APPLICATION OF AN ULTRA-LONG ELECTROMAGNETIC WAVE DETECTING TECHNIQUE IN GEOTHERMAL EXPLORATION

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SUMMARY - The ultra-long electromagnetic wave detecting technique, which can avoid electronic disturbance, is both easy to operate and is portable. A test at Tianjin City shows the possibility of using ultra-long electromagnetic wave detecting technique in geothermal exploration. The test results show the top of the Meso-Proterozoic Jixian System which is composed of dolomite. It is the major thermal reservoir of the Tianjin thermal field. The high wave amplitude with some "U" shape valleys may indicate the best hot water prospects.

1. INTRODUCTION

Nonseismic geophysical exploration with its portability and low cost is becoming popular in geophysical exploration (Liu, 1993). The ultra-long electromagnetic wave detecting technique is one of the low cost, portable, sensitive and rapid geophysical exploration sensitive methods. The ultra-long electromagnetic wave, with frequencies in the range from 1 Hz to 1000 Hz that can not be detected aurally can be received by a detector developed by Peking University. The ultra-long electromagnetic wave can pass through deep strata (Fujiwara, 1990). The new detector, with its highly sensitive sensor, can receive ultra-long electromagnetic waves from deep lithological contacts where the ultra-long electromagnetic waves are stimulated by energy from solar wind, global thunder, or from the earth's core (David, 1991; Galeys, 1972; Wait, 1982; Liu, 1994).

The detector is controlled by a portable computer. It comprises three parts: the main instrument with a portable computer, antenna with amplifier and an external power source which detects data automatically from underground through the sensitive electromagnetic antenna. The detecting depth ranges from 20 metres to 10,000 metres. Detecting 1000 metres takes about 1 minute.

The advantages of the detector are its small size, easy operation, quick data collection and processing which automatically saves and displays it. The ultra-long electromagnetic wave detecting technique can be readily applied to both continental and oceanic exploration in a range of topographies, for example, petroleum and geothermal exploration.

The data collected can be displayed in frequency curves, whose ordinate is depth(m) and abscissa is the energy received from ultra-long electromagnetic waves (μV). Many field experiments show that the amplitude of the frequency curve is related to the density and porosity of the deep rocks based on the analogy between the frequency curves and logs (Hou, 2000). Normally, the rocks with the highest density but lowest porosity display a frequency curve with high amplitude whereas rocks of low density and high porosity display a frequency curve with low amplitude. For example, rocks with high amplitude include magnetic rocks, metamorphic rocks (granulite and gneiss), carbonates (limestone and dolomite) and compact mudstones. Rocks with low amplitude are sandstones, conglomerates, sand-mud interbeds and shales. The water, coal and petroleum bearing reservoirs display frequency curves with low amplitudes. The weathering crust, the leached horizon, the reservoir and fracture zones also display extensive fluctuated frequency curves with low amplitude. In general, the amplitude of the ultra-long electromagnetic wave is related to the physical properties of the reservoir rocks, so the frequency curves reveal information about petrophysics. These principles, learnt from many experiments, show that the ultra-long electromagnetic wave detecting technique can be applied to geological and geothermal exploration (Hou, 1998).

2. GEOLOGY

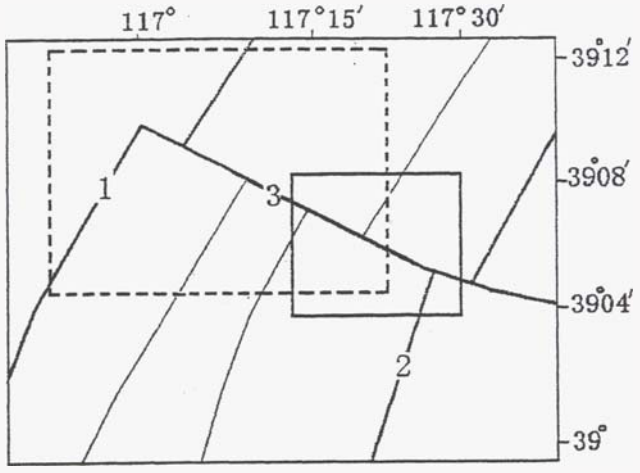
The Tianjin geothermal field is the most developed one in China. Tianjin City, with abundant thermal water resources is located 160 km southeast from Beijing, in the northern North China Plain. Pre-Mesozoic carbonate rocks are the major thermal reservoir of the geothermal system. They are covered by about 1000 metres of Cenozoic rocks. The waters at differing temperatures occur in sand and conglomerate strata. Geothermal development began in the 1930s but large scale exploration and mining occurred in the 1970s. Most thermal water since 1970 has been extracted from the Cenozoic reservoirs so that a geothermal-shaped funnel formed below Tianjin City. The thermal water is extracted from the Cenozoic Erathem in a limited amount. It is now necessary to explore for typical thermal waters in fractured basement rocks of Paleozoic and Mesoproterozoic age.

