

The effect and application of "false extreme" in frequency-domain electromagnetic sounding

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Abstract—In frequency-domain sounding, "false extreme" phenomenon often appears in the apparent resistivity curve. Previous investigations focused on the subject without considering strata information containing in false Extreme. The use of false extreme effect is a new attempt to explain data. This paper analyzes the effect of false extreme value and its physical mechanism. The buried depth of subsurface structure of the North China coal has been determined using false extreme effect in apparent resistivity curve. Firstly, get the electromagnetic sounding curves corresponding to the false extreme effect over the borehole. Then, according to borehole logs, obtain the correlation coefficient between frequency points corresponding to the false extreme effect and burial depth of coal seam. Finally, based on the correlation coefficient, the buried depth of coal seam in entire survey area is evaluated. This method has been applied in northern area of Taiyuan, Shanxi, and achieved good results.

Keywords—false extreme; apparent resistivity

I. INTRODUCTION

The "false extreme" phenomenon in frequency domain electromagnetic method means that when the apparent resistivity varies suddenly from low value (or high value) to high value (or low value), it will go down first (or rise) and then continue to rise (or go down). "False extreme" phenomenon will disturb further resolution of deep strata and increase the change range of apparent resistivity curve^[1]. Geological information in "false extreme" can be extracted by a certain method^[2]. In this paper, we use "false extreme" effect to determine the buried depth of basal structure in north China type coal field through analyzing the "false extreme" phenomenon and its reason in frequency electromagnetic sounding curve. The buried depth of Ordovician interface can be determined by borehole data and characteristic frequency of "false extreme". The feasibility of this method is verified through exploratory application in northern survey area in Taiyuan, Shanxi.

II. "FALSE EXTREME" ANALYSIS

Fig. 1 is G-type curve of two-layer model and the parameters are: $\rho_1 = 1\Omega \cdot m, h_1 = 100m, \rho_2 = 10\Omega \cdot m$. Fig 1a and fig 1b have the same geo-electric sections. Fig 1a is G-curve of DC and fig 1b is G-curve of electromagnetic sounding.

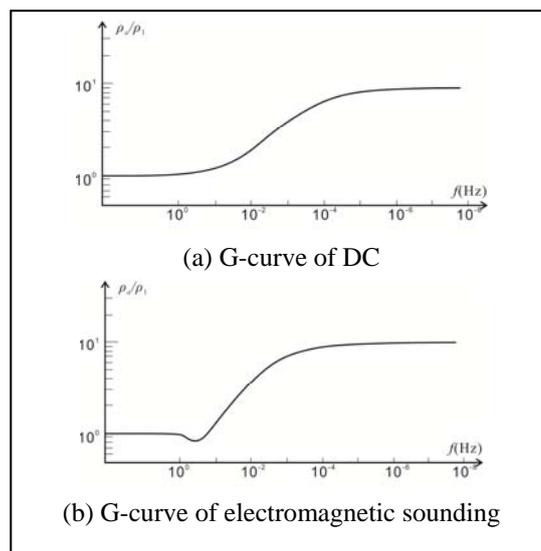


Fig. 1. G-curve comparison between DC and electromagnetic sounding

As shown in Fig.1b, we can see that first part of the curve is parallel horizontal axis and the apparent resistivity is equal to true resistivity of the first layer, which represents the far-zone field. But as the wavelength-depth ratio increases, the resistivity curve goes down before rise up. For the same geo-electric model, there is no "false extreme" phenomenon in sounding curve of direct current, shown in Fig.1a.

III. CASE STUDY

A. Overview of Survey Area

As shown in Fig 2, survey area is located in Yangqu County, Taiyuan, whose structure type is rifting basin. It is generally covered by Quaternary and the thickness is about 300 to 400 m. From old to new, the strata are: middle Ordovician, middle and Upper Carboniferous, and Permian Cenozoic. The main coal-bearing stratum is Taiyuan group of Upper Carboniferous. This group contains lower 15# coal seam whose thickness is about 1.45 m and 15# coal seam whose thickness is about 6.73 m. The basal strata are Ordovician limestone with high resistivity constituting standard electrical layer in this area. We use frequency-domain electromagnetic sounding with equatorial array, and the electric field component is observed, $r = 3,000$ m, $AB=1,000$ m, $MN=200$ m.

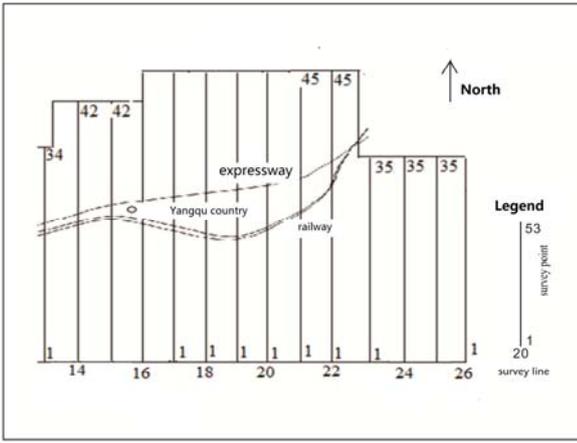


Fig. 2. Project layout

DP-1 digital frequency-measurement instrument developed in Xi'an is used. It contains two parts, transmitter and receiver. The largest supply current of transmitter is 10A and power supply is 8KW generator. The relationship between observation frequency numbers and square root of period is given as follow:

The characteristic period T_k can be obtained by observation frequency numbers f_k :

$$T_k = \frac{1}{f_k} \quad (1)$$

The square root of period, K can be obtained by characteristic period f_c :

$$K = \sqrt{T_k} \quad (2)$$

B. The Characteristic Period Parameters of Electromagnetic Sounding

The frequency-domain electromagnetic sounding curve at drilling ZP1 in the survey area was obtained. The apparent resistivity curve of different frequency at drilling ZP1 was also obtained (as shown in Fig 3). The ordinate represents apparent resistivity values measured at drilling ZP1, and the horizontal axis represents frequency numbers.

