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Application of Enhanced Local Wave Number Technique to the Total Field Magnetic Anomalies for Computing Model Parameters of Magnetized Geological Structures

Manyetize Olmuş Jeolojik Yapıların Model Parametrelerinin Belirlenebilmesi için Gelişmiş Lokal Dalga Sayısı Tekniğinin Toplam Alan Manyetik Anomalilere Uygulanması

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Abstract: In this study, enhanced local wave number (ELWN) technique is presented to compute some model parameters of isolated and magnetized geological structures such as horizontal position (exact origin), depth and source geometry using the total field magnetic anomalies (TMAs). The technique uses analytical signal amplitude (ASA) and first- and second-degree horizontal and vertical derivatives of observed TMAs, and then simply computes the model parameters without requiring a priori knowledge about the nature of the causative magnetized body. Additionally, inclination and declination angles of both magnetization and ambient field have no effects on the results. In the ELWN technique source geometry, viz., structural index (contact/fault, dyke, horizontal cylinder and sphere) is determined using the depth and exact origin computed previously. Hypothetic simulations performed using TMAs due to some simple shaped geological models have showed the ability of the technique. Moreover, an actual magnetic data taken over the Kesikköprü iron deposit (Central Turkey), one of the largest iron reserve in Turkey, has been also analysed. A depth of 21.39 m has been computed for the magnetized geological source which includes the mafic rocks rich in magnetic properties, and the iron ore body. The structural indices obtained have indicated a dike-like or an intermediate form between a dike and a horizontal cylinder body for the magnetized source. These findings are compatible with those of a recently published study. Hence, the use of ELWN technique is proposed for rapid and reliable model parameter estimations from TMAs as an alternative or supportive experiment to the inverse modelling studies.

Keywords: Directional derivatives, Enhanced local wave number, Magnetized geological structures, Model parameters, Total field magnetic anomalies.

Öz: *Bu çalışmada, toplam alan manyetik anomaliler (TMA) kullanarak izole ve manyetize olmuş jeolojik yapıların ölçüm profili düzlemindeki yatay uzaklığı, derinliği ve yapı geometrisi gibi model parametrelerinin hesaplanabilmesi için gelişmiş lokal dalga sayısı (GLDS) tekniği sunulmuştur. Teknik, ölçülen TMA'lerin analitik sinyal genliğini (ASG) ve birinci- ve ikinci-dereceden yatay ve düşey türevlerini kullanmakta ve ardından manyetik anomaliye neden olan kaynağın doğası hakkında herhangi bir ön bir bilgiye ihtiyaç duymaksızın model parametrelerini kolay bir şekilde hesaplamaktadır. Ayrıca, mıknatıslanma ve ortam manyetik alan doğrultularının (eğim ve sapma açıları) sonuçlar üzerinde bir etkisi bulunmamaktadır. GLDS tekniğinde yapı geometrisi, yani yapısal indeksi (kontak/fay, dayk, yatay silindir ve küre) bir önceki hesaplamalardan elde edilen yapı derinliği ve yapının profil düzlemindeki yatay uzaklığı yardımıyla hesaplanmaktadır. Bazı basit şekilli jeolojik modellerden üretilen TMA'lerle gerçekleştirilen teorik uygulamalar tekniğin kullanışlılığını göstermiştir. Ayrıca, gerçek veri uygulaması olarak Türkiye'nin en büyük demir rezervlerinden biri olan Kesikköprü-Bala demir yatağında (Orta Türkiye) ölçülmüş TMA analiz edilmiştir.*

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Manyetik özellikçe zengin mafik kayaçları ve demir cevherini içeren manyetize olmuş kaynak yapı derinliği 21.39 m olarak hesaplanmıştır. Yapısal indeks değerleri ise dayk-benzeri veya dayk ve yatay silindir arası manyetize olmuş bir yapıyı işaret etmiştir. Bu bulgular yeni yayınlanmış bir çalışmanın sonuçlarıyla da uyumludur. Bu nedenle, TMA'lerden hızlı ve güvenilir model parametreleri kestirimi yapabilmek için GLDS tekniğinin kullanımı ters çözüm çalışmalarına bir alternatif veya destekleyici çalışma olarak önerilmektedir.

Anahtar Kelimeler: *Gelişmiş lokal dalga sayısı, Manyetize olmuş jeolojik yapılar, Model parametreleri, Toplam alan manyetik anomaliler, Yönsel türevler.*

INTRODUCTION

Magnetic method aims at investigating and exploring Earth's interior using the anomalies in the Earth's magnetic field originated from magnetic minerals (e.g. magnetite, pyrrhotite, maghemite and ilmenite) contained in the surface and subsurface rocks (Kearey et al., 2002). Although some of the rock-forming minerals are effectively non-magnetic, some types of rocks and man-made ferrous materials contain sufficient magnetic minerals to produce detectable and also observable high amplitude magnetic anomalies (Kearey et al., 2002). Thus, magnetic surveys are easily performed in many studies and range from small-scale explorations such as archaeological ruins (e.g. Drahor et al., 2008; Ekinci et al., 2014) to medium-scale surveys such as mineral/ore deposit investigations (e.g. Mandal et al., 2013 and 2015; Biswas, 2017) to large-scale explorations dealing with geological boundaries between the rocks having magnetic contrast (e.g. Ekinci and Yiğitbaş, 2012).

