

Gold Ore Body Exploration Using Correlation coefficient of Analytic Signal to Magnetic Prospecting Data

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Abstract

In the exploration of gold ore body, magnetic prospecting is effective in elucidating the geological structure influenced to mineralization, but it is affected by several factors such as remanent magnetization of the surrounding rock mass. The analytic signal is insensitive to magnetization direction in 2D, so it is widely used to detect the boundary of magnetic source. Recently, a method using correlation coefficient of the analytic signal of real data and model data by assumed source has been proposed for the interpretation of magnetic data. To calculate the magnetic anomaly of the assumed model, it is necessary to know the structural index, which is information about the type of source. We propose a method using the correlation coefficient of analytic signal of measured data (ASSMD) directly on known orebody in the deposit area, rather than the assumed source, and apply it to real data to clarify the distribution of gold orebody.

Keywords: gold exploration; magnetic prospecting; correlation coefficient; analytic signal.

Original Research Article

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1. Introduction

Magnetic prospecting is the oldest method of geophysical exploration and is widely used method in mineral exploration (Nabighian et al., 2005). Magnetic prospecting is the primary prospecting tool for mineral exploration. Magnetic prospecting is now extended to wide range of geological problem, such as the locating of fault, outlining contact of lithofacies, as well as the exploration of various minerals such as iron, gold, copper, molybdenum, etc. With the use of high-sensitive modern magnetometer and GPS, the analysis of magnetic prospecting data has undergone qualitative change, and the interpretation method starting from simple graphical method have recently been widely used, practically used with high-resolution, high-speed, and 2D and 3D magnetic imaging technique. Magnetic

prospecting uses variation in the rock composition and magnetic anomaly that can be produced in the rock structure (Nabighian et al., 2005).

Magnetic method consists of data collection, data processing and data interpretation. Map of magnetic prospecting data are often used to identify anomalous area that may be associated with geological structure or object of interest. Data interpretation provides a more quantitative estimation for magnetic characteristics as well as the simple spatial location of anomalous source (Nabighian et al., 2005).

In mineral exploration, magnetic prospecting is often used to explore magnetic mineral directly, but it is also useful to identify the magnetic anomaly that is relative to non-magnetic mineral symbiosed with magnetic mineral and to explore the associated useful mineral (Eldosouky, 2023). Magnetic anomaly may



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be positive or negative depending on the difference in magnetization and magnetic susceptibility.

The main object of magnetic prospecting in mineral exploration is to evaluate the susceptibility contrast and remanence characteristics of vein and rock hosting mineral vein, with particular emphasis on the relationship between the magnetic property, metamorphism and mineralization product of the causative body. In magnetic prospecting, the quality of the interpretation is affected by not only the induced magnetization but also the remanent magnetization (Jinpeng et al., 2017). This cause the interpreted result that is the depth and the location of the geological boundary, is different from reality. Therefore, in the interpretation of magnetic prospecting data, the estimation of the location of the geological boundary, which is not affected by the direction of magnetization, is an important problem that must be solved. The extensive investigation and wide study of magnetic prospecting apply to prospecting for various orebodies and valuable minerals (Gang Sop et al., 2014). Aeromagnetic prospecting data used to evaluate the relationship of structure and the deposit and to determine the depth and geometry of the magnetized ore body (kumar et al., 2020). The high magnetic anomaly reflects metavolcanic and mafic rock, and the subsurface magnetic distribution clearly distinguishes mineralized alteration zone. The location of most gold deposit is either positive magnetic anomaly or negative magnetic anomaly of RTP, and at their boundary. The study is carried out to reduce the influence of the magnetization direction, along with the evaluation of the deep extension of the orebody, the classification of hydrothermal alteration zone, and the susceptibility imaging for the detection of geological structure. The shape of the magnetic anomaly depends on the geometry of the causative body, the susceptibility, the magnetization intensity, the declination and inclination of the normal geomagnetic field, etc. Due to the large number of factors affecting the shape of the magnetic anomaly, the location of the anomalous body is not obtained by a simple procedure. To simplify the anomaly form propose a mathematical method called reduction to pole (Nabighian et al., 2005). This method transforms the measured anomaly into a normal field with both

