are quite developed, with two large-angle step-type forward faults, accompanied by many small faults; From the geopolarization sub-band reflects that there are many faults in this area, and the formation energy fluctuates greatly, indicating that the energy accumulation and formation energy of the formation are not continuous, and there is a complete anomaly in the upper and lower formation energy at a certain depth;

2. Through the comparison between the original well data in the work area and the latest magnetotelluric polaron exploration data, the conditions of the underground strata, structure and basement in the front of the Qinling Mountains in the work area were found out. The analysis suggests that there is an interface between the sedimentary rock layer and the underlying Qinling piedmont basement rock in this area. The overlying strata are tertiary sedimentary rocks, and the lower basement strata are Qinling Archaean granite layers, which will provide further guidance for later geothermal exploration and development;

3. The exploration of this area through the magnetotelluric polaron exploration technology, combined with the drilling data, fault distribution and basic data of two geothermal wells in the area, has been compared and analyzed, which confirms that the advanced technology is more accurate in the identification of strata and faults, and its resolution and reliability are high.

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