It is well-known that magnetic surveying is one of the earliest geophysical methods. The first magnetic survey was applied in Sweden (1640) to detect magnetic iron ores using a magnetic compass (Pilkington, 2007). Magnetic instruments were developed in the 1880s to measure the Earth's magnetic field intensity and thereafter mineral/ore deposit explorations using magnetic method became widespread (Hanna, 1990). Since the variations in the observed magnetic field reveal the distribution of magnetic minerals in the Earth's crust, magnetic surveys are performed to detect and draw the spatial distributions of these magnetic sources (Pilkington, 2007). A large number of data processing techniques clearly simplifies the analysis of the magnetic anomalies. Among these techniques, derivative-based algorithms are widely used for both visual interpretation of anomaly maps (e.g. Oruç and Keskinsezer, 2008; Cooper and Cowan, 2006; Oruç and Selim, 2011; Balkaya et al., 2012; Büyüksaraç et al., 2014) and model parameter predictions (e.g. Nabighian, 1972; Thompson, 1982; Reid et al., 1990; Srivastava and Agarval, 2010; Ekinci 2016; Ekinci et al., 2017). Derivative-based techniques commonly use various combinations of first- or second-degree vertical or horizontal derivatives (Ekinci et al., 2013). One of the derivative-based techniques used for the prediction of spatial parameters (i.e. depth and location) of the 2D magnetized sources (i.e. a fault/contact, a dyke, a horizontal cylinder and a sphere) is the enhanced local wave number (ELWN) which does not need any prior knowledge about the nature of the causative structure (Salem et al., 2005). Additionally, the technique uses traditional local wave number field and its phase-rotated version, namely, the vertical local wave number field which also enables to calculate the shape of the causative body (Salem et al., 2005). Here, efficiency of ELWN technique on parameter estimations from total field magnetic anomalies (TMAs) has been outlined using both synthetic data sets and a real data taken from an iron deposit, Central Turkey.

METHODOLOGY

ELWN Technique

Local wave number is briefly described as the rate of the change of the local phase with respect to the horizontal direction (x) and is defined as (Thurston and Smith, 1997; Salem et al., 2005)

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

where, θ denotes the local phase, $\partial T / \partial x$ and $\partial T / \partial z$ represent the first-degree horizontal and vertical derivatives of the magnetic field T, respectively, $|A|$ is the analytic signal amplitude (ASA) (Nabighian, 1972).

The local wave number kx over some simple shaped sources is expressed as (Smith et al., 1998)

$$kx = \frac{(n+1)(zo - z)}{(x - xo)^2 + (z - zo)^2} \tag{2}$$

where, zo and xo denote horizontal location and depth, respectively, n represents source geometry (structural index) (Thompson, 1982). Structural indices have the values of 0, 1, 2 and 3 for a contact (sheet poles), a thin dike (line poles), a horizontal cylinder (line dipoles), and a sphere (point dipole) respectively (Thompson, 1982; Salem et al., 2005; Hinze et al., 2013). Phase-rotated version of the local wave number obtained by the derivation of the local phase in downward direction is expressed as follows (Salem et al., 2005)

$$kz = \frac{\partial \theta}{\partial z} = \frac{(n+1)(x - xo)}{(x - xo)^2 + (z - zo)^2} \tag{3}$$

Phase-rotated version of the local wave number can be also obtained as (Salem et al., 2005)

$$kz = \frac{\partial \theta}{\partial z} = \frac{-1}{|A|^2}\left(\frac{\partial^2 T}{\partial x \partial z}\frac{\partial T}{\partial z} - \frac{\partial^2 T}{\partial z^2}\frac{\partial T}{\partial x}\right) \tag{4}$$

Division of Eq. 2 by Eq. 3 yields a simple linear equation as

$$kx\, x + kz\, z = kx\, xo + kz\, zo \tag{5}$$

The linear equation in Eq. 5 involves Eqs. 1 and 4 and it can be solved by a conventional methods of matrix inversion (Salem et al., 2005). Once the location and the depth are determined by means of Eq. 5, Eqs. 2 and 3 are used to find the structural indices (Salem et al., 2005) which should be in the range of 2D magnetic sources (Thompson, 1982; Reid et al., 1990). More detailed description about the solution strategy of ELWN technique can be found in (Salem et al., 2005).

Here, the effectiveness of ELWN method was tested in the estimation of model parameters using some idealized hypothetical models. Applications were performed using TMA responses of a dike and a horizontal cylinder models via MATLAB based algorithms.

Forward Equations

The general forward equation for TMA of a dike-like body is expressed as follows (Nabighian, 1972)

$$T(x) = A\frac{zo\cos\alpha + x\sin\alpha}{(x - xo)^2 + zo^2} \tag{6}$$

where,

$$A = 2kF\left(1 - \cos^2 i \sin^2 D\right)\sin d \tag{7}$$

and,

$$\alpha = 2\left(\arctan\left(\tan i / \cos D\right) - d - 90\right) \tag{8}$$

where, F is the Earth's magnetic field, k denotes the susceptibility contrast, i represent the inclination of Earth's magnetic field, zo is the depth to the top of the causative source, d denotes the dipping angle, D is the angle between magnetic north and positive x axis, xo represents the horizontal location of the causative body, x is observation coordinates and A is the amplitude coefficient.