magnetization and normal field. That is, the measurement is transformed as done at the magnetic pole. The reduction to pole result in the symmetry of the asymmetry, which is caused by the direction of the magnetization, and the presence of an anomalous body in the center of the magnetic anomaly profile and the contour map. This method requires information about the direction of the magnetization, often assumed to be parallel to the normal field. This is based on the assumption that the remanent magnetization intensity is negligible or parallel to the normal field. If not so, the reduction to pole operation produces unsatisfactory result. The reduction to pole is now applied usually for all data except for those obtained in the high latitude region.(Nabighian et al., 2005) The reduction to pole operator becomes unstable in the magnetic low-latitude region. This is because the singularity appears when the magnetic orientation and the magnetic inclination of the object approaches zero. To overcome this problem, numerical method propose. A method of converting the measured anomaly at low latitude into the equator rather than the pole, which can overcome instability but has the disadvantage of difficulty to interpret the anomaly shape. All these method assume that the direction of magnetization intensity and normal field do not change over the entire research area.

In addition, the combined application of magnetic prospecting and other geophysical prospecting method for gold deposit prospecting is widely applied. Eldosouky et al. (2023) reports a combination of various geophysical methods, including gravity, magnetic and magnetotelluric method in mineral exploration. Li et al. (2023) performs high-precision magnetic prospecting, induced polarization method, transient electromagnetic method in gold ore body, applied to the explain of relationship between metallogenic structure and gold deposit, and report good result for deep-geology solution. Atta (2023) introduces the result of the application to large-scale gold ore exploration, indicating that the general correlation of the ternary image of radioactive data with the gradient of aeromagnetic data such as analytic signal, vertical gradient, and horizontal gradient is a tool for geological mapping. Farquharson et al. (2020) reports that the result of using aeromagnetic and frequency

domain electromagnetic survey data to investigate rock mass related to gold ore deposit, to confirm the magnetic susceptibility distribution of the iron ore layer, overcoming the influence of magnetic orientation. Olisa et al. (2022) applied aeromagnetic and radiometric survey to find the rock structure and hydrothermal alteration zone associated with gold ore body. Filtering method to identify possible ore-body boundary that satisfy the geological condition of gold ore-body formation, reveal that high magnetic anomaly directly reflect fault, fragmentation zone, and lens of new deposit. Alejolowo et al. (2021) considers the contour map of aeromagnetic anomaly and point out that the derivative anomaly reflect the structure of hydrothermal fluid and that it is effective in regional study to find object in area where orebody is unknown. Techniques such as reduction to the equator, upward continuation, total horizontal derivative, analytic signal, source edge detection and tilt-angle derivative of total horizontal derivative are applied to the interpretation of magnetic prospecting data.

Magnetic prospecting combined with geological survey in the exploration of gold deposit is a useful method for improving the efficiency of gold deposit exploration and for elucidating metallogenic structure. In general, the best way to solve the ambiguity in interpretation of geophysical prospecting data is to use of prior information such as geological survey data, within the limit of the possible as much as possible. Combining geology data, structure distribution and borehole data with magnetic or gravity data is a useful tool for improving the resolution of granite-related resource exploration and for increasing exploration depth. Magnetic prospecting combined with geological survey is the main tool in finding the most productive gold deposit historically and has been successfully used to explore kimberlite rock containing diamond. Since the intensity of magnetic field varies with different condition associated with the geological environment, even in the same orebody present in a rock mass, it is difficult to interpret the elongation of the gold ore body with only a single usage of the magnetic anomaly contour map. Hence, many filtering techniques based on susceptibility contrast and remanence have been proposed. The proposed

