Mühendislik Bilimleri ve Tasarım Dergisi
Cilt:1 Sayı:2 s.87-90, 2010

Journal of Engineering Science and Design
Vol:1 No:2 pp.87-90, 2010

Interpretation of Magnetic Anomaly in The South of Lake Sapanca Using an Enhanced Local Wave Number Method

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Abstract- The total field magnetic anomaly can be interpreted to estimate the depth and horizontal location and geometry of the magnetized sources using enhanced local wave number (ELW) method. This method uses the phase-rotated local wave numbers to produce a linear equation as a function of the model parameters. The equation is solved to determine the horizontal location and depth of a 2D magnetic body without specifying a priori information about the source geometry. Once the source location is estimated, a value for the structural index, characterizing the source geometry is determined using the relation between structural index and ELW. Therefore, the source geometry is estimated by computing the structural index from previously estimated depth and horizontal location.

The ELW method has been applied to the total field magnetic anomaly from a study area in the south of Lake Sapanca in eastern Marmara region. The results have demonstrated that faulted basement has finite-vertical offset.

Keywords- Magnetic interpretation, depth estimation, local wave number, structural index.

Yığma Yerel Dalga Sayısı Yöntemini Kullanarak Sapanca Gölünün Güneyindeki Manyetik Anomalinin Yorumlanması

Özet-Yığma yerel dalga sayısı (ELW) yöntemini kullanarak, toplam alan manyetik anomalisi manyetik kaynakların yatay lokasyonu, derinliği ve geometrisini belirlemek için yorumlanabilir. Bu yöntem, model parametrelerinin bulunmasında kullanılan doğrusal bağıntılar sistemini elde etmek için kullanılır. Bu bağıntı, kaynak geometrisi ile ilgili olarak önceden bir bilgi olmaksızın iki boyutlu manyetik bir kütlenin yatay lokasyonu ve derinliğini bulmak için çözülür. Kaynak lokasyonu belirlendikten sonra, kaynak geometrisini karakterize eden bir yapısal indeks değeri, ELW ve yapısal indeks arasındaki ilişki kullanılarak belirlenir. Böylece kaynak geometrisi, derinlik ve yatay lokasyon bilgisinden elde edilen yapısal indeks değerine göre belirlenir.

ELW yöntemi Marmara bölgesinin doğusundaki Sapanca gölünün güneyindeki çalışma alanında ölçülen toplam alan manyetik anomali haritasına uygulanmıştır. Sonuçlar faylı temel kayanın sonlu ve düşey atımlı olduğunu göstermiştir.

Anahtar Kelimeler- Manyetik yorumlama, derinlik kestirimi, yerel dalga sayısı, yapısal indeks.

1. INTRODUCTION

An interpretation difficulty with total field anomalies is that they are dipolar (anomalies having positive and negative components) such that the shape and phase of the anomaly depends in part on the magnetic inclination and the presence of any remnant magnetization. Therefore, magnetic anomalies are in general complex in nature when compared to other geophysical anomalies.

The most important objective of magnetic interpretation techniques is to determine magnetic source parameters such as locations of boundaries and depth. One of these techniques is the source parameter imaging (SPI) method (6), which requires second-order derivatives of the total field. It uses a term known as the local wavenumber to provide a rapid estimate of the depth to sources. However, the method is model dependent since it needs information about the nature of the source to estimate the depth. Recent improvements in the local-wavenumber method (5, 7) have made it possible to estimate both the location and nature of the sources. (4) has developed the ELW, to identify the nature of source geometry without any assumptions.

In view of the advantages of the ELW technique, we have used this technique, to analyze magnetic anomaly of a local area in the south of the Lake Sapanca.

2. MATERIALS AND METHODS

Lake Sapanca is situated in the western part of the NAFZ to the eastern Marmara region (Figure 1a). The lake is approximately 20 km east of Izmit Bay, in a tectonic pull-apart basin.

The Sapanca front of the Samanlı Mountains, situated on the southern margin of the lake, consists of Paleozoic-Mesozoic rocks that include metamorphic (schist, marble, gneiss and quartzite) and meta-ophiolitic rocks (peridotite, gabbro and amphibolite) (Figure 1b).

The Samanlı Mountains (Figure 2a) to the south of the study area were uplifted as a pressure ridge structure (2). (1) suggest that a relatively high degree of tectonic activity along the Sapanca front in the south, in contrast with a low degree of tectonic activity along the Eşme front in the north of the study area. Lake Sapanca developed with its E-W trending elongated morphology on the İzmit-Sapanca Corridor and the floor of the depression is filled with Plio-Quaternary alluvial fan and alluvium deposits (1).

A set of SCINTREX ENVI Magnetic Geophysical System with an effective reading accuracy of 1 nT was mainly used in the field survey to record the total field data. To account for the diurnal variation of the earth's magnetic field, geomagnetic total field data from Kandilli Observatory was used. A diurnal correction of less than 20 nT/hour was observed and applied to the measured data. Then, the total magnetic field was corrected for the normal variation (regional correction). After making these corrections, the total field anomaly map (Figure 2b) was obtained. Dipolar magnetic anomaly of this map has attracted. We point out that this anomaly is associated with metamorphic basement. Our goal is to identify geologic form in the basement. Figure 3 shows a magnetic profile across the structure (see Figure 2b for location).

