Layered soil exploration based on the time domain spectral induced polarization method

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Abstract. Soil stratification is the basic problem of soil development and utilization in the farmland, which can be used as a reference for later development and planting. Traditional soil stratification method is inefficient and needs to introduce new methods and techniques. In this paper, time domain spectral induced polarization method was introduced to carry out electric sounding exploration for the certain soil, and the observed data were processed and interpreted by using half-life time and deviation degree. The results show that the application of time domain spectral induced polarization method in soil stratification is feasible, and the half-life time and deviation degree are effective as interpretation parameters. The measured results and conclusions of this work can provide a basis for related research and the reference for relevant work.

1. Introduction

Soil stratification is an important problem. Effective soil stratification can provide useful information for later development and planting. At present, soil stratification depends on chemical testing methods. However, this method has low efficiency, long test cycle and high cost. On the other hand, the time domain induced polarization method, a kind of electrochemical exploration technology, can identify and distinguish the corresponding polarization anomalies by observing the induced polarization field generated by the electrons and ions, and has achieved good results in ore exploration and groundwater investigation. However, conventional time domain induced polarization method uses the polarizability and resistivity as the interpretation parameters. Due to the influence of complex geological conditions and low polarization properties of soil, the exploration effect is poor. As an important development technology of time domain induced polarization method, time domain spectral induced polarization method has higher stability and sensitivity [1], can be used as an alternative technology in exploration.

The time domain spectral induced polarization method is a kind of exploration technology to solve geological problems by observing polarization effects at different times and analysing the time-varying polarization state. The research for spectral induced polarization method began in the late 1970s, the observation instrument was successfully developed in the mid-1980s, and the series of methods and technologies were proposed for the processing and interpretation of time-varying observation data [2]. Since the 1990s, this technology has been successfully applied to the exploration of chemical pollution survey [3], landfill investigation [4] and underground water exploration, and achieved good results. In China, the research and development of time domain spectral induced polarization method is earlier, and certain scientific research achievements have been achieved in groundwater exploration [5] and metal exploration [6]. Relevant technical indexes and working experience have been summarized, and the time spectrum parameters have been elaborated in the national standard [7].
In this paper, the time domain spectral induced polarization method is introduced into the stratification of soil. The shallow electrical sounding was carried out on the farmland soil in the actual area, and the observation results were processed and interpreted by combining with the calculation of relevant time spectrum characteristic parameters. The results of this work can provide a reference for related work or research.

2. Time spectrum observation and data processing

2.1. Time spectrum observation
The work area is located in a mountainous area in the west of Shijiazhuang, Hebei Province, China. The soil in this area is relatively thin and mixed with sand and gravel. The work area as shown in the Figure 1. The instrument used in this work is the DZD-6 direct current induced polarization instrument. The sounding observation device as shown in the Figure 2, is a symmetrical quadrupole device. The current electrode distances AB are 2, 3, 4, 5, 6 and 7 meters, and observation electrode distance MN is 0.4 meters. The power supply current intensity is not more than 6 amperes. The charging time is 8 seconds, and the working cycle is 32 seconds. The 4 observation time channels are 0.2, 0.3, 0.5 and 0.92 seconds after power end. The observation parameters are time-varying polarizability and primary field resistivity. The 7 sounding points were observed with a distance of 10 meters.

2.2. Data processing
The main calculation parameters of time-varying characteristics for induced polarization field include half-life, deviation degree, Cole-Cole model parameters and decay rate. Assuming that the induced polarization field is in an exponential decay state, the half-life time refers to the time it takes for the induced polarization field to decay by half of the initial field, and the deviation degree refers to the
degree of the data in each channel to deviate from the exponential decay. These two explanatory parameters can well reflect the time-varying velocity of the induced polarization field, and do not involve multiple solutions, so they are widely used in time induced polarization exploration. In this paper, the parameters are used to characterize and interpret the time-varying characteristics of the observation field.

The half-life time $T^{\text{half}}$ calculation equation as follows:

$$T^{\text{half}} = \frac{t_N - t_1}{2.3 \ln \left( \frac{m_i}{m_N} \right)}$$

(1)

The deviation degree $D_d$ calculation equation as follows:

$$D_d = \left( \sum_{i=1}^{N} m_i / N \right)^{-1} \sqrt{\frac{\sum_{i=1}^{N} (m_i + K \ln t_i - B)^2}{N}} \cdot 100\%$$

(2)

Where, $m$ is the polarizability, $t$ is the observation time, $N$ is the number of observation channels, and $B$ and $K$ are the auxiliary calculation parameters.

3. Interpretation and results

Figure 3 shows the contour map of apparent polarizability and apparent resistivity. The ordinate is the depth and the abscissa is the measuring point. It can be seen from the figure that the apparent resistivity has poor stratification effect on the soil, with basically no identifiable horizontal layered structure, and an unidentified anomaly body appears at the point 103. After practical verification, it is believed that the anomaly is a false anomaly caused by poor grounding observation effect. Apparent polarizability has a certain feasibility on soil stratification, such as the horizontal layered structure at point 100, but the overall effect is still not obvious, especially the false anomaly at point 103.

Figure 4 shows the contour map of half-life and deviation degree, with ordinate as depth and abscissa as measuring point. It can be seen from the figure that the soil is basically layered, which is basically consistent with the actual situation. The characteristics of high half-life appeared at points 100 and 101, which was speculated to be caused by high soil moisture content. Through the actual drilling verification, it is confirmed that the two measuring points have a depth of about 1 meter to 1.5 meter below, and there is a sand and soil layer with high moisture content.
4. Conclusion
(1) It is feasible to use time domain spectral induced polarization method for soil stratification.
(2) The half-life time and deviation degree are effective and stable as the identification parameters of soil layer.
(3) The observation results of apparent resistivity and apparent polarizability are easy to be affected by the environment, so targeted treatment is needed to improve the work.

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References
[1] Liu, S. (1994) Spectrum induced polarization method. China University of Geosciences Press, Wuhan.
[2] Soininen, H. (1984) Inapplicability of pulse-train time-domain measurements to spectral induced polarization. Geophysics., 49: 826–827.
[3] Dahlin, T., and Leroux, V. (2012) Improvement in time-domain IP data quality with multi-electrode systems by separating current and potential cables. Near Surface Geophysics., 10: 545–565.
[4] Gazoty, A., Fiandaca, G., Pedersen, J., Auken, E., and Christiansen, A. V. (2012) Mapping of landfills using time-domain spectral induced polarization data: The Eskelund case study. Near Surface Geophysics., 10: 575–586.
[5] Li, J. M. (1988) A fundamental theoretical study of ground water prospecting by induced polarization method. Geological Publishing Houses, Beijing.
[6] Zhuang, M. S., and Shang, S. G. (1995) The effect of applying IP time spectrum apparent parameters to the appraisal of IP anomalies. Geophysical and Geochemical Exploration., 19(3): 218-223.
[7] Pelton, W. H., Ward, S. H., Hallof, P. G., Sill, W. R., and Nelson, P. H. (1978) Mineral discrimination and removal of inductive coupling with multifrequency IP. Geophysics., 43: 588–609.
[8] Sogade, J. A., Scira-Scappuzzo, F., Vichabian, Y., Shi, W., Rodi, W., Lesmes, D. P., and Morgan, F. D. (2006) Induced polarization detection and mapping of contaminant plumes. Geophysics., 71: B75–B84.