methods are effectively applied to the separation of the edge, structure, boundary and other geological feature of magnetic source (Elkhateeb et al., 2016; Eldosouky et al., 2021). High-speed analysis method are widely used in potential field data interpretation (Keating et al., 2004; Phillips, 2000) and this method have been originally investigated to locate the horizontal position of geological boundary such as rock outline, fault, etc. Since the 1970s, several semi-automatic methods based on the use of gradient (derivative) of magnetic field anomaly have been developed to determine the geometrical parameter such as the boundary position and the depth of the causative body (Nabighian et al., 2005). A number of modern approaches to estimate boundary and depth to the source are based on horizontal and vertical derivative. It can be seen from many study that the position of the maximum horizontal gradient amplitude in gravity data as well as in magnetic data is the boundary of the source. Blakely et al. (1986) proposes a useful method to automatically find the position of the maximum value of the horizontal gradient amplitude and Thurston et al. (1994) develops a convolution operator to control the frequency component of the horizontal derivative to detect the boundary. To determine the boundary of the source, a moving window approach and improved horizontal gradient method to detect change in the horizontal gradient direction proposes (Fedi et al., 2001). The horizontal gradient emphasizes the weak anomaly feature and directly reflects the boundary position. The main advantage of the horizontal gradient method is its ease of use and stability against noise (Phillips, 2000; Pilkington et al., 2004). The disadvantage is that the edges are steep or close to each other (Phillips, 2000), and the higher order of gradient calculation result in a greater influence of the disturbance involved in the observation. To correct the drawback of overlaying gradient of the short wavelength anomaly and the long wavelength anomaly, Grauch et al. (2002) develops a windowed approach to distinguish the local gradient from the regional gradient. Analytic signal method is a common method widely used for the interpretation of magnetic anomaly (Keating et al., 2004; Nabighian, 2005; Phillips, 2000). The analytic signal method is a method for detecting the boundary location of the

magnetic body. Among the methods for detecting the boundary of a source, analytical signal method is recognized as the basic method with horizontal gradient method, which gives an interpretation result independent of the influence of the magnetization direction in two dimensions (Nabighian, 1972). The application of analytic signal technique to 2D magnetic anomaly interpretation proposed by Nabighian (1972), and later developed by Pedersen et al. (1997). In the profile data of the magnetic anomaly, the horizontal and vertical derivative in principle correspond to the real and imaginary part of the complex analytic signal (Nabighian, 1972). The amplitude of the analytic signal define as the square root of the sum of the square of two orthogonal vertical and horizontal derivative of the magnetic field, where the horizontal and vertical derivative of the magnetic field are the Hilbert transform pair above a two-dimensional source. In two dimensions, the amplitude of the analytic signal is equal to the full gradient amplitude value, independent of the direction of magnetization, and represents the total (sum) of the vertical and horizontal derivative in the direction of the sum of the geomagnetic field and magnetization of source (Nabighian, 1972). An automatic method for magnetic dike parameter using analytic signal technique is proposed and the possibility to apply analytic signal to environmental magnetic exploration is reported by Salem et al. (2002). Guoqing et al. (2013) proposes a method that directly uses the analytic signal of magnetic anomaly to calculate the depth and the structural index of the source. The amplitude of the analytic signal of the magnetic anomaly can be easily calculated. Horizontal derivative can be calculated directly from the total field grid data using a simple filter, and horizontal and vertical gradient can be calculated in the frequency domain using the conventional Fast Fourier transform (FFT) technique. To apply the analytic signal method to the interpretation of magnetic anomaly, some assumptions about the type of source are required. The geometry is usually assumed to be two-dimensional magnetic source such as step, contact, horizontal cylinder or dyke. The factor that reflects the shape of the magnetic body is the Structural Index. The shape of the amplitude of the analytic signal on such a geological body is a bell-

