Application of wavelet multi-scale analysis in the separation of aeromagnetic data potential field

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Abstract. The aeromagnetic data obtained in the field is a comprehensive reflection of all geological bodies in the ground. When interpreting and inferring a field in different depths, it is necessary to separate the anomalies. As a widely used mathematical transform, wavelet transform introduces the concept of multi-scale analysis, which can effectively separate the aeromagnetic anomalies, clearly reflect the abnormal forms in different depths, and effectively improve the recognition accuracy of aeromagnetic data and provides a solid foundation for the processing and interpretation of aeromagnetic data.

1. Introduction
In the actual aeromagnetic measurement process, the aeromagnetic data obtained through various basic correction processing is a comprehensive reflection of all media subsurface [3]. In the interpretation of local anomalies in aeromagnetic data, it is necessary to analyze the anomalies at different depths [5], and then infer the distribution of media subsurface at different depths. This requires the separation of aeromagnetic anomalies. There are many commonly used separation methods, such as upward continuation, trend analysis and interpolation cutting [1]. Of varied methods, Wavelet transform can decompose aeromagnetic signals into different channels and frequencies or different scale components with its unique characteristics of multi-scale analysis. And it obtains perfect effect of magnetic field separation.

2. Wavelet transform
As a new transform analysis method, wavelet transform is originated from Fourier transform [4]. It inherits the advantages of Fourier transform and overcomes the disadvantages of window size not changing with frequency. Wavelet transform can provide a "time-frequency" window changing with frequency [6], and has the ability of multi-scale analysis. It is an ideal tool for signal time-frequency analysis and processing.

At present, wavelet transform has achieved perfect application effect in many fields. Taking geophysics as an example, wavelet transform plays a huge role in the data denoising process of seismic exploration, magnetic prospecting, etc.

2.1. Introduction to Wavelet transform
The main feature of wavelet is that it can fully highlight the characteristics of some aspects of the problem through transformation, it can analyze the time (space) frequency localization, and gradually refine the signal (function) through the expansion and translation operation, and finally achieve the time subdivision at high frequency and the frequency subdivision at low frequency, which can automatically adapt to the requirements of time-frequency signal analysis, so as to focus on any signal. For example, wavelet transform effectively overcomes the weak point of Fourier transform in the processing of signals with spikes and mutations.

There is a known function $f(x) \in L^2(R)$, and the wavelet transform of the function can be expressed as follows [2]:

$$W_f(a, b) = \langle f, \varphi_{a,b}(t) \rangle = |a|^{-\frac{1}{2}} \int_{-\infty}^{+\infty} f(t) \overline{\varphi\left(\frac{t-b}{a}\right)} dt$$

In the formula (1), $\varphi_{a,b}(t) = |a|^{-\frac{1}{2}}\varphi\left(\frac{t-b}{a}\right)$ is the definition of wavelet. Where $a$ is the scale parameter and $b$ is the displacement parameter. The inverse wavelet transform formula corresponding to formula (1) is:

$$f(t) = C_a^{-1} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} W_f(a, b) \varphi_{a,b}(t) \frac{da}{a^2} db$$

2.2. The Principle of Wavelet multiscale analysis

Wavelet multi-scale analysis is also called multi-resolution analysis. For the discrete sequence signal $f(t) \in L^2(R)$, its wavelet transform adopts Mallat fast algorithm, and after the decomposition of the signal scale by $j = 1, 2, ..., J$, we get the orthogonal subspaces in $L^2(R)$ which is $\{W_1, W_2, ..., W_p, V_r\}$, where $A_j \in V_j$ represents the approximation part of $j$ scale, and $D_j \in W_j$ represents the detail part. Then the signal can be expressed as $f(t) = A_j + \sum_{j=1}^{J} D_j$, according to which the function can be reconstruct-ed by the approximation part of multiscale $j = J$ and the details of $j = 1, 2, ..., J$.

Wavelet transform introduces the idea of multi-scale analysis, which has good local analysis properties in both spatial domain and frequency domain. Wavelet transform can decompose the signal into various frequency or scale components (Zeng, 2015), and analyze it by focusing on any detail of the signal. These characteristics of wavelet analysis determine that it is an effective tool for geophysical numerical analysis. Using the above characteristics of wavelet transform, we can decompose the magnetic anomalies and get the characteristics of magnetic anomalies in different depths.

3. Aeromagnetic data processing

According to the principle of wavelet transform multi-scale analysis, the aeromagnetic data of Xiaoqinling gold field in Shanxi province are decomposed in multi-scale. Xiaoqinling gold field is a famous gold metallogenic area, it has successively built several gold mines, such as Tongguan xitongyu gold mine, Dongtongyu gold mine, Xiaokou gold mine, etc.

The scale of aeromagnetic data is 1:25000. The survey area starts from the Patrol Road fault in the South and ends at the Piedmont fault in the north. The East and west sides are bounded by Wenyu rock mass and Huashan rock mass. It is 40km wide from the east to the West and about 16.7 km from the south to the North. The total area of the survey area is 667 km². The distance between aeromagnetic data points is less than 5 m. It also has a good response to small abnormal bodies.

