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Integrated interpretation of dual frequency induced polarization measurement based on wavelet analysis and metal factor methods

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Abstract: In mineral exploration, the apparent resistivity and apparent frequency (or apparent polarizability) parameters of induced polarization method are commonly utilized to describe the induced polarization anomaly. When the target geology structure is significantly complicated, these parameters would fail to reflect the nature of the anomaly source, and wrong conclusions may be obtained. A wavelet approach and a metal factor method were used to comprehensively interpret the induced polarization anomaly of complex geologic bodies in the Adi Bladia mine. Db5 wavelet basis was used to conduct two-scale decomposition and reconstruction, which effectively suppress the noise interference of greenschist facies regional metamorphism and magma intrusion, making energy concentrated and boundary problem unobservable. On the basis of that, the ore-induced anomaly was effectively extracted by the metal factor method.

Key words: dual frequency induced polarization method; wavelet analysis; metal factor; Arabian−Nubian shield; volcanogenic massive sulfide deposit

1 Introduction

The induced polarization method (including frequency domain and time domain induced polarization method) is a conventional geophysical methods, and widely used in the exploration for mineral resources [1−3]. Due to the non-ore induced polarization anomaly caused by carbonaceous rocks, regional metamorphism, cleavage zone and other complex geological structure, the induced polarization anomaly becomes more complex. The use of apparent resistivity and apparent polarizability (or apparent frequency) parameters is difficult to effectively represent the anomaly source. So, how to suppress non-mineral anomalies and to distinguish them from mineral anomalies becomes an important problem for the induced polarization during the exploration of mineral resources. As to induced polarization method, the geophysicist has proposed and developed a variety of approaches. KHESIN et al [4] proposed the rapid interpretation method, which resolved terrain correction, qualitative and semi-quantitative interpretation of polarizability anomalies through approximate procedures. SAEIN et al [5] put forward the concentration−volume fractal method to separate high and moderate sulfide zones from low sulfide zone and barren wall rocks in the deposit based on the induced polarization and resistivity. LI et al [6] proposed the concept and applied program of the morphological interpretation of induced polarization anomalies based on the study of morphological characteristics of induced polarization anomalies from a lot of data tested in field. WENG et al [7] used the normalized total gradient method to explain induced polarization with the purpose of obtaining space information on anomaly sources. However, these methods are limited on the premise of no greater interference, and the processed results of methods above can hardly achieve the desired results as to induced polarization anomaly of complex geologic bodies.

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work. Firstly, taking advantage of wavelet multi-resolution and Mallat fast algorithm, the induced polarization data are processed by selecting the appropriate wavelet base and decomposition scale, then decomposition and reconstruction of original induced polarization are proceeded, by which the complex geological noise interference is effectively suppressed. On the basis of that, the metal factor method is used to extract ore-induced information and distinguish it from other anomalies by weighting the polarization data after processing with apparent conductivity. The results show that the integrated interpretation method of the wavelet analysis and metal factor is an effective process method, which has a good guidance meaning in the application of geophysics with the complex geological structure.

2 Theory and methods

2.1 Dual frequency induced polarization

The induced polarization method is one of the geophysical exploration methods which take the electrochemical properties of rocks and minerals as the physical premise. Dual frequency induced polarization method is an innovative frequency domain induced polarization technology invented by HE [8,9]. The basic idea of the dual frequency induced polarization method is to superimpose two frequency square wave currents to form dual frequency combinations of current (low and high frequency) into the ground at the same time, to accept the potential difference information of the induced polarization total field from the ground floor consisting of two main frequency induced polarizations.

After a series of steps, such as the amplification of the inner instruments, the frequency selection and the detector, a low-frequency potential difference and high-frequency potential difference can be obtained at the same time [10,11]. The apparent resistivity can be calculated by

$$\rho_s = K\frac{\Delta V_G - \Delta V_D}{I} \tag{1}$$

and the apparent frequency is defined as

$$F_s = \frac{\Delta V_D - \Delta V_G}{\Delta V_G}\times 100\% \tag{2}$$

where ΔV_G is the high-frequency potential difference; ΔV_D is the low-frequency potential difference; I is supply current.

2.2 Wavelet analysis

2.2.1 Mallat fast algorithm

The wavelet transform which has the characteristic of multi-resolution is the time-scale (or time−frequency) analysis method of a signal, and it has the ability to characterize the local features of the signal in the two domains of time and frequency. So, it is a time−frequency localization analysis method with fixed window size but changeable shape and time−frequency window [12].

When $\forall f(t)\in L^2(R)$, continuous wavelet transform of $f(t)$ (sometimes refer to the integral wavelet transform) is as follows:

$$WT_f(a,b)=|a|^{-1/2}\int_{-\infty}^{\infty} f(t)\,\psi^*(\frac{t-b}{a})\mathrm{d}t, \quad a\neq 0 \tag{3}$$

where a is the scale factor; b is the translation factor.

Inverse transformation (recovery signal, or the reconstruction of the signal) is written as follows:

$$f(t)=C_\psi^1\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\psi_{a,b}(t)WT_f(a,b)\mathrm{d}b\frac{\mathrm{d}a}{|a|^2} \tag{4}$$

In practical work, in order to use the Mallat pyramid fast algorithm, we use discrete wavelet transform mostly in the form of orthogonal wavelet transform, which requires the selected wavelet to be orthogonal wavelet. Selecting orthogonal wavelet to conduct discrete transform can avoid the redundancy of continuous wavelet transform. So, we can greatly reduce the amount of calculation without losing the original signal.

Any function $f(x) \in L_2(R)$ can be perfectly reconstructed according to the resolution 2^{-N} of the low-frequency section (approximate part) and the resolution $2^{-j}(1\leq j\leq N)$ of the high-frequency section (detail section). Multi-scale analysis is only on further decomposition of the low frequency part regardless of the high frequency part [13]. The specific decomposition relation is

$$f(x)=A_n+D_n+D_{n-1}+\cdots+D_2+D_1 \tag{5}$$

where $f(x)$ is data signal; A is the approximate low-frequency part; D is the high-frequency details section; n is the decomposition scale.

2.2.2 Selection of wavelet base and scale

With the development of wavelet theory, various wavelet bases are developed to meet the need of different industries. In general, each kind of wavelet base has different forms and functions, and all meeting the wavelet conditions can be used as wavelet base function. Some famous wavelet bases have Daubechies, Symlets, Coiflets, Morlet and Meyer etc [14,15]. In practice, the selection of wavelet base usually follows three principles [16]:

1) The self-similarity principle. For binary wavelet transform, the choice of wavelet base should have certain similarity with signal, the energy relatively concentrated after transforming, which can effectively reduce the computation cost.

2) The discriminant function. The discriminant