shaped symmetrical function located directly on the source body. The analytic signal approach has been successfully used in the form of cross-sectional data to locate the position of dike (Nabighian, 1972). Unlike the two-dimensional case, the analytic signal in three dimensions is dependent on the direction of the magnetization (Haney et al., 2003). The main advantage of the analytic signal is that it is independent of the slope of dike and the direction of the magnetization, at least in two dimensions. The method used to determine the edge detection of a magnetic body using a peak of horizontal gradient can also be applied to the determination of the peak of the analytic signal. Source Parameter Imaging (SPI) is a method for determining the parameter of the source boundary position, depth, tilt angle, magnetic susceptibility contrast, etc. from homogeneous grid data based on complex analytic signal (Nabighian, 2005; Phillips, 2000). Pilkington et al. (2004) suggests that the horizontal and vertical local wavenumber is equal to the normalized vertical and horizontal derivative of the amplitude of the analytic signal, respectively. Thurston et al. (2002) proposes that the local wavenumber is another function with a maximum value on the boundary of the magnetic body. The full expression for calculating the three-dimensional local wavenumber is complex and tends to produce noisy result (Huang et al., 2000). Considering only the effect of a two-dimensional source, much better result obtains (Phillips, 2000; Pilkington et al., 2004). Like the analytic signal, the local wavenumber exhibits a maximum on the boundary of isolated source, regardless of the dip, geomagnetic latitude, magnetization direction, and type of source. As above, the reduction to pole, analytic signal method and source parameter imaging method is signal transformation method to solve the problem of the influence of the magnetization direction in the interpretation of magnetic anomaly, and convert the observational anomaly into a simple type of anomaly independent of the magnetization direction.

Recently, attempt have been made to improve the efficiency of detection of geological boundary by using a combination of signals, beyond the step that have been taken to use only the individual transformation signal (Düzgüt, 2006; Fregoso, 2015).

To increase the efficiency of the interpretation, method using the correlation of geophysical anomaly propose. At first, correlation coefficient used to represent the correlation of gravity and magnetic anomaly in the study area (Bahía, 2024), which helps to take advantage of each method reflecting different property and to present useful result in the interpretation of physical prospecting data, supplementing the shortcoming. Baghzendani et al. (2021) proposes that combining more geophysical data to reduce the ambiguity in the interpretation, and the high correlation between magnetic susceptibility and density in the horizontal and vertical direction is a good correlation with the average physical parameter in the iron-gold deposit. Gilmanova et al. (2022) performs geophysical modeling based on magnetic and gravity data in gold-copper-sulfide ore body and interprets the structure to identify the partial zone of mineralization. Khalil et al. (2023) introduces a method of combining the well-known magnetic field in the gold ore-body region with the magnetic field in the new gold ore-body region, and reports that combining is useful method for gold ore-body survey. And then, a method to rapidly detect the ore body in the absence of outcrop on the surface was investigated. Hongfei et al. (2021) introduces new result of the discovery of gold and some mineral deposit using airborne electromagnetic and aeromagnetic data in shallow-buried mineral exploration, and reports that object can be found quickly in the absence of outcrop on the surface.

A typical study using correlation is then the method using correlation of the analytic signal (Guoqing et al., 2013). To estimate the structural index and depth of a two-dimensional source, a method using the correlation coefficient between the analytic signal of real data and the analytic signal of model data by the assumed source was proposed (Guoqing et al., 2013). Assuming that the source is at different location in the subsurface and the structural index of the assumed source varies from 0 to 3, the correlation coefficient of the measured and the above analytic signal by each assumed source is calculated individually. The correlation coefficient has a maximum when the structural index and location of the assumed source coincide with the actual source. It is found that this method can successfully be solved the inverse

problem of magnetic prospecting data, and it is proved that the location of the source and the structural index can be obtained to effectively resolve the location of the geological boundary. In this paper, we present the result of the correlation between the analytic signal data (standard data) of the magnetic prospecting data measured on the actual ore body and the analytic signal of the magnetic data by means of general measurement to improve the efficiency of the interpretation of the strike-extension of the ore body in the exploration of gold ore body.