The Tianjin geothermal field is located in the NNE-trending Changxian uplift of the North China Basin, which itself is controlled by the NE-trending Changdong fault, the NE-trending Tianjin fault and other NW-trending faults (Fig. 1)(Zhao, 2000). The Baitangkou depression, controlled by the NE-trending Baitangkouxi fault and the NE-trending Changdong fault, is one of several small depressions in the Changxian uplift. The Tianjin geothermal field is located in a Mesozoic and Cenozoic basin where the sandstone and mudstone overly a basement composed of Paleozoic limestones and Mesoproterozoic dolomites. These are the major deep geothermal reservoir at Tianjin.

Fig. 1 Sketches of faults in the Tianjin geothermal field

1 Tianjinxi Fault; 2. Changdong Fault; 3. Haihe Fault

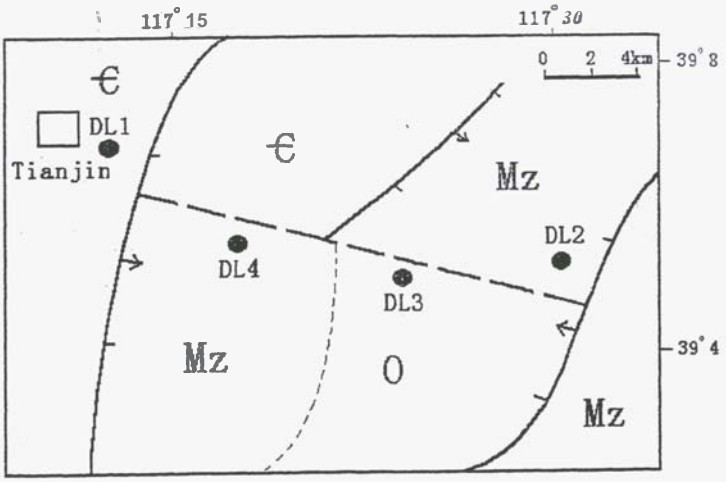
Dash square shows the Tianjin City
Solid square shows the location of Fig. 2



The ultra-long electromagnetic wave detecting technique applied to geothermal exploration at the Tianjin geothermal field

The Tianjin geothermal field is mostly located within a city with developed industry and large population where normal geophysical exploration, for example, seismic exploration, is very difficult to do.

Fig. 2 Detection sites in Baitangkou depression



The Cenozoic cap rock covers the major thermal reservoir of Paleozoic limestone and Mesoproterozoic dolomite. The interface between them is very clear, with a distinct petrophysical contrast. The characteristics of the thermal reservoir makes it suitable to apply the ultra-long electromagnetic wave detecting technique.

The Baitangkou depression is in the geothermal prospect area in Tianjin. A chosen section, with a SEE strike, passes through the Baitangkou depression (Fig. 2). There are four observation points along this section, two of which are located in the Baitangkou depression (DL4 and DL3); one is located on the Changxian uplift (DL1) and another (DL2) is located in the Huanghua depression. Drillholes at both ends of the section are known, but the centre of the section lies in unknown strata. The observations were conducted on April 4th, 2000. The boundary depths and thickness of the thermal reservoir are forecast by comparing the two sets of geological interpretation with the ultra-long electromagnetic frequency curves.

Geological interpretation of two frequency curves for the two known drillholes is based upon their logs. These were used to interpret the frequency curves for the two unknown sites.

Eight measurements were made at all 4 sites over about one hour. The intention was to forecast the depths of the geothermal reservoirs in Paleozoic limestone and Mesoproterozoic dolomite. Table 1 shows the *strata* and their depths as interpreted from the four frequency curves. Cenozoic strata, for example Nm, Ng, Ed and Ek (Fig. 3) are sandstone and mudstone interlayers that show amplifier frequency curves lower than do the Paleozoic limestone and Mesoproterozoic dolomite.

Fig. 3 Comparison of ultra-long electromagnetic wave frequency curves between two known drillhole sites (DL1, DL2) and two without drillhole control

