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The use of Complex Attributes in Interpreting Magnetic data from Archaeological Sites.

The present paper deals with the exploitation of the complex attributes of the magnetic signal in order to extract properties of the sources of the anomalous fields. Of course, the analytic signal comprises the most well known among them. The "local phase" and the "instantaneous wavenumber" comprise the other two quantities which lead also to source parameters mapping.

The analytic signal amplitude (Nabighian, 1972; 1974) poses some attractive features for any sort of magnetic prospecting. Its advantageous "geophysical" property is that is peaks exactly over the edge of the buried dipping contact that causes the magnetic anomaly. Also, its amplitude is independent of inclination, declination, remanent magnetization and dip if the sources are 2-D. With respect to archaeological Geophysics, the only disadvantage is that the analytic signal anomalies are relatively much broader than the lateral extent of the buried target.

The aim is to delineate the edges of the buried bodies, to estimate their susceptibility contrasts, to assess strike angles and produce burial depth estimates all at once. The complex attributes analysis offers the means to carry this out. It is exactly their applicability and effectiveness in exploring the subsurface for buried antiquities which is investigated in these pages.

The analytic signal amplitude for the simple contact model which produces the magnetic total field, T, is

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

and the local phase, i.e. the phase of the analytic signal for any particular location is

$$\vartheta = \tan^{-1}\left[\frac{\partial T}{\partial x} \Big/ \frac{\partial T}{\partial z}\right] \qquad (2)$$

The local frequency is defined as the rate of change of the local phase, but customarily the local wavenumber is used

$$k = \frac{1}{|A|^2}\left(\frac{\partial^2 T}{\partial x \partial z}\frac{\partial T}{\partial z} - \frac{\partial^2 T}{\partial x^2}\frac{\partial T}{\partial z}\right) \qquad (3)$$

If we substitute the expressions for the vertical and horizontal gradients of the anomaly produced by a sloping contact Nabighian (1972) into the local wavenumber formula (3) yields

$$k = \frac{h}{h^2 + x^2} \qquad (4)$$

where h is the burial depth (Thurston and Smith, 1997; Smith et al. 1998). If we define the coordinate system such that $x = 0$ directly over the edge, the maximum occurs at the same point and offers a means for burial depth estimation since at $x = 0$, then $h = \frac{1}{k}$

Thurston and Smith (1997) devised a technique to estimate the local dip and local susceptibility contrast as well by means of equation (3). That is $\delta = \theta + 2I - 90^0$ again at $x = 0$. The local susceptibility is obtained by

$$k = \frac{|A|}{2kFc\sin d} \qquad (6)$$

A useful model in various geophysical applications is the slab which also serves in archaeological Geophysics. For instance, a mesh of ruins which the archaeologists call "destruction phase" can be modeled as a magnetic slab. The same applies in some cases for structures like kilns, pits, tombs. The slab used here is buried at 1 m depth, its thickness is 0.5 m and its susceptibility contrast is 0.0005 (emu).Figure (1) shows the recovered local strike esimates of this source. The plane view of a slab is also shown in the same figure. The edges are completely delineated and strike angles recovered give a clear idea of the shape of the target.

References

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Fig.1. The local strike estimates inferred from the complex attributes of the anomaly which the slab model produces. The plane view of the model is represented by the solid line. Strike estimates are grouped in two categories