Application of comprehensive geophysical prospecting method in groundwater exploration

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Abstract. In order to solve the problem of shortage of water resources in northern Shaanxi, we selected rectangular large loop source transient electromagnetic method with high water affinity, and radioactive α measurement method which can delineate the water storage structure, comprehensive geophysical prospecting methods to look for groundwater. Algorithm has established a forward model, and compared all-time apparent resistivity in late-time apparent resistivity is better than late. We can find out the exact location of the groundwater and thus improving wells rate by comparatively using these two kinds of geophysical prospecting method. Hydrogeology drilling confirmed water inflow of a single well can be up to 40 m^3/h, it can fully cover native Domestic and Agricultural water, and provide an important basis for groundwater exploration.

1. Introduction

China is a country with lacking and unevenly distributed water resources. The shortage of water is a restriction of the development of economic and life level even in the northwest region and many mountain regions. Nowadays underground water-bearing structures have a great research significance for mining, environmental protection, agriculture and underground engineering apartments. Therefore, high-precision and high-efficiency exploration of groundwater has becoming the first subject in the study of water resources [1].

In the exploration of underground water, people tends to use single geophysical prospecting method such as DC resistivity method and induced polarization method [2]. Limited by the topography and volume effects of exploration, wells rate is hard to be improved. In recent years, the integrated geophysical method to search for water is rapidly developed in our country. Song Yi used the magneto telluric method and the transient electromagnetic method to search for water, and Liu Chunhua used the transient electromagnetic method and the electrical sounding method to search for water [3-4]. Both of them can effectively identify the underground aquifers and reflect them on the section. Drilling holes has confirmed that integrated geophysical method can improve the wells rate and overcome the one-sidedness of traditional geophysical analysis theory.

2. Principles and Theory Model

2.1. TEM:

Transient electromagnetic method is the use of ungrounded line (large-loop magnetic dipole) sent into the ground, during a break, using transmission line receives secondly induced magnetic field, the second was inspired by underground conductors of electromagnetic eddy currents generated by the instability caused by magnetic fields. Because of its high vertical and horizontal resolution, low being affected by geological noise and insensitiveness for low resistance characteristics, it has been widely applied to groundwater exploration [5-6].

2.2. 1-D forward model

The field work, we adopted all-time apparent resistivity method, it can eliminate the apparent resistivity(ρ_s) of "distortion".

Vertically on a horizontal electric dipole uniform half-space rate of change of magnetic flux density of time is [7]:

$$\frac{\partial B_Z(\mathrm{t})}{\partial t} = \frac{3I_0\rho_1 dl}{2\pi r^4}\frac{y}{r}[\Phi(u) - \sqrt{\frac{2}{\pi}}u(1+\frac{u^2}{3}e^{-\frac{u^2}{2}})] \tag{1}$$

Rectangular loop source any of the vertical magnetic field on the time derivative is:

$$\frac{\partial B_Z(t)}{\partial t} = \sum_{i=1}^{4}\int_0^{li}\frac{\partial B_Z(t)}{\partial t} \tag{2}$$

1-D forward modeling Fig 1.: wireframe 200*200 m , point margin 20 m , power supply current 3 A , logging gate number 20.

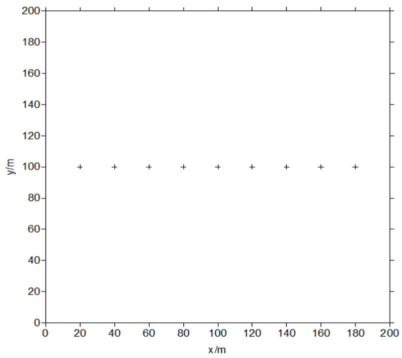

Fig. 1 1-D forward modeling of Planar graphs

Modle	Layers	Resistivity ($\Omega \bullet m$)	Tinkness (m)
H	1	100	200
	2	20	100
	3	200	∞