For the TMA of a horizontal cylinder, forward equation can be expressed as (Prakasa Rao et al., 1986)

$$T(x) = A\left[\frac{z^2 - (x-xo)^2\cos\theta + 2z(x-xo)\sin\theta}{\left((x-xo)^2 + z^2\right)^2}\right] \quad (9)$$

where, A denotes the amplitude coefficient, z defines the depth to the centre of the cylinder, θ represents the effective magnetization angle or the index parameter and, *xo* and *x* are given previously.

SIMULATIONS

Synthetic Examples

TMA due to a dike model was produced using Eq. 6. A 50-m long profile with a 1 m sampling interval was used. Model parameters of the dike body and the corresponding TMA are shown in Table 1 and Figure 1a, respectively. ASA values of the synthetic magnetic anomaly, demonstrated in Figure 1b, were obtained performing some frequency domain filtering operations through fast Fourier transform as defined previously by Agarval and Srivastava (2008). It is clearly seen from Eqs. 1 and 4 that computations of local wave numbers require second-degree horizontal and vertical derivatives. Even in the absence of noise, these second-degree derivatives may cause an enhancement of undesired effects due to the nature of the computations. Thus the oscillations at the beginning and end of the profile (Figure 1c), which may cause some false solutions, were ignored in the calculations. As clearly proposed by Salem et al., (2005), a window including data points near to and centred on the high amplitude anomaly peak, highlighted by a band in Figure 1c, was used. Thus, using 31 data points (Figure 1d) source locations (horizontal position and depth) were estimated using Eq. 5 and then structural indices for each source location solution were determined by means of Eqs. 2 and 3. Here, when the structural indices computed from *kx* and *kz* values were far from each other, the solutions of that data point were ignored. Application of ELWN technique produced satisfactory solutions. Results showed that the horizontal location of the causative body is 24.97 m far from the origin and obtained depth for the source is 5.1 m, which are very close to actual ones (Table 1). Structural indices computed via Eqs. 2 and 3 are 1.06 and 0.96, respectively (Table 1). These values are very close to 1, and clearly indicate a dike-like body as it should be.

For the second example, synthetic TMA (Figure 2a) caused by a horizontal cylinder model was produced via Eq. 9 using the model parameters listed in Table 2. Figures 2b and 2c show the ASA values and the local wave number fields, respectively. Undesired effects caused by the nature of computations are clearly seen in Figure 2c. Those data points observed at the beginning and end of the profile were not taken into consideration during the computations. Again, using a single window (blue band in Figure 2c) of 31 data points (Figure 2d), source location solutions were determined. Although using a data window of 31 points that is placed at the centre of the profile, some slight oscillations at the beginning and the end of the profile are seen. However, since these data points do not show sharp oscillations, *kx* and *kz* values of these data points were used during the computations. It must be noted that if the data window was wider, some false and undesired anomalies would occur, which would directly affect the solutions unfavourably. Results of the ELWN technique indicated a horizontal distance of 25.01 m from the origin and a depth of 5.1 m for the source model. Additionally, 2.01 and 1.89 values were obtained for the structural indices, indicating a horizontal cylinder-like body. These synthetic simulations clearly showed the feasibility of ELWN technique for model parameter estimations from TMAs.