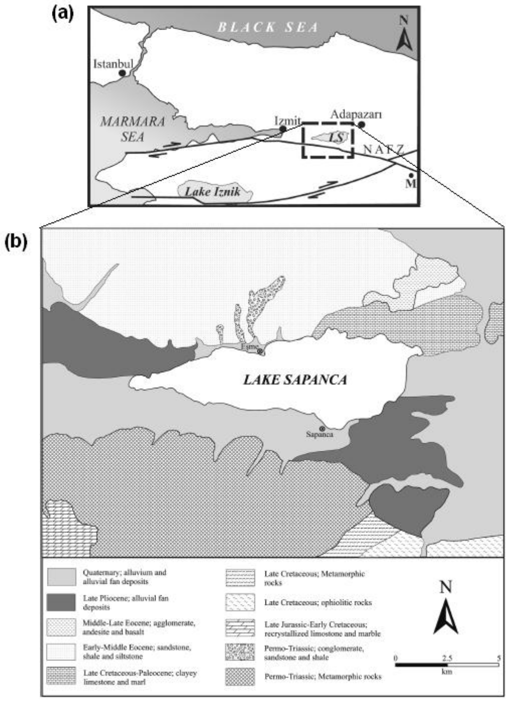

Figure 1. (a) General location map of the study area. NAFZ: North Anatolian Fault Zone. M:Mudurnu (b) Geologic setting of the area (modified after (1)).

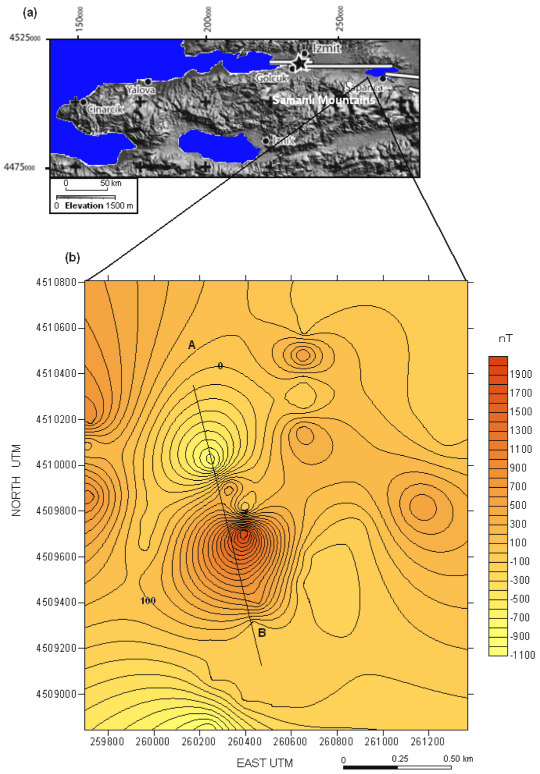

Figure 2. a) Map showing study area in the South of the Lake Sapanca; b) A measured total-field anomaly (ΔT) with a contour interval of 100 nT. Line AB indicates location of profile in Figure 3.

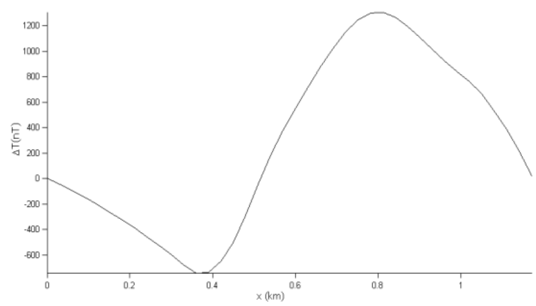

Figure 3. Magnetic profile of the ΔT anomaly from Figure 2b. Sampling interval is 0.03 km

3. THE ELW METHOD AND APPLICATION TO FIELD DATA

A local phase has defined by (6) as

$$\theta = \tan^{-1}\left(\frac{\partial \Delta T / \partial z}{\partial \Delta T / \partial x}\right), \qquad (1)$$

where $\partial T/\partial x$ and $\partial T/\partial z$ are the derivatives of the magnetic total field T in the x and z directions. Local wave numbers can be defined in terms of horizontal and vertical derivatives by taking the derivative of Eq.(1) in the x and z directions (6, 4) as

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

And

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

where $|A|$ is the amplitude of the analytic signal (3) expressed as

$$|A| = \sqrt{\left(\frac{\partial \Delta T}{\partial x}\right)^2 + \left(\frac{\partial \Delta T}{\partial z}\right)^2}\ . \qquad (4)$$

The k_x and k_z over simple sources (such as contacts, thin dikes, and horizontal cylinders), with horizontal location x_0 and depth z_0, is given (5) by

$$k_x = -\frac{(N+1)(z-z_0)}{(x-x_0)^2 + (z-z_0)^2} \qquad (5)$$

and

$$k_z = \frac{(N+1)(x-x_0)}{(x-x_0)^2 + (z-z_0)^2}, \qquad (6)$$

where N is a parameter characterizing the source geometry and also known as the structural index in the Euler deconvolution method and derived values of N shown in Table 1 are from (4).