Table 1. 1-D forward modeling parameters

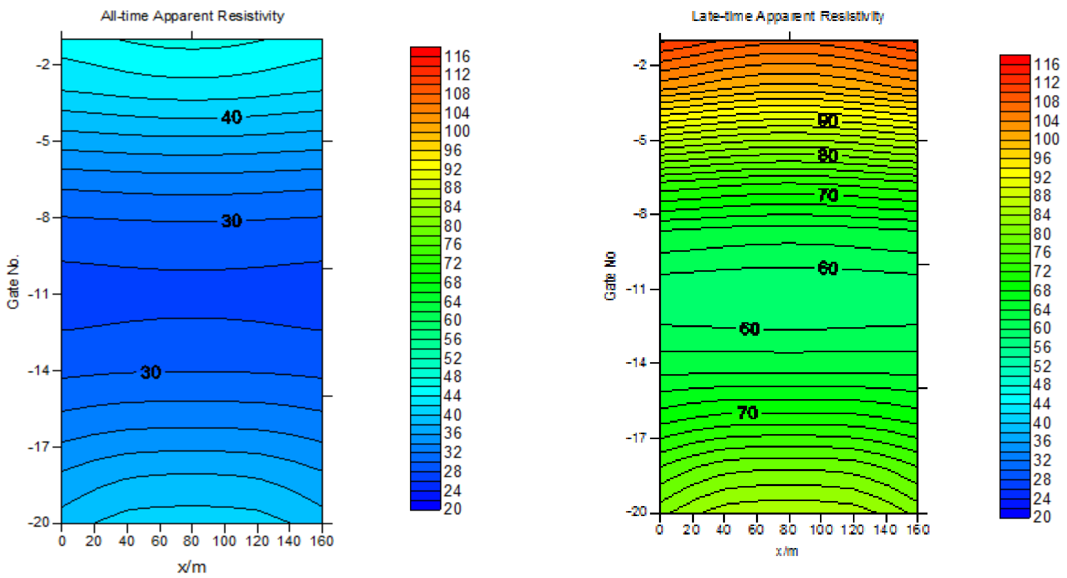

Fig. 2 Profile of apparent resistivity

All-time apparent resistivity (b) Late-time apparent resistivity

From the late-time apparent resistivity Fig2. (b), there is a strong "border effect", the apparent resistivity curves downward and locals high-resistance, it shows fate high-resistance from early gate. All-time apparent resistivity profile Fig2. (a), it will not be "border effect" like the late-time apparent resistivity, and the early gate does not appear fate high-resistance, to better reflect the model features.

2.3. *Radioactive measurement method*

This method is mainly used to measure radon measurement of soil, water and atmospheric radon concentration, and then through the study of the distribution of radon concentrations to locate the storage structure. Radon transfers in the form of ion-atom in the rock fissures or pores in nature, so structural fracture zone and fractured zones are both good channels for radon gas's migration [8].

3. Example application

3.1. *Geology*

The district is located in the southern margin of the Ordos basin and central-edge of the Fen-Wei graben, geological structure is complicated. In the region, tectonic is mainly fault and the fold and fissure is in the second place, fault is well-developed water fault, having a controlling effect on water fissure. Terrain shows a ladder-shaped, and increases gradually from the southwest to the Northeast, Huang-long mountains South winding parts, elevation 900~1543.8 m , relative height difference is 150~250 m .

3.2. *Field work*

In the transient electromagnetic exploration, we used the Changsha Baiyun Instrument Development Co., Ltd. produced MSD-2 transient electromagnetic, the wireframe is a rectangular loop of 300*500m, we decorated with a measuring line inside the wireframe, and arranged for the North-South direction, point margin 20 m , power supply current 3 A , logging gate number 40, receiving the equivalent area of 1080 m^2 , frequency 25 Hz , stack folds to 100.

The radioactive measurement method used the FFA-2 fast digital scintillation radiometer, measuring points coincide with the transient electromagnetic method. Each point records five times the data, whichever is the sum of the radioactive curves.

3.3. Results and Discussion:

After a series of processing of the collected data, the apparent resistivity profile and the radioactive curve are plotted.

1). Transient electromagnetic apparent resistivity profile Fig 3(a), we can see in the horizontal:

①. In the deep (-150~-50 m), for the whole area is relative high resistivity zones and resistance is basically the same.

②. In the deep(-600~-150 m), at 60~520 m , the apparent resistivity is high and reflects in 340~530 $\Omega \bullet m$, apparent resistivity is increased first and then decreased; At 60~520 m , the apparent resistivity profile shows low resistivity and reflects 130~260 $\Omega \bullet m$, apparent resistivity is decreased first and then increased, there is a local low-resistance anomaly; At 750~1770 m , the apparent resistivity shows a high and low resistance between the phases, which has two local low-resistance anomalies of 1290~1340 m and 1530~1710 m .

2). Radioactive α curve Fig 3(b), we can find three high points of 390 m ,600 m and 1610 m .