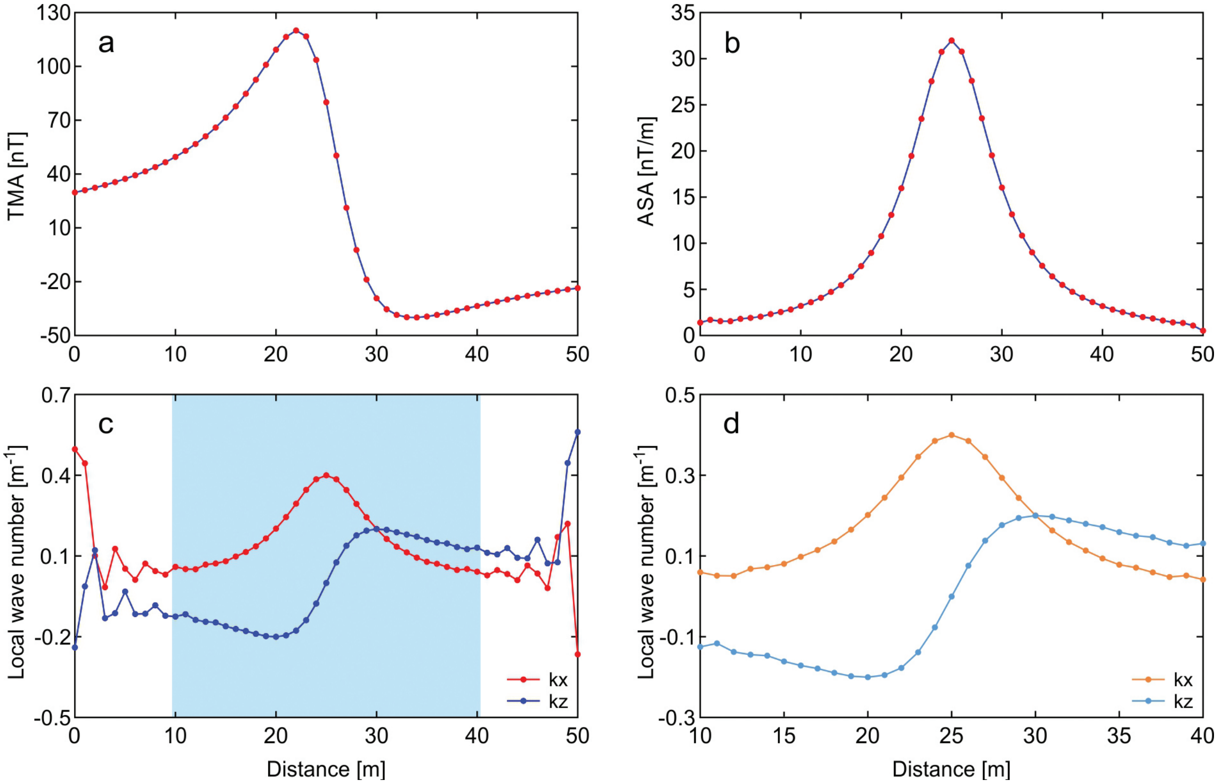

Figure 1. a) TMA of dike model, b) ASA values computed from TMA, c) Local wave numbers and the data window highlighted by blue band, d) Local wave numbers used for source position and geometry calculations.

Şekil 1. *a) Dayk modelinin TMA'si, b) TMA'dan hesaplanan ASG değerleri, c) Lokal dalga sayıları ve mavi bant ile gösterilmiş veri penceresi, d) Kaynak pozisyonu ve geometrisi hesaplamalarında kullanılan lokal dalga sayıları.*

Table 1. True and calculated parameters of theoretical dike model.

Çizelge 1. *Kuramsal dayk modeline ait gerçek ve hesaplanan parametreler.*

Parameters	True	Calculated
A [nT]	800	
zo [m]	5	5.1
xo [m]	25	24.97
i [°]	60	
D [°]	0	
d [°]	90	
kx	1	1.057 ± 0.043
kz	1	0.957 ± 0.056

Table 2. True and calculated parameters of theoretical horizontal cylinder model.

Çizelge 2. *Kuramsal yatay silindir modeline ait gerçek ve hesaplanan parametreler.*

Parameters	True	Calculated
A [nT]	800	
zo [m]	5	5.1
xo [m]	25	25.01
θ [°]	50	
kx	2	2.013 ± 0.061
kz	2	1.886 ± 0.069