Table 1: N (structural index) values for magnetics (4)

Source	N
Sphere	3
Horizontal cylinder	2
Fault for small throw.	1
Fault/step for finite offset	0.5
Fault for large throw	0

Dividing Eq. (5) by Eq. (6), (4) derived an equation:

$$k_x x_0 + k_z z_0 = k_x x + k_z z\ . \qquad (7)$$

Equation 7 is a simple linear equation without involving N, and can be solved for the source position (x_0, z_0) using conventional methods of matrix inversion. If the total field anomaly is measured on ground surface, the parameter z will equal 0.

The first horizontal derivative (Figure 4a) of magnetic data (Figure 3) has been calculated using the central differences and the vertical derivative (Figure 4b) from the horizontal derivatives using a Hilbert transform operator. Figure 4c shows the second mixed derivative $\partial^2 \Delta T / \partial x \partial z$, calculated from the horizontal derivative of the vertical derivative. Figure 4d shows the second horizontal derivative. Figure 5 displays local wave number field k_x calculated from Eq. 2. It should be noted that k_x has instabilities, caused by derivative curves from Figure 4 at the beginning and the end of the profile.

We use only a single window (7-point) of selected data points close to k_x and magnetic anomaly peak location, corresponding points between 0.72 and 0.9 km. Results of the ELW method indicate that a source at a horizontal location of 0.758 km, a depth of 0.205 km. By substituting these values in Eq.(5), the variation of N can be determined at the measuring points. As shown in Figure 5, It is obtained a significant result corresponding to the source geometry. Based on this analysis, the anomalous source corresponding to the structural index of 0.5 is determined as a finite-offset fault or contact with vertical offset (step) (Figure 6).

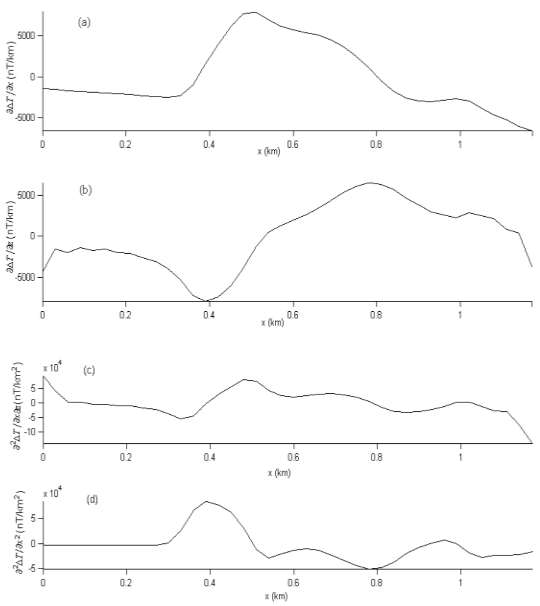

Figure 4: Derivatives computed from Figure 3. (a) The first horizontal, and (b) vertical derivative. (c) The second mixed derivative. (d) The second horizontal derivative.

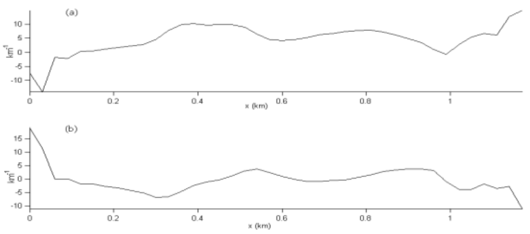

Figure 5: a) Local wave number field k_x and (b) k_z computed from data set of Figure 4.

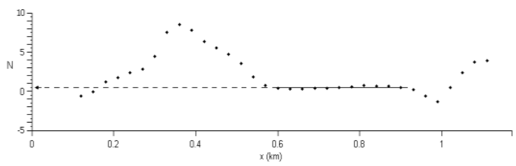

Figure 6: Estimate of the N (structural index) from Eq. (5) as a function of *x*. Note the N values around the zone of maximum anomaly are stable and value of N is 0.5.

CONCLUSIONS

The most important advantage of the ELW method provides a generalized equation to estimate the horizontal location and depth to source without any assumption on the nature of source geometry, susceptibility contrast, etc. The nature of the sources is subsequently determined using the source position parameters. In this study, our aim was to simulate magnetic data for a basin with nonmagnetic sediments overlying a faulted basement. Our results demonstrate that a structural index of 0.5 gives the typical source structures are finite-offset faults or contact with vertical offset (step).

ACKNOWLEDGEMENTS

This study is supported by Kocaeli University Research Fund (Project No:BAPB:2005/12). The authors are grateful to the Kocaeli University.

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