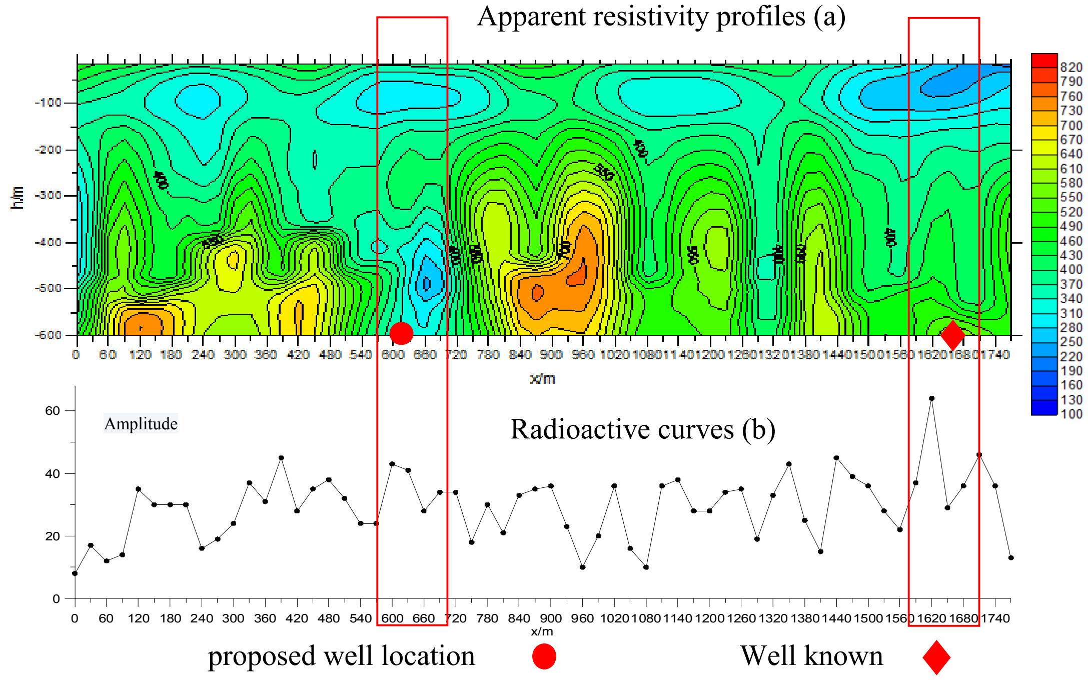

Fig. 3 Transient electromagnetic apparent resistivity profile and radioactive α curve

According to the apparent resistivity of the gradient zone and the location of the existing drilling data to estimate the drilling formation:

It shows relatively high-resistance of 0~110 m , according to the existing geological data of the layer is a loess layer and the water content of the loess layer is poor, the depth of the bedrock is about 120 m .

At 110~400 m , the apparent resistivity is relatively high-resistance. Its lithology is mainly grayish brown, dark gray limestone, medium thick layer of limestone, dolomitic limestone and dolomite, containing water is poor too.

Under the 400 meters, lithology is mainly gray, dark gray thick layer of gray dolomite and limestone. From the horizontal point of view, the apparent resistivity shows a high and low resistance between the phases, so the resistivity distribution in this section is not uniform, it has crack or fracture. Comparison of radioactive α measurement curve, there have the upward exception of 600 m and 1610 m . Based on the analysis of the transient electromagnetic and radioactive profiles, it is speculated that the anomaly is caused by the fissure development zones. Therefore, it is suggested that the well position should be arranged at the point corresponding to $600 \sim 630\,m$. Drilling was done at a later stage and drilled at a distance of $610\,m$, and its depth is $600\,m$.

4. Conclusion

1) Based on known hydrogeological information of the study area, selecting transient electromagnetic method for finding low-resistance anomaly, radioactive find structural fracture zone and fractured. Two results are compared to find water-rich area and determine the location of drilling, hydrogeology drilling confirmed water inflow of a single well can be up to $40\,m^3/h$.

2) Based on magnetic source transient electromagnetic theory of 1D forward shows: All-time apparent resistivity can eliminate "border effect" of the late-time apparent resistivity, and there is no ate high-resistance from early gate, it would better reflect the model of electricity. It was good for processing and interpretation of the large loop source work, and improving the interpretation of geophysical data accuracy.

3) Using comprehensive geophysical prospecting method can inhibit the multiplicity and improve work efficiency.

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