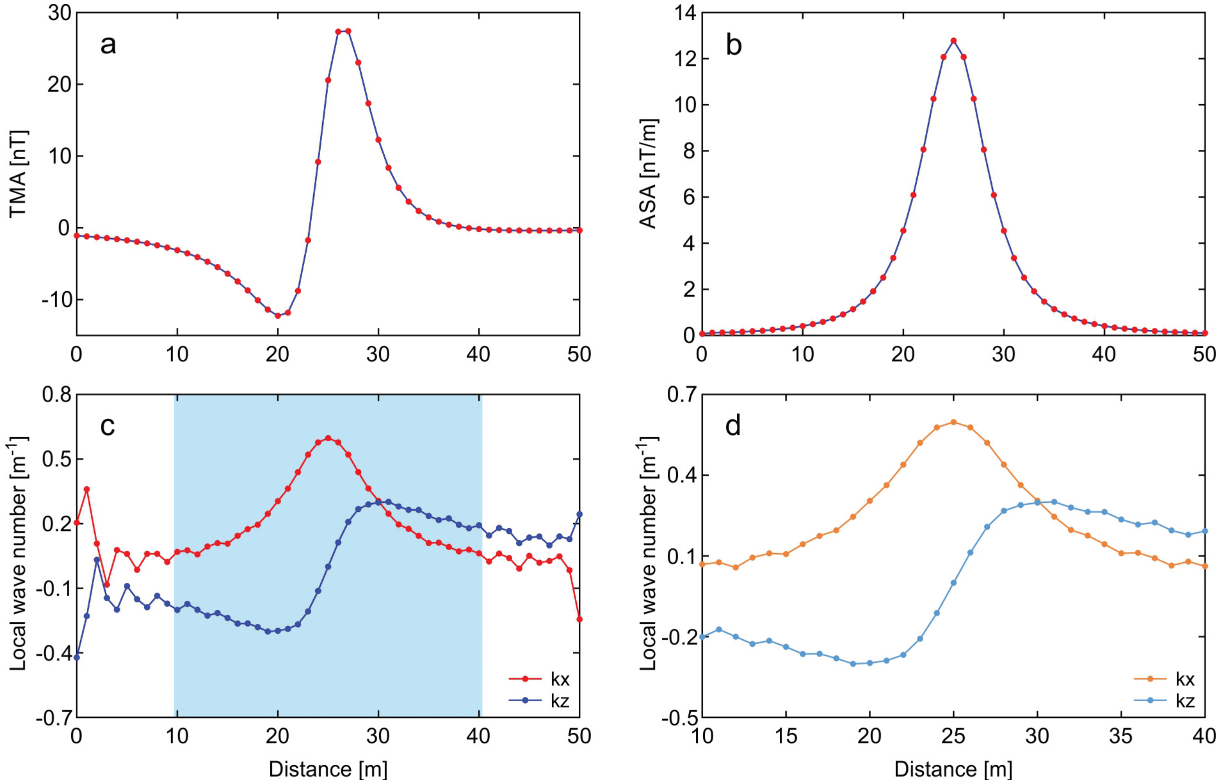

Figure 2. a) TMA of horizontal cylinder model, b) ASA values computed from TMA, c) Local wave numbers and the data window highlighted by blue band, d) Local wave numbers used for source position and geometry calculations.

Şekil 2. *a) Yatay silindir modelinin TMA'si, b) TMA'dan hesaplanan ASG değerleri, c) Lokal dalga sayıları ve mavi bant ile gösterilmiş veri penceresi, d) Kaynak pozisyonu ve geometrisi hesaplamalarında kullanılan lokal dalga sayıları.*

Real Data Example

This example presents a TMA obtained from an iron deposit (Bala, Turkey). Kesikköprü iron deposit (Figure 3), located in Central Anatolian Crystalline Complex, is one of the largest iron reserve in Turkey with grades of 32-54 % Fe and total reserve of 13.6 million tonnes (Terzi and Yılmazer, 2015). Doğan et al., (1998) suggests that Kesikköprü iron deposit is a Divriği type deposit, that is, iron is not derived from granitic rocks but formed by the enrichment resulting from dissolution of source rocks. Mineralization in the deposit occurred at the contact between granitoids consisting of granite, granodiorite, monzonite and their porphyry, and crystalline limestone (locally dolomitic) and/or mafic-ultramafic rocks composed of gabbro and pyroxenite (Terzi and Yılmazer, 2015). The basement of the area is composed of rock groups of Kırşehir massive. The basement is covered by the upper Cretaceous ophiolitic complex together with sedimentary and volcanic-volcaniclastic rocks and by a sedimentary cover of Tertiary age (Doğan et al., 1998). The skarn and vein deposits are the significant part of the metallogeny of the Central Anatolian Crystalline Complex (Kuşcu and Erler 1998). Possible origin model of the iron deposit using the information obtained from a drilling is shown in Figure 4 (Doğan et al., 1998).

The residual total field magnetic data set was obtained by General Directorate of Mineral Research and Exploration of Turkey (MTA) within the scope of a national project. Here, a part of this data set having a length of 120 m was used for model parameter estimation. The profile TMA was digitized using 3 m data intervals (Figure 5a). ASA and local wave number fields are shown in Figure 5b and 5c, respectively. Using a data window (Figure 5c) containing 27 data points (Figure 5d) a horizontal location of 61.81 m from the beginning of profile and a depth of 21.39 m were computed for the magnetized source. Structural indices of 1.44 and 1.32 obtained from local wave number fields suggest a dike-like model for the causative body. It must be noted that the depth to the top of the ore body is 105 m based on the drilling information (Figure 4). Therefore, it is seen that the depth obtained from ELWN technique is quite shallower than the one obtained from drilling. However, the existence of mafic rocks (Figure 4) up to 100 m depths having notable magnetic properties locally, was reported previously (Doğan et al., 1998). From this point of view, it is clear that these mafic rocks most likely effect the magnetic anomaly. The depth obtained in this study indicates the depth of the composite magnetized sources including the mafic rocks rich in magnetic properties and the iron ore body. Additionally, the residual magnetic anomaly probably results from the superposition of the mafic rocks rich in magnetic properties to the ore body. Oruç (2013) analysed this residual magnetic anomaly through continuous wavelet transform and he stated a spheric (point dipole) structure for the magnetized source having a depth of 42 m. Additionally, performing ASA inversion via differential evolution algorithm a dike-like magnetized body located at a depth of 24.4 m was reported by Ekinci et al. (2017). It is seen that the depth obtained from this study match well with the latter one. Based on the structural index values obtained through the ELWN technique, the magnetized geological structure can be approximated to a dike-like or an intermediate form between a dike and a horizontal cylinder body.