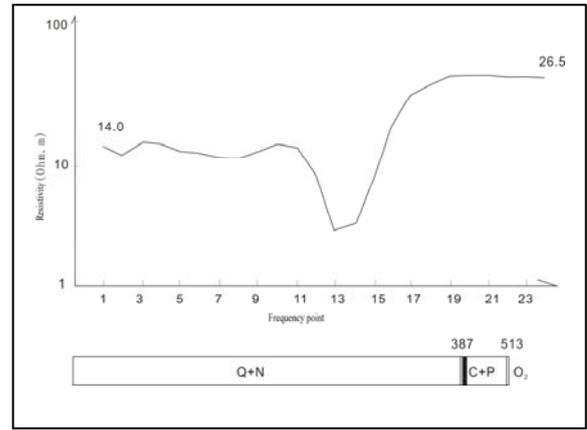


Fig. 3. The curve of apparent resistivity with frequency numbers and borehole logs above the drilling ZP1

Then we can determine the observation frequency numbers corresponding to minimum value of characteristic points in the curve. From TABLE I, its frequency value is $f_k = 43.8Hz$, square root of period is $\sqrt{T_k} = 0.151$.

TABLE I. OBSERVATION FREQUENCY NUMBERS AND SQUARE ROOT OF PERIOD

NO.	f_k	$\sqrt{T_k}$	NO.	f_k	$\sqrt{T_k}$
1	3956	0.0159	12	67.8	0.1214
2	2799	0.0189	13	43.8	0.151
3	1402	0.0267	14	30.5	0.181
4	982.7	0.0319	15	21.8	0.2141
5	699.8	0.0378	16	14.8	0.2559
6	489.5	0.0452	17	10.8	0.3029
7	349.3	0.0535	18	5.45	0.4283
8	244.9	0.0639	19	3.816	0.5119
9	174.5	0.0757	20	2.724	0.6058
10	123.4	0.0905	21	1.929	0.724
11	87.3	0.107	22	1.362	0.8567

C. Calculation Coefficient of the Buried Depth of Coal Seam of Drillings

We can get calculation coefficient of the buried depth of coal seam of drillings using characteristic period of electromagnetic sounding curve at drillings divided by buried depth of coal seam. From TABLE I, calculation coefficients can be calculated from characteristic period as follows:

$$M = \frac{\text{periodic square root}}{\text{buried depth of coal seam of drillings}} \times 10^7 = \frac{0.151}{387} \times 10^7 = 3901$$

Likely, calculation coefficients of the buried depth of other drillings can be obtained.

D. Calculation Coefficient Template of the Buried Depth of Coal Seam in All Survey Area

As shown in Fig 4, calculation coefficient of the buried depth of coal seam of drillings in rectangular coordinate is designed, where coefficient is the ordinate and the horizontal axis represents frequency numbers. According to the distribution trend of these coefficients in the coordinate system, we can get the relationship curve between buried depth of coal seam and square root of period, which is calculation coefficient template of the buried depth of coal seam in all survey area.

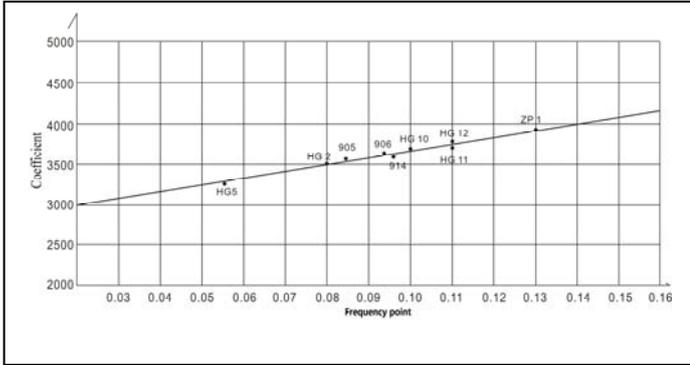


Fig. 4. Coefficient template of buried depth

E. The Buried Depth of Coal Seam at Any Point

For the sounding curve of any point in the survey area, square root of characteristic period corresponding to minimum value of characteristic point in the curve was got. Then we can get the calculation coefficients in calculation coefficient template of the buried depth of coal seam. The buried depth of coal seam at any point can be obtained through square root of characteristic period multiplied by corresponding calculation coefficient. Thus, the buried depth of coal seam at any point is calculated.

IV. CONCLUSION

"False extreme" is a common phenomenon in frequency domain electromagnetic method. In order to determine the detection depth, we use borehole data and "false extreme" characteristic frequency to determine the buried depth of Ordovician interface according to the characteristics of North-China type coal field. The feasibility of this method is verified through exploratory application in northern survey area in Taiyuan, Shanxi.

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