2. Methodology

2.1. Geological setting

The study area is tectonically located on the northwestern margin of the Tokchon-Maengsan Shimbun, the South Phyongan Valley. The study area includes the migmatite, gneiss and the biotite granite of the Early Archean Rangnim Formation (Mansik et al., 2011). The ore body is a gold-bearing sulfide quartz vein, which is located in the fragmentation zone in the gneiss of the Rangnian Formation and the biotite granite of the Linvolcanic Formation. There is a Tanchon Rock intrusion at a point 2.5 km north of the area. The fault structure is dominated by the northeast-like fracture and there are some northwest-oriented faults. Along some faults of the northeast series, granitic and quartz porphyry dike is injected. The rock hosting the orebody is severely fractured by the NE-trending fragmentation zone, Orebody forms along the crevice. The orebody strike 40-50° and slop 60-80° to the north-west. The strike length of the orebody is 1.2 km. The relative variation in thickness of the ore body is serious. The outcrop is 0.6-1.5 m thick, but becomes thicker as it goes down to the depth. Gold ore body of the deposit is of the quartz-gold-iron sulfide type. The quartz-gold-iron sulfide ore group mainly consists of pyrrhotite, arsenopyrite, pyrite, natural gold and galena. The ore contains various elements such as Au, Ag, Pb, Zn and so on. Arsenopyrite is a good ore mineral with good gold content and formed in the gold-bearing sulfide stage with pyrite. Later in the mineralization stage, quartz became quartz vein containing metallic mineral and native gold-quartz vein containing native gold. The country rock is silicified, sericite-chlorite and

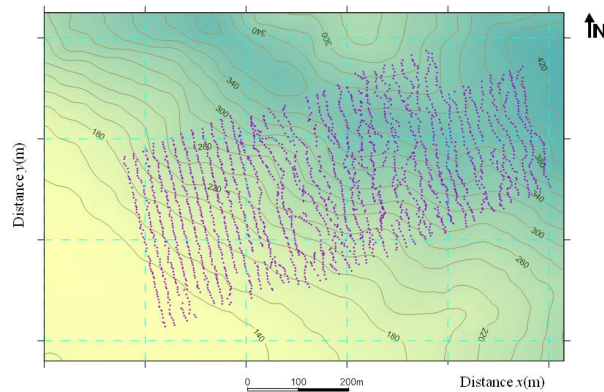
aluminolithic. The deposit in the study area is a polymetallic-gold hydrothermal deposit formed under mesohypogenic-mesothermal condition.

2.2. Magnetic data

The magnetic field strength in the study area measure by a G-856A proton magnetometer. In

magnetic field survey, the distance between the main profiles is 20 m and the measuring point interval is 5 m. An area survey is conducted throughout the exploration area and additional exploration lines are placed near the ore body to increase the network density. Fig. 1 shows the distribution of the magnetic measurement points.

Fig. 1. Map of the magnetic measuring points



The magnetic prospecting data are processed and interpolated with grid data spacing 5 m. Data process perform using MagPick 3.25 of Geometrics and a contour map draw using Surfer 12.7 of Golden Software. The magnetic anomaly is obtained from the total magnetic intensity measured in the study area. IGRF is used to distinguish the magnetic anomaly. The result obtained by Magpick\Inverse\IGRF model of Geomatics is $T_0=52350.59$ nT, $I_0=57.8^\circ$, and $D_0=-8.6^\circ$. The observed total magnetic intensity is subtracted from T_0 to abstract the magnetic anomaly and then the analytic signal AS is calculated. Since the analytic signal is independent of the magnetization direction

in two dimensions, it can be used in the presence of remanent magnetization. Analytic signal method is widely used for the interpretation of real magnetic data (Nabighian, 1972; Nabighian et al. 2005; Phillips, 2000). The amplitude of the analytic signal is directly related to the position parameter of the anomalous body. The amplitude of the analytic signal is maximum on the boundary of the magnetic source (Guoqing et al., 2012). To calculate the amplitude of the analytic signal $AS(x, z)_i$ of the magnetic anomaly data $T(x, z)_i$ obtained at the field station $(x, z)_i$, we must first obtain the horizontal and vertical gradient(Nabighian, 1972).