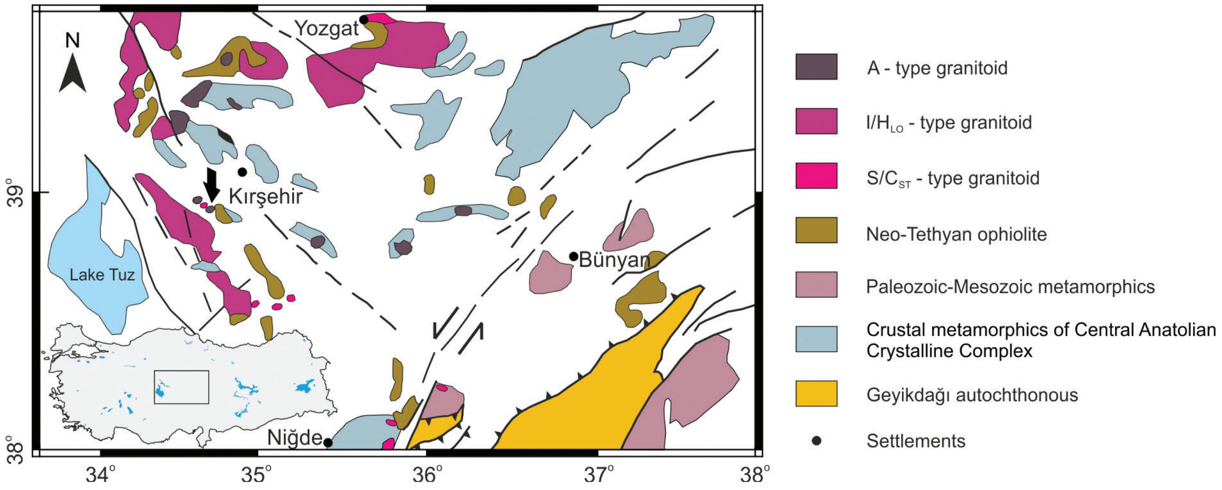

Figure 3. Geographical settings of the plutonic and metamorphic rocks in the Central Anatolia, Turkey (modified after Bingöl, 1989, Boztuğ, 1998, Tatar and Boztuğ, 1998). Black arrow at the west of Kırşehir settlement shows Kesikköprü pluton.

Şekil 3. *Türkiye orta Anodulu'da plütonik ve metamorfik kayaçların coğrafik konumları (Bingöl, 1989, Boztuğ, 1998, Tatar ve Boztuğ, 1998'den düzenlenmiştir). Kırşehir'in batısında bulunan siyah ok Kesikköprü plütonunu göstermektedir.*

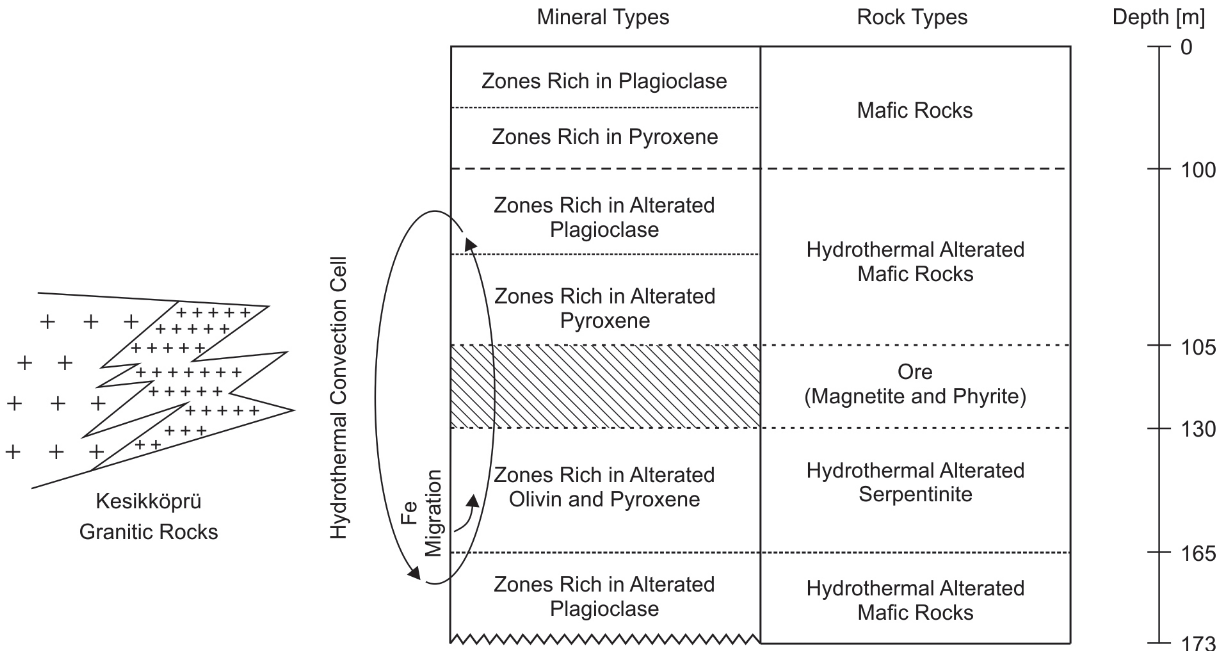

Figure 4. Possible origin model of Kesikköprü iron deposit based on the information obtained from a drilling (modified after Doğan et al., 1998). Not to scaled.

Şekil 4. *Bir sondajdan elde edilen bilgiye göre hazırlanan Kesikköprü demir yatağının olası kökensel modeli (Doğan vd.., 1998'den düzenlenmiştir).* Ölçeksizdir.