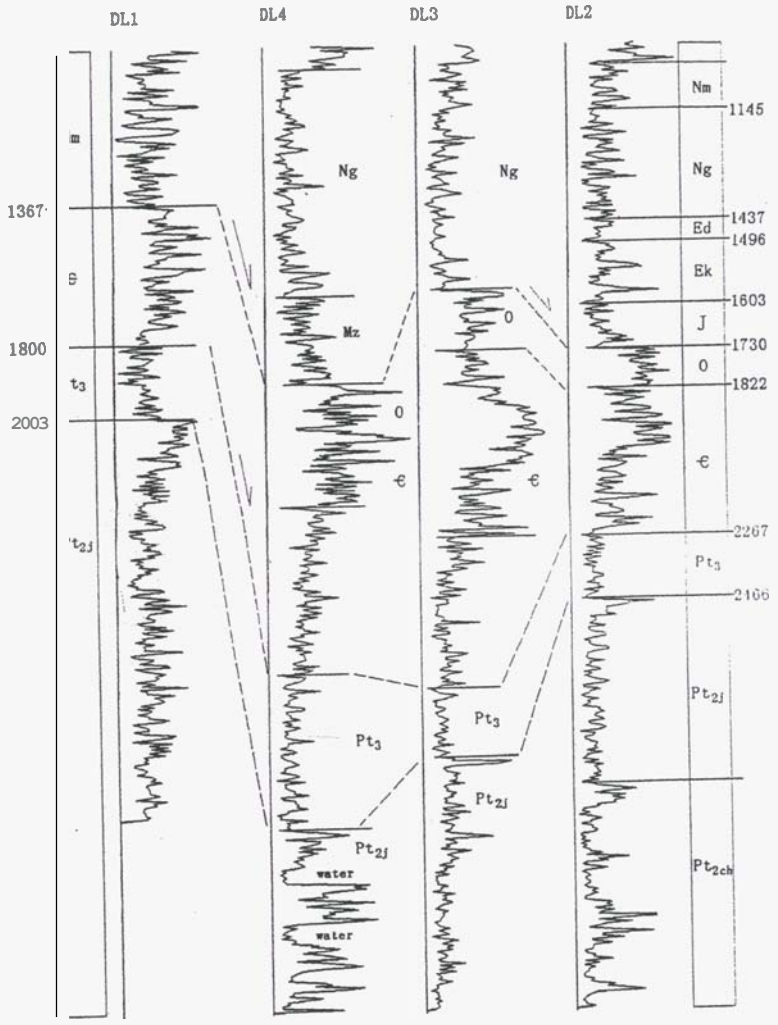


Table 1: Profile of four ultra-long electromagnetic wave frequency curves across Baitangkou sag in Tianjin City

Age	Lithology	Depth (m) below ground surface				Amplifier Value
		DL1	DL4	DL3	DL2	
Ordovician system	Limestone		1875	1530	1730	High
Cambrian system	Limstone	1367	2190	1800	1822	High
Upper Proterozoic	Shale and sandstone	1800	2775	2650	2267	Low
Middle Proterozoic	Dolomite	2003	3030	2850	2466	Low

The amplifier of the Ordovician limestone is lower than that of the Cambrian limestone because the former is more weathered and leached. The curve segment from 3030 to 3500 metres shows a conspicuously high amplifier in the Middle Proterozoic basement at DL4 with "U" shape valleys perhaps revealing water reservoirs with very low amplifiers. The results show that DL4 is the best site to drill a well.

3. CONCLUSIONS

The ultra-long electromagnetic wave remote detecting technique is easy to apply. Data are collected quickly and processed easily nor they are affected by human activity. This method can be used in a city to explore its geology, geothermal geology and geohydrology. The test at Tianjin City shows that this technique can be applied to explore its geothermal field based on detecting and interpreting thermal water reservoirs in the basement according to their frequency curves. The remote detecting technique will aid prospecting in urban areas.

4. REFERENCES

Galeys, J., 1972: Terrestrial Propagation of Long Electromagnetic Waves, *Pergamon Press,* New York, 113p.

Gubbins, D., 1991: Core-mantle interactions, *Tectonophysics,* 187: 385-391.

Guiting, H., 2000: The application of ultra-long electromagnetic wave remote sensing to deep petroleum exploration under Bohai Sea. Acta Scientiarum Naturalium Universitatis Pekinensis, 36 (in Chinese).

Guiting, H., 1998: The application of ultra-long electromagnetic wave remote sensing to geological exploration, *SPIE*, 3503, 79-84.

Hong, L., 1994: The availability of high sensitively detection of petroleum and water using natural electromagnetic field, *Acta of Geophysics Sinica,* 37(6), 75-79.

Ruogu, L., 1993: A study of source field about petro-sonde method, *Acta of Geophysics Sinica,* 36(1), 113-120.

Teruo, F., Hiroshi, K., Ryutaro, J., 1990: Availability of geophysical prospecting using ultra-long wave, *Geophysical Exploration Conference Proceeding,* 71: 123-124.

Wait, J.R., 1982: Geo-Electromagnetism, *Academic Press,* New York, 104p.

Weiming, Z., Hongxiang, S., Zhijie, L., 2000: The thermal mineral water in Tianjin, *Acta Scientiarum Naturalium Universitis Pekinensis,* (in press).