The 2D analytic signal (AS) of the magnetic anomaly T can be written as (Nabighian, 1972) :

$$|AS| = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2} \quad (1)$$

Where $\partial T/\partial x$, $\partial T/\partial z$ are the horizontal and vertical gradient of the magnetic anomaly, respectively.

The 2D analytic signal of a magnetic source located at the horizontal position x_0 and depth z_0 can be written as (Guoqing et al., 2013);

$$AS(x, z) = \frac{k}{\left[(x - x_0)^2 + (z - z_0)^2 \right]^{(N+1)/2}} \quad (2)$$

Where k is a constant value (amplitude factor associated with the magnetization of the source), N represents the structural index of the source, $N = 0$ at the contact, $N = 1$ at the vertical dyke, $N = 2$ at the horizontal cylinder, and $N = 3$ at the dipole.

The analytic signal is a bell-shaped symmetry curve with a maximum on the boundary of the source and is not affected by the direction of magnetization. This approach can highlight anomaly in individual cross sections, but it is possible to calculate the analytic signal by knowing the structural index of the source in advance. The contour map of the analytic signal obtained in the study area using Magpick\Operations\Gradients\Analytic Signal is shown in Fig. 2. The high

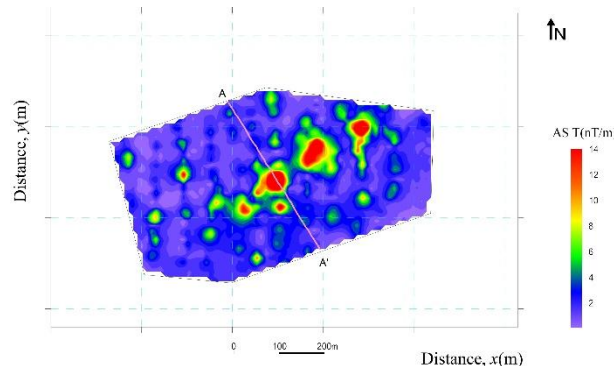


Fig. 2. Contour map of AST

Value of AS reflect the geological structure. High AS value reflect the strike extension of the NE tectonic zone, but the continuity is poor and the magnitude of the anomaly is large, making it difficult to determine accurately the horizontal boundary position of the structure. And in the southwest extension direction, it is difficult to locate the correct structure due to the dispersion of anomaly value

2.3. ASSMD Method

The outcrop of the ore body in the study area is only present at some point and is covered by overburden in many parts. The correlation of the analytic signal (Guoqing et al., 2013) is used to determine the horizontal position of the orebody under overburden. The analytic signal reflects the

boundary position of the anomalous body, but there is some difficulty in identifying the small change that involve the background field, because the intensity of the analytic signal varies with decreasing or increasing intensity of the observatory anomaly.

The correlation of the analytic signal is superior to emphasizing anomaly by standard criteria in the whole exploration area. The maximum value of the correlation coefficient of the analytic signal of the assumed source and the analytic signal of the observed data represents the maximum value on the boundary of the source in each cross section. Therefore, the position where the maximum value of this correlation coefficient occurs is the position of the real anomalous body boundary.