CONCLUSIONS

In this study one of the derivative-based techniques, named ELWN, which is used for estimating some model parameters of isolated geological structures such as exact origin, depth and source geometry using TMAs is presented. The technique uses first- and second-degree horizontal and vertical derivatives and also the ASAs of measured TMAs. One of the most important advantages of the technique is that the magnetization and ambient field directions have no effects on the solutions. Additionally, the technique does not need a prior information for the source geometry. An important issue that should be taken into consideration when applying the ELWN technique is the selection of the data window length for the computations. If all local wave number fields (*kx* and *kz*) are selected for the depth and structural index computations, unreasonable solutions may be obtained. Thus in the local wave number fields the data points having false anomalies characterized by sharp oscillations occurred due to the nature of second-degree horizontal and vertical derivatives should be removed from the computations, which may require some trial-and-error applications.

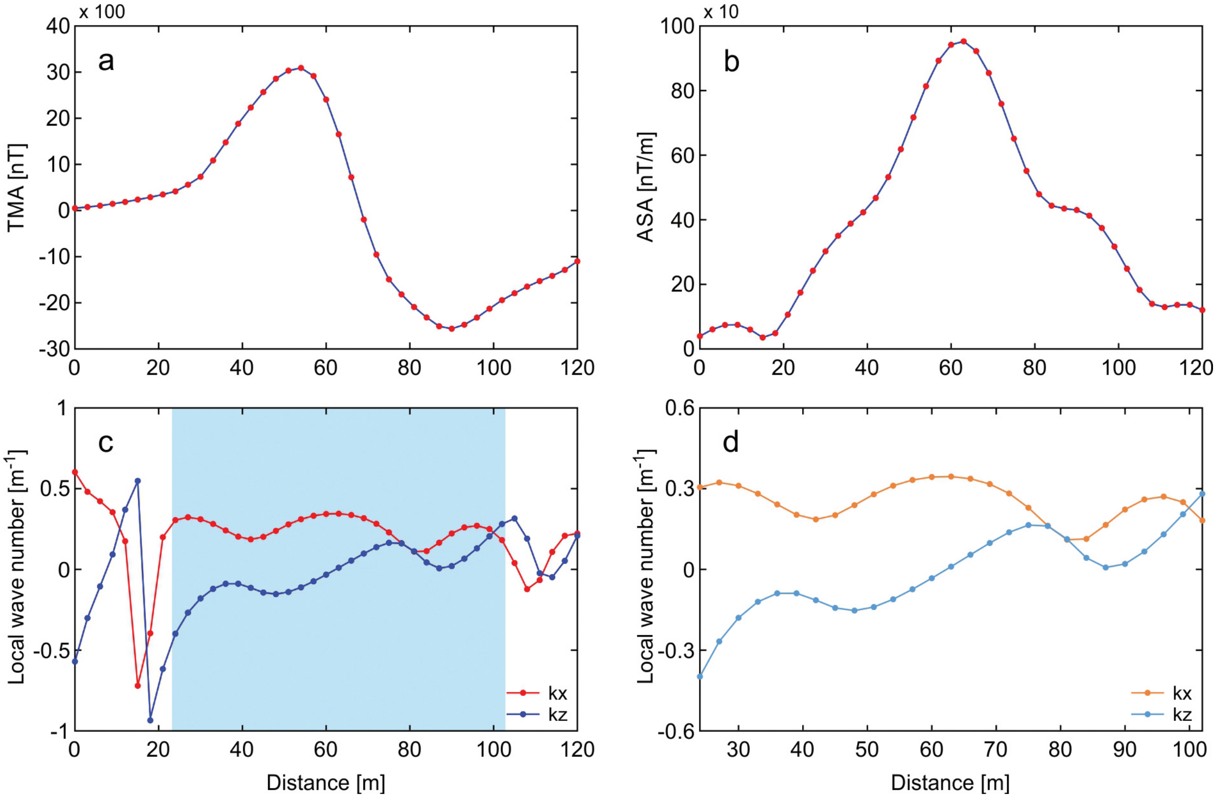

Figure 5. a) TMA observed over Kesikköprü iron deposit, b) ASA values computed from TMA, c) Local wave numbers and the data window highlighted by blue band, d) Local wave numbers used for source position and geometry calculations.

Şekil 5. *a) Kesikköprü demir yatağı üzerinde ölçülen TMA, b) TMA'dan hesaplanan ASG değerleri, c) Lokal dalga sayıları ve mavi bant ile gösterilmiş veri penceresi, d) Kaynak pozisyonu ve geometrisi hesaplamalarında kullanılan lokal dalga sayıları.*

Synthetic applications performed using some model bodies such as a dyke and a horizontal cylinder clearly showed the feasibility of the ELWN technique. All model parameters in each example were accurately resolved. Moreover, a real residual TMA measured on an iron deposit (Bala, Central Turkey) was also analysed. In the interpretations information obtained from a drilling was also used. This study showed that the residual TMA is caused by the ore body and also the shallower mafic rocks rich in magnetic properties. ELWN technique yielded 21.39 m depth to the top of the magnetized sources producing the superimposed residual TMAs. Additionally, structural indices obtained from *kx* and *kz* values indicated that the magnetized geological structure can be approximated to a dike-like or an intermediate form between a dike and a horizontal cylinder body. Both theoretical and actual anomaly examples showed that the use of ELWN technique should be a well strategy for parameters estimation problems of magnetic profile anomalies.

