Geophysical Research Abstracts
Vol. 14, EGU2012-1936, 2012
EGU General Assembly 2012

An improvement approach to the interpretation of magnetic data

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There are numerous existing semi-automated data processing approaches being implemented which specialize in edge and depth of potential field source. The mathematical expression of tilt-angle has recently been developed into a depth-estimation routine, known as “tilt-depth”.

The tilt-depth was first introduced by Salem et al (2007) based on the tilt-angle which use first-order derivative to detect edge. In this paper, we propose the improvement on the tilt-depth method, which is based on the second-order derivatives of the reduced to pole (RTP) magnetic field, called edge detection and depth estimation based on vertical second-order derivatives (V2D-depth).

Under certain assumptions such as when the contacts are nearly vertical and infinite depth extent and the magnetic field is vertical or RTP, the general expression published by Nabighian (1972) for the magnetic field over contacts located at a horizontal location of x=0 and at a depth of z_0 is

$$\Delta T(x,z) = 2kFc \cdot \arctan\left(\frac{x}{z_0 - z}\right) \tag{1}$$

Where $k$is the susceptibility contrast at the contact, F the magnitude of the magnetic field, $c = 1 - \cos^2 i \cdot \sin^2 A$, A the angle between the positive h-axis and magnetic north, i the inclination of earth’s field.

The expressions for the vertical and horizontal derivatives of the magnetic field can be written as

$$\frac{\partial \Delta T}{\partial h} = 2kFc \cdot \frac{z_0 - z}{x^2 + (z_0 - z)^2} \tag{2}$$

$$\frac{\partial \Delta T}{\partial z} = 2kFc \cdot \frac{-x}{x^2 + (z_0 - z)^2} \tag{3}$$

Based on Equations 2 and 3, we have

$$T_{zz} = \frac{\partial^2 \Delta T}{\partial z^2} = 2kFc \cdot \frac{2x(z_0 - z)}{[x^2 + (z_0 - z)^2]^2} \tag{4}$$

$$T_{zh} = \frac{\partial^2 \Delta T}{\partial z \partial h} = 2kFc \cdot \frac{(z_0 - z)^2 - x^2}{[x^2 + (z_0 - z)^2]^2} \tag{5}$$

$$T_{zG} = \sqrt{T_{zh}^2 + T_{zz}^2} = 2kFc \cdot \frac{x^2 + (z_0 - z)^2}{[x^2 + (z_0 - z)^2]^2} \tag{6}$$

Using Equations 4, 5 and 6, when z=0, we can get

$$\frac{T_{zz}}{T_{zG} + T_{zh}} = \frac{x}{z_0} \tag{7}$$

The V2D-depth is defined as

$$\theta = \tan^{-1}\left(\frac{T_{zz}}{T_{zG} + T_{zh}}\right) = \tan^{-1}\left(\frac{x}{z_0}\right) \tag{8}$$

The V2D-depth amplitudes are restricted to values between –45° and +45°. It has the same interesting properties like the tilt-depth. Its responses vary from negative to positive. Its value is negative when outside the source region, passes through zero when over, or near, the edge, and is positive when over the source. This can not only outline edge but also indicate the relative magnetization contrast. As we know that tilt-depth which use the zero amplitude of first-order vertical derivative for edge detection is not the best. The tilt-depth calculates the depth to top by measuring the physical distance between tilt-angle pairs, with particular emphasis on the locus of the complementary 0° and $\pm 45^{\circ}$ pairs. As Ahmed Salem et al pointed out in 2007, because of the anomaly interference and the breakdown of the two dimensionality assumption, the distance between the two $\pm 45^{\circ}$ contours and the 0° contours is not everywhere identical around the perimeter of each body.

Comparison with the tilt-depth approach, this V2D-depth method can obtain a clearer field source edge and inverse a more realistic depth, while it also overcomes the interference by superimposed anomaly which tilt-depth approach does. The numerical experiment shows the method is effective.