The correlation coefficient of the analytic signal AS_r

of the observed data with the analytic signal AS_j calculated by the j th virtual source is expressed as

(Guoqing et al., 2013):

$$R_j = \frac{\text{cov}[AS_r, AS_j]}{\sqrt{D[AS_r]D[AS_j]}} \quad (3)$$

$$\text{cov}[AS_r, AS_j] = \frac{1}{M} \sum_{i=1}^M [(AS_r)_i (AS_j)_i]$$

$$D(AS_r) = \frac{1}{M} \sum_{i=1}^M [(AS_r)_i]^2$$

$$D(AS_j) = \frac{1}{M} \sum_{i=1}^M [(AS_j)_i]^2$$

Where M is the length of the window and the center of the window is the horizontal position of the j th source. The size of the window M in each profile should be set reasonably. Depending on the type of object to be explored, the structural index of the source is chosen, and the coordinate (x_j, z_j) of each assumed source is known. The analytic signal AS_r of the real data can be calculated by the Eq. (1). And analytic signal AS_j calculated by the j th virtual source is expressed as (Guoqing et al., 2013)

$$AS_j(x, z) = \frac{k}{[(x - x_j)^2 + (z - z_j)^2]^{(N+1)/2}} \quad (4)$$

By simplifying the correlation coefficient expression, we can obtain

$$R_j = \frac{\text{cov}[AS_r, B_j]}{\sqrt{D[AS_r]D[B_j]}} \quad (5)$$

Where,

$$B_j(x, z) = \frac{k}{[(x - x_j)^2 + (z - z_j)^2]^{(N+1)/2}}$$

The assumed source distributes according to certain rule. According to Eq. (1), the correlation coefficient of the analytic signal of the real data and the analytic signal by the assumed source can be calculated, and the correlation coefficient can have a maximum when the location of the assumed source and the structural index coincide with the actual source. The position where the maximum value of this correlation coefficient occurs is the horizontal position of the real anomalous boundary. To apply the correlation of the analytic signal, one must know

in advance the structural index of the assumed source, which means that we already know the type of geological body to be analyzed. Moreover, the shape is also limited to one of the contact, vertical dyke, horizontal cylinder, and dipole.

We propose to use the analytic signal of standard measured data (ASSMD) directly on known orebody, rather than the analytic signal of the assumed source. ASSMD is the standard measurement of the correlation coefficient calculation. The use of correlation coefficients by

ASSMD is the main objective of this paper.

The correlation coefficient of the analytic signal AS_r of magnetic data measured at any cross-section x and

$$R_j = \frac{\text{cov}[AS_r, ASSMD_j]}{\sqrt{D[AS_r]D[ASSMD_j]}} \quad (6)$$

$$\text{cov}[AS_r, ASSMD_j] = \frac{1}{M} \sum_{i=1}^M [(AS_r)_i (ASSMD_j)_i]$$

$$D(ASSMD_j) = \frac{1}{M} \sum_{i=1}^M [(ASSMD_j)_i]^2$$

Where M is sized to cover the anomalous width of the known orebody.

Using the analytic signal of the standard measurements, it is possible to highlight the anomaly caused by the orebody present in the study area, to eliminate the influence of the interference factor and to clearly better reflect the horizontal boundary position of the orebody. This method does not require the calculation of the structural index and gives result independent of the direction of magnetization.

3. Application to field data

The proposed method is applied to clarify the development characteristics of gold ore body developing in the study area. The A-A' line shown in

the analytic signal of the standard measured data $ASSMD_j(j=1 \sim M)$ along a known cross-section of the orebody is expressed as :

Fig. 2 represents the position of the cross-section line containing the known orebody to obtain the standard measurement data. The analytic signal of magnetic anomaly on the gold ore body measured along this section, AST and elevation, are shown in Fig. 3. In Fig. 3b, the red triangle represents the outcrop position. On known orebody AST exhibits obvious anomaly. This anomaly is referred to as the analytic signal of standard measurement data (ASSMD). Using the correlation coefficient between AST and ASSMD of Eq. (6), we determine the horizontal boundary position of the orebody. The correlation coefficient between AST and ASSMD in all section is calculated, plotted as a contour map, and the maximum values are connected to determine the horizontal boundary position of the orebody (Fig. 4).