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GENİŞLETİLMİŞ ÖZET

Yatay ve düşey türev tabanlı veri işlem teknikleri potansiyel alan (manyetik ve gravite) verilerinin yorumlanmasında oldukça sık kullanılmaktadır. Hem anomali haritalarında ilk bakışta göze çarpmayan değişimleri ve çizgisellikleri ortaya koyabilmek yani görüntü zenginleştirme amacıyla, hem de kaynak yapıların bazı model parametrelerinin belirlenebilmesi amacıyla kullanılmaktadır. Profil verilerinin değerlendirilmesi amacıyla kullanılan tekniklerden biri olan gelişmiş lokal dalga sayısı (GLDS) tekniği ile toplam alan manyetik anomaliler (TMA) kullanarak yeraltında izole olmuş jeolojik kaynakların profil düzlemindeki yatay uzaklığı, derinliği ve yapı geometrisi (yapısal indeks) gibi model parametreleri hesaplanabilmektedir. Teknik, ölçülen TMA'lerin birinci- ve ikinci-dereden yatay ve düşey türevlerini ve de analitik sinyal genliklerini (ASG) kullanmakta ve ardından kaynak doğası hakkında hiç ön bir bilgiye ihtiyaç duymaksızın model parametrelerini kolay bir şekilde hesaplamaktadır. Yöntemin en büyük avantajlarından birisi de, elde edilen sonuçların hem kaynak manyetizasyonunun hem de genel alanın eğim ve sapma açılarından bağımsız olmasıdır. GLDS tekniğinde kaynak yapı geometrisi, yani yapısal indeks (kontak/fay, dayk, yatay silindir veya küre) bir önceki hesaplamalardan elde edilen yapı derinliği ve yapının profil düzlemindeki yatay konum bilgilerinden hesaplanmaktadır.

Bu çalışmada MATLAB ortamında geliştirilen bazı algoritmalar yardımıyla GLDS tekniği ele alınmıştır. Uygulamalarda hem kuramsal olarak üretilmiş hem de gerçek arazi verileri kullanılmış ve bazı sonuçlar ortaya konmuştur. GLDS tekniğinin kullanımı aşamasında en dikkat edilecek unsurlardan biri veri pencere boyunun seçimidir. Tekniğin matematiksel temeli birinci- ve ikinci-dereceden yatay ve düşey türevlerin hesaplanması esasına dayanmaktadır. Bu nedenle, yatay ve düşey yönde lokal dalga sayılarının hesaplanması aşamasında profil başlarında ve sonlarında özellikle ikinci-dereceden türevlerin matematiksel doğasından kaynaklanan bazı salınımlar oluşabilmektedir. Uygulamalarda bütün veri setinin hesaba katılması durumunda baş ve sonlarda oluşan bu istenmeyen yapay salınımlar hatalı olabilecek model parametrelerinin elde edilmesine neden olabilir. Bu nedenle, lokal dalga sayıları anomalilerinde eğrinin tepe noktası ve civarındaki veri noktalarını hesaba katacak uygun bir pencere boyu seçilmeli ve işlemler pencere içinde kalan veri noktalarıyla gerçekleştirilmelidir.

Dayk ve yatay silindir modellerinin ürettiği TMA'ler kullanılarak gerçekleştirilen kuramsal çalışmalarda GLDS tekniğinin yatay uzaklık, derinlik ve yapısal indeks gibi model parametrelerinin belirlenmesinde oldukça başarılı sonuçlar verdiği gözlenmiştir. Ayrıca, Türkiye'nin en büyük demir yataklarından biri olan Kesikköprü (Bala, Türkiye) sahasından alınan TMA'de analiz edilmiştir ve jeolojik olarak anlamlı bazı bulgular elde edilmiştir. Yorumlama aşamasında çalışma sahası civarında bulunan bir sondaj verilerinden de yararlanılmıştır. Manyetik anomalinin sadece alandaki demir cevherini temsil etmediği aynı zamanda daha sığ kesimlerde gözlenen manyetik özellikçe zengin mafik kayaçları da temsil ettiği belirlenmiştir. Dolayısıyla bu çalışmadan elde edilen derinlik bilgisinin demir cevherine ait olmadığı, bu cevherle manyetik özellik bakımından zengin mafik kayaçların birleşiminden oluşan manyetize olmuş jeolojik birimlerin derinliği olduğu sonucuna varılmıştır. Manyetik anomali üreten bu birimlerin üst derinliği 21.36 m olarak hesaplanmıştır. Ayrıca, hesaplanan yapısal indeks değerlerine göre kaynak yapının büyük olasılıkla dayk benzeri veya dayk ve yatay silindir arası bir geometriye sahip

olduğu belirlenmiştir. Hesaplanan derinlik ve yapı geometrisi yayınlanmış iki çalışmanın sonuçlarıyla karşılaştırılmış ve sonradan yayınlanan çalışmayla uyum içinde olduğu gözlenmiştir. Sonuç olarak bu çalışma TMA'lerden hızlı ve güvenilir model parametreleri kestirimi yapabilmek için GLDS tekniğinin geleneksel ters çözüm tekniklerine iyi bir alternatif veya destekleyici bir araç olduğunu göstermiştir.

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