Discussion

On: "Magnetic interpretation using the 3-D analytic signal" by W. R. Roest, J. Verhoef, and M. Pilkington (GEOPHYSICS, 1, 116–125, January 1992).

It is quite interesting to learn the 3-D analytic signal interpretation of Roest et al. (1992), using the vector addition.

However, I am quite skeptical about their objective of determining the depth under the assumption that the magnetic anomalies are caused by vertical contacts from gridded magnetic data which, it appears to me, is nothing but an oversimplification of interpretation. Here are my comments:

1) Simulated example: The immediate neighboring circles, shown along the edges of prisms [Figure 4(b)], are so varied that they reflect a depth variation of more than 1 km in less that 0.9 arbitrary units of distance.
2) Field examples: In Figure 5(c), circles representing the depth range of 2–20 km (a) are overlapped at many places (are due to step faults); (b) show smaller sizes inscribed in bigger sizes, and are clustered at several places.
3) From Figure 5(c) I could not trace the pattern of circles along the edge of circular features of the magnetic source body [marked (c) in Figure 5(b)], like the one shown in simulated example [Figure 4(b)].
4) Are Grenville fronts [In Figure 5(c) labeled 1 and 2] indications of faults? If so, here also I could not find such features, nor in their image [Figure 5(b)].

It is beyond my comprehension how the magnetic sources are distributed beneath the surface of the earth. It is equally true with the other field example of Sydney Basin (Figure 6). The correlation with seismics is very vague.

Their method of depth determination, in my opinion, somewhere has gone wrong or the computed depth ranges in the form of circles might have been represented inappropriately. The method of Roest et al. (1992) by itself is not unique since they said that the 60–80 percent of the magnitude of the bell-shaped analytic signal could be considered for depth estimation (p. 120). The magnetic data collected over an X-Y plane essentially are caused by magnetic sources which are 3-D in nature and, as a result, it might not be meaningful to attribute every analytic signal peak to a vertical contact. Moreover, the upper surface of any 3-D body beneath the surface of the earth, no doubt, may vary in depth, but one may not find depth variation of a few km as their simulated and field examples indicated.

Our short note on the 3-D analytic signal (Mohan and Anand Babu, pending review in GEOPHYSICS, 1993), using the vector (Roest et al., 1992) and scalar (Ofoegbu and Mohan, 1990) summation, has adequately proved that they are one and the same.

Finally, I am afraid that Roest et al. might have interpreted even peaks caused by noise, as the analytic signal is essentially a byproduct of a horizontal derivative where noise is bound to creep in.

There is a typographical error in page 120. Equation (14) should read as equation (12).

ACKNOWLEDGEMENT

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Reply by the authors to N. L. Mohan

The purpose of our paper (Roest et al., 1992) was to present the generalization of the analytic signal (Nabighian, 1972) from two to three dimensions and illustrate its use in magnetic interpretation. The comments by Dr. Mohan can be separated into three categories:

1. The general utility of automated methods for potential field interpretation.

No automated interpretation method can circumvent the inherent ambiguity of potential field data. Therefore, automated methods should be regarded as tools that can help the experienced interpreter when considering different interpretations. We are well aware of the fact that short wavelength noise is a significant problem, as demonstrated by the track-corrugations and level problems in Figure 5 of Roest et al. (1992). Any method that involves the calculation of spatial derivatives (e.g., Euler deconvolution), should be applied with caution. However, the possibility of poor data quality does not render invalid the method we presented. With the availability of detailed gradiometer survey data, examples exist of excellent data sets that can be used directly in this type of analysis.

2. The results from the depth estimation routine and the assumption that magnetic anomalies are caused by vertical magnetic contacts.