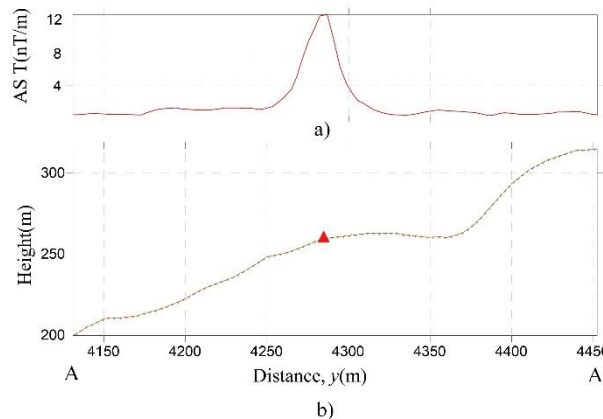


Fig. 3. Analytic signal of standard measurement data (ASSMD). a) AST b) topography

The line connecting the maximum values of correlation coefficient between AST and ASSMD is just the orebody strike. Comparing the AS contour map (Fig. 2) with the contour map of the analytic signal correlation coefficient by the proposed

method (Fig. 4), the strike of the NE-orienting gold ore body are clearly visible, especially the SW-orienting orebody extension that is not distinguished from the AS contour.

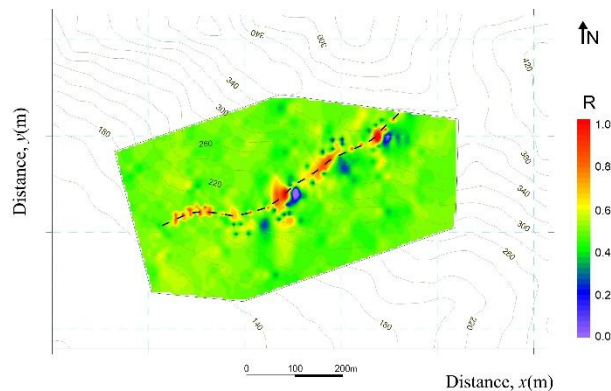


Fig. 4. Horizontal boundary of orebody detected by correlation coefficient of AST and ASSMD

Two tunnels tunnel to determine the horizontal boundary position of the orebody interpreted by the proposed method. To confirm the position of the calculated horizontal boundary of the ore body, two tunnels excavate: at 130 m and 156 m, respectively, strike vein of ore body. Thus, using the horizontal boundary position of the ore body as determined in the deep estimation can improve the efficiency of the ore-body distribution interpretation.

4. Conclusions

The proposed methodology can be used to highlight the magnetic anomaly in the overburden region, which can reflect the horizontal boundary position of the gold ore body. Comparing the correlation coefficient (Fig. 4) of the analytic signal using the magnetic field survey (Fig. 2) and the analytic signal of the standard measured data (ASSMD) on the gold ore body, it can be seen that the discontinuous distribution of the gold ore body is clearly linearly separated. Converting cross-sectional anomaly with different intensity and range to analytic signals, calculating correlation coefficient

with ASSMD and connecting the maximum correlation coefficient values, clearly distinguishes the horizontal position of the orebody in the study area. According to the data excavated in the two galleries, it can be confirmed that the boundary position of the gold ore body corresponds to the maximum position of the correlation coefficient of the analytic signal using the analytic signal of the standard measured data (ASSMD). The proposed method shows that the emphasis on magnetic anomaly in overburden area with no outcrop, can help to solve practical problems such as the identification of horizontal boundary and fault structure of ore body. The method has the same meaning as considering the influence of the magnetization direction.

This approach can be extended to geological problems such as geological structure investigation or sheet boundary detection. The proposed method shows that the emphasis of magnetic anomaly in survey area that covered the outcrop with overburden can help to solve realistic problems such as the

identification of the horizontal boundary and fault structure of the ore body. And method can be extended to geological problems such as geological structure investigation or lithologic boundary subdivision.

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