3.1. The geological, mineral and aeromagnetic characteristics of the work area

The working area is located on the second-class structural unit of the North China block in the southwest margin of the North China plate. It spans two third-class units in the south margin of the Ordos block and the North China block, involving three fourth-class structural units in the Weihe Fault Depression Basin, Taihua fault uplift and the thrust fold belt in the south margin of North China. Taihua ancient continental core is composed of Taihua Group of basement, and the caprock is Proterozoic.

Taihua Group is the source bed of gold deposits in this area. After the formation of Taihua Group, it has experienced multi-stage tectonic thermal events, accompanied by multi-stage metamorphism. The basement structure framework was formed in pre-Jinning period, and regional metamorphism occurred...
in Jinning and Caledonian periods, accompanied by the activation, migration and enrichment of gold, which provided some material sources for gold mineralization in the area. In the late Indosinian Yan-shanian period, large-scale magmatism not only transformed the gold-bearing quartz vein but also formed new gold-bearing quartz vein and structural altered rock type gold deposit. Therefore, the distribution of the Taihua Group, especially the dayuanping group, and the occurrence form of the concealed rock mass are important indicators of regional prospecting.

3.2. The aeromagnetic characteristics of work area
Through this 1:25000 high-accuracy aeromagnetic survey, we have obtained the rich magnetic field information of this area which are the comprehensive reflection of different tectonics, magmatic activities, stratigraphy and lithologic distribution areas.

As shown in Figure 1, there are three main reasons for the formation of aeromagnetic anomalies in the survey area: the first one is the positive anomaly of moderate strong fluctuation caused by acid rock mass, which is mainly distributed in Wenyu rock mass area to the east of Xiyu, Huashan rock mass area to the west of Duyu and the distribution area of Proterozoic granites in the southeast and southwest corners of the survey area. The second one is the weak~strong complex magnetic anomaly caused by metamorphic rock of Taihua Group, which is mainly distributed in the area between the Piedmont fault and the Patrol Road fault. The third is the low and gentle negative anomaly caused by the Changcheng System shallow metamorphic sedimentary rock, which is mainly distributed in the south of the fault.

![Figure 1. Xiaoqinling gold field aeromagnetic ΔT anomaly map](image)

3.3. wavelet multiscale decomposition
The processing data is 1:25000 aeromagnetic data. Kriging method in surfer software is used to grid the data. The grid spacing is 50 m * 50 m. After daily variation correction, height correction, lag correction and leveling processing steps, the data is corrected to the elevation of 1536 m. The field separation of the aeromagnetic data is carried out by wavelet multi-scale decomposition. Figure 2 is the detail map of 1-4 order wavelet of aeromagnetic ΔT anomaly in Xiaoqinling gold field. Figure 3 shows the fifth order wavelet details.

![Wavelet decomposition](image)
According to the results of wavelet multi-scale analysis in Fig. 2 and Fig. 3, the amplitude range of the first-order wavelet anomaly is the smallest. According to the results of the logarithmic power spectrum of the first-order wavelet analysis, the depth reflected is 96 m, which is mainly affected by the noise of the shallow surface and the data itself. Due to the advantages of the aeromagnetic data itself, the point spacing is small and the amount of data is large, which has a great impact on the good resolution of shallow abnormal bodies. According to the results of the log power spectrum of the second and third-order, the depth of the field source is 218 m and 424 m respectively. The results of the fourth and fifth-order reflect a deeper depth and a larger range. The depth of the fifth-order detail has reached 1340 m. It has a good description of the deep concealed rock mass, which is conducive to the analysis of the deep metallogenic factors.

Wavelet multi-scale analysis can cut the original aeromagnetic data into parts with different depth interfaces, which can perfectly reflect the distribution of the stratigraphy of Taihua Group in the deep part of the area. For example, in the northwest of Wenyu rock body and the back part of the Piedmont fault, according to the results of wavelet multi-scale analysis of order 1-5, combined with the actual geological survey results, it shows that the stratigraphy of Taihua Group extend to the deep part. Since the stratigraphy of Taihua Group is the main source for the mineral in the area, it is of great significance to determine the distribution of Taihua Group in the deep.

3.4. The effect comparison of other abnormal separation methods
Since the deep reflection of the wavelet fifth order decomposition, the result of wavelet fifth order approximation is taken as the region field, and the local field result is obtained by adding the above wavelet detail results. Take the aeromagnetic data from the southeast corner of the work area and Xiaohe rock mass, and compare the effect of other methods in separating local field and regional field in aeromagnetic data.
In addition to the wavelet multi-scale analysis, trend analysis and difference field are also used to separate the abnormal field of aeromagnetic data. According to the results in Figure 4, the three methods have similar separation effect for the abnormal field, and the obtained magnetic anomaly shape and amplitude range are close. The advantage of wavelet multi-scale analysis is that it can decompose the aeromagnetic data according to different depth, and it is convenient to study the distribution law of aeromagnetic data form and magnetic body in different depth range.

4. Conclusions
Wavelet multi-scale analysis method has a good effect of anomaly field separation. With the increase of order, the depth of its reflection is gradually deepened, and the size of the anomaly body is gradually increased. At the same time, wavelet multi-scale analysis method provides slice display of different depth magnetic field.

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