Nabighian (1972, 1974) demonstrated that if the source body is polygonal in shape, the analytic signal reaches a maximum over each corner of the polygon. The half width of the analytic signal maximum is then a measure of the depth to the source. In our paper, we simplified this approach and calculated depth estimates based on the assumption of vertical contacts and isolated 2-D anomalies [compare Roest et al., equation (12). Note that where equation (14) is referred to in the paper it should read equation (12)]. If this basic assumption is invalid, the results become inaccurate. To assure that the selected anomalies are linear and we are not just analyzing isolated peaks, the method of Blakely and Simpson (1986) is used to locate linear maxima. However, one has to realize that the properties of the analytic signal are strictly valid only for isolated two-dimensional bodies. Whenever there is interference between multiple anomalies, the results are unreliable and considerable scatter occurs. This scatter is similar to that observed when using Euler deconvolution (Reid et al., 1990).

3. The correct definition of the 3-D analytic signal, as a generalization of the concept developed by Nabighian (1972) for 2-D.

We would like to take this opportunity to elaborate more on the correct definition of the analytic signal. The analytic signal, (or energy envelope), originally developed in signal processing theory, is defined as a complex function whose real and imaginary parts are Hilbert transforms of one another. Nabighian (1972, 1974) demonstrated the usefulness of the amplitude of the analytic signal for interpretation along magnetic profiles. This amplitude is defined as

$$|\mathbf{A}(x, y)| = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \tag{1}$$

and has the interesting property that it is independent of the direction of the ambient field and of the source body magnetization.

Nabighian (1984) described the fundamental relations for generalized Hilbert transforms but did not, however, formally derive the analytic signal in three dimensions. Neither did he provide practical applications of the Hilbert transform method for the analysis of gridded data.

Ofoegbu and Mohan (1990) were among the first to use the generalized Hilbert transforms in the analysis of observed potential field data. An inspection of their equations, however, shows that their definition of the analytic signal is incorrect. For the purpose of this reply, we will only consider the amplitude of the analytic signal as defined by Roest et al. (1992):

$$|\mathbf{A}(x, y)| = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \tag{2}$$

and by Ofoegbu and Mohan (1990):

$$|\mathbf{B}(x, y)| = \sqrt{\left(\frac{\partial M}{\partial x} + \frac{\partial M}{\partial y}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \tag{3}$$

The difference between the two equations reflects the use of a vector addition of the two horizontal gradients by Roest et al. (equation 2), and a scalar addition by Ofoegbu and Mohan (equation 3).

Rather than using mathematical arguments, a simple example is effective in demonstrating the difference between equations 2 and 3. For this purpose, we calculated the magnetic anomaly over a circular disk assuming, for simplicity, vertical magnetization and vertical ambient field. A circular symmetric anomaly results. Equations 2 and 3 are then used to calculate $|A(x, y)|$ and $|B(x, y)|$, respectively. Figure 1 shows that the use of equation 2 preserves the circular nature of the original anomaly, whereas equation 3 does not.

Since the diameter of the disc in Figure 1 is much larger than its depth (ratio 20:1), the edges can be considered 2-D contacts. Therefore, Figure 1 effectively demonstrates that the analytic signal (equation 2) over two-dimensional structures is independent of the strike. However, when equation (3) is used, the signal is strike dependent, and only for north-south and east-west striking features is it equal to the 2-D signal. Consequently, equation (3) does not represent the correct generalization of equation (1). This is once more illustrated by the profiles in Figure 2, one profile trending 45°, the other 135° (see Figure 1 for location). The analytic signal according to equation (2) is equal on both profiles (solid line). The signal amplitude according to equation (3) exhibits two maxima on profile 2. Hence, we have demonstrated that the correct generalization of the analytic signal, as defined by Nabighian (1972), to 3-D is based on the vector addition of the horizontal gradient components.

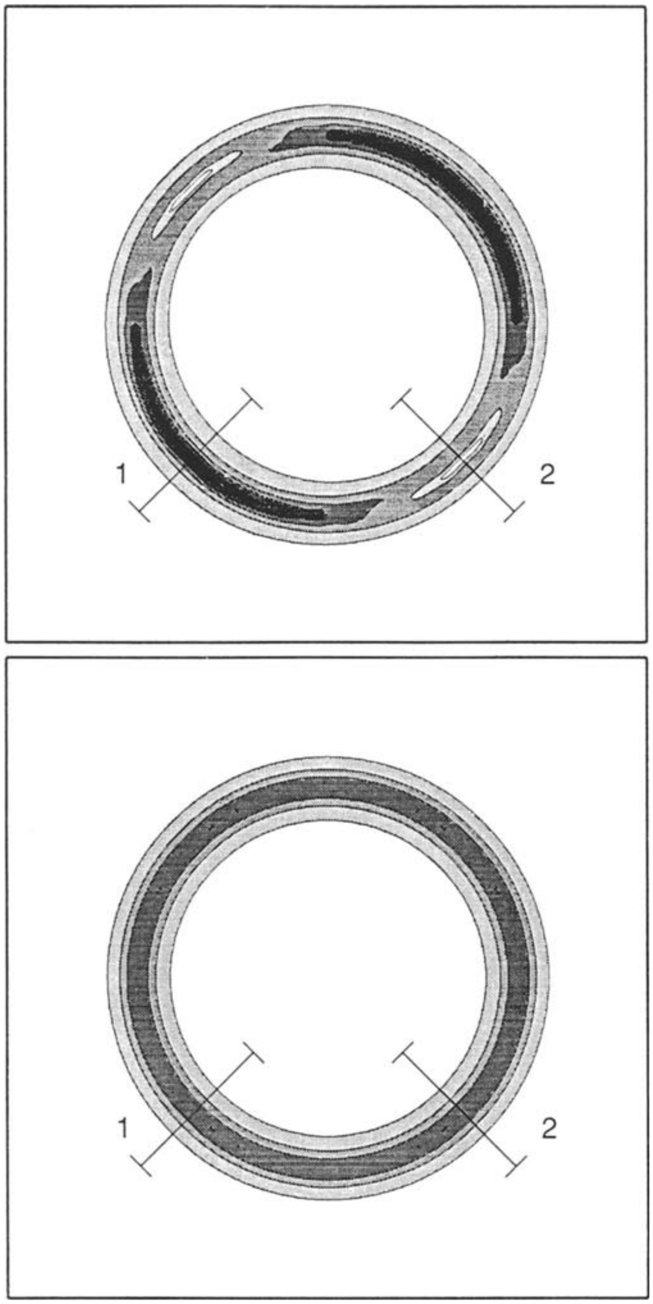

FIG. 1. Analytic signal calculated for a circle symmetric magnetic anomaly over a magnetized disk (bottom). Using the vector addition (equation 2), and (top) using the scalar addition (equation 3). The locations of profiles 1 and 2 shown in Figure 2 are also indicated.

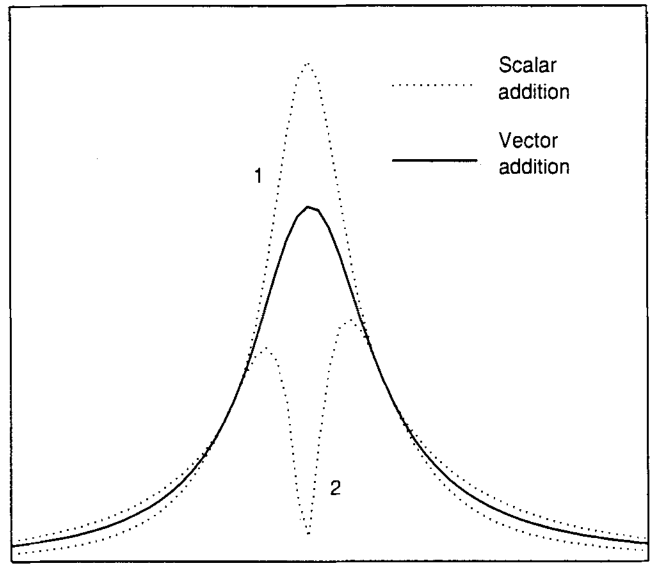

FIG. 2. Analytic signal along profiles 1 and 2 (see Figure 1 for location). The analytic signal based on the vector addition is circle symmetric and, therefore, the same along both profiles. However, when the scalar addition is used, the shape of the analytic signal is sensitive to the local strike of the anomaly. Along profile 1, the maximum amplitude is almost twice the correct value, and along profile 2, the amplitude drops to zero.

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