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ANALYTIC SIGNAL INFERRED FROM REDUCED TO THE POLE DATA

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Abstract: *Analytic signal is one of the quantitative methods developed for interpretation of potential field data. In earlier studies, it was stated that the use of the analytic signal results in source body characteristics and the direction of the body magnetization was not needed for these estimations. However some form of distortion remains in the presence of remanence. A synthetic example demonstrates that if the analytic signal calculations are performed to the reduced to the pole anomalies, it produces better results. The analytic signal of reduced to the pole data is calculated for the aeromagnetic anomalies near the towns of Yozgat and Akcakent in central northern Turkey. In the studied area, the geological setting does not indicate any visible cause of the magnetic anomalies.*

Key words: *Analytic signal, Reduction to pole, Central northern Turkey, Magnetic anomalies.*

1. INTRODUCTION

Many methods based on the horizontal and vertical derivatives have been developed to process magnetic anomalies. Several methods developed for gravity data cannot be applied to magnetic data, as the magnetic sensitivity of the crust is much bigger than its density variation. In addition, the interpretation of magnetic data is more difficult than gravity data because the Earth's field and the magnetization vectors induce a certain degree of asymmetry.

Roest and Pilkington (1993) suggested a method to estimate the direction of the body magnetization with limited success. Ates and Kearey (1995) developed a new method to estimate the direction of body magnetization and presented its application to the potential field anomalies of the Worcester Graben area in South Central England. Bilim and Ates (1999) compiled a computer program to estimate the direction of the body magnetization using the root-mean square method based on the method of Ates and Kearey (1995).

In this paper, it is illustrated by a synthetic example that the distortion caused by the body magnetization remains in the analytical signal. However, if the analytic signal is applied to a reduced to the pole anomaly, it produces a better result. This procedure was applied to the magnetic anomalies near the cities of Yozgat and Akcakent in Central northern Turkey.

2. THE METHOD

2.1. Analytic signal

The analytic signal is formed by the horizontal and vertical gradient of the magnetic anomaly. In the 3-D case, the analytic signal is given by

$$\mathbf{A}(x,y) = \frac{\partial M}{\partial x}\hat{\mathbf{i}} + \frac{\partial M}{\partial y}\hat{\mathbf{j}} + i\frac{\partial M}{\partial z}\hat{\mathbf{k}} \quad (2.1.1)$$

Where, $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$, and $\hat{\mathbf{k}}$ are the unit vectors in the x, y, z directions, respectively, and M , is the magnitude of the magnetic anomaly. In the frequency domain, Equation (2.1.1) can be written as

$$\hat{t} \cdot F\,[\mathbf{A}(x,y)] = \hat{h} \cdot \nabla F[M] + i\hat{z} \cdot \nabla F[M] \quad (2.1.2)$$

where ∇ is the gradient operator in the frequency domain ($ik_x\hat{x} + ik_y\hat{y} + |\mathbf{k}|\hat{z}$); $\hat{t} = \hat{x} + \hat{y} + \hat{z}$ and $\hat{h} = \hat{x} + \hat{y}$ (Roest et al., 1992). The horizontal derivative and the vertical derivative of the anomaly are the real and the imaginary part of equation (2.1.2), respectively.

From equation (2.1.1), the amplitude function of the analytic signal is

$$|\mathbf{A}(x,y)| = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \quad (2.1.3)$$

2.2. Test Case

The performance of the analytic signal when applied to reduced pole was tested on the magnetic anomaly of a model. A prism shaped body, buried at 2 km depth, has dimensions 5×5×4 km (Fig. 1) with an intensity of magnetization (J) of 1 Am^{-1}. The inclination and declination of the Earth's magnetic field were set to 55° and 4°, respectively, and the values of 55° and 80° were used for the corresponding parameters of the magnetization of the body. The produced magnetic anomaly is shown in Figure 2. Analytic signal transformation was applied to these data using the method described by Blakely (1995). The peak the amplitude of the analytic signal map (Fig. 3) has shifted towards the SW in the same way as does the amplitude of the magnetic anomaly (Fig. 2). In order to demonstrate the success of reduced to the pole transformation prior to analytic signal estimation, the magnetic anomaly map shown in Figure 2 firstly, was reduced to the pole (Fig. 4) with the aforementioned parameters of the direction of the Earth's magnetic field and body magnetization. Secondly, the analytic signal transformation was applied to the reduction to pole transformed map shown in Figure 4. The analytic signal map produced in this way is given in Figure 5. Dislocation of the peak of the amplitude towards the SW is eliminated in this analytic signal estimation of reduced to the pole data.

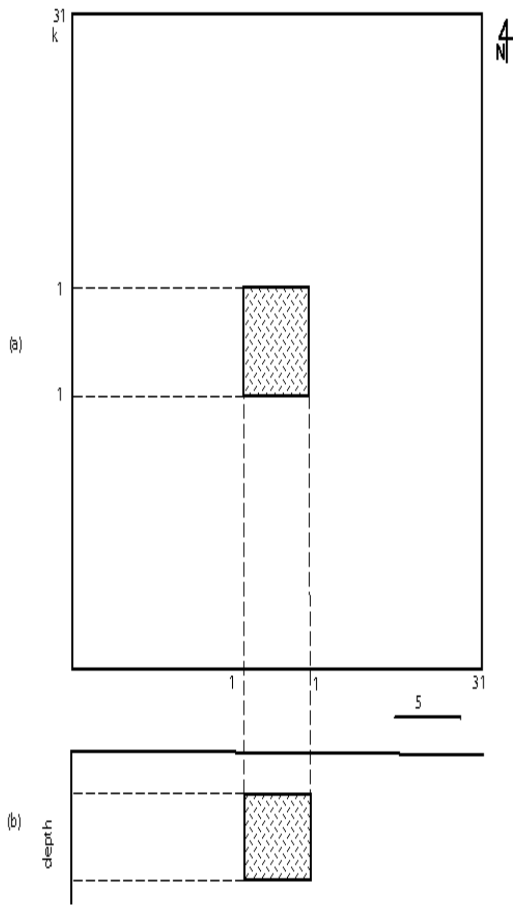

FIG. 1: Model (A-plan view, B-section) used to produce magnetic anomalies. The dimensions are 5×5×4 km and the burial depth of the upper surface is 2 km. The intensity of magnetization (J) = 1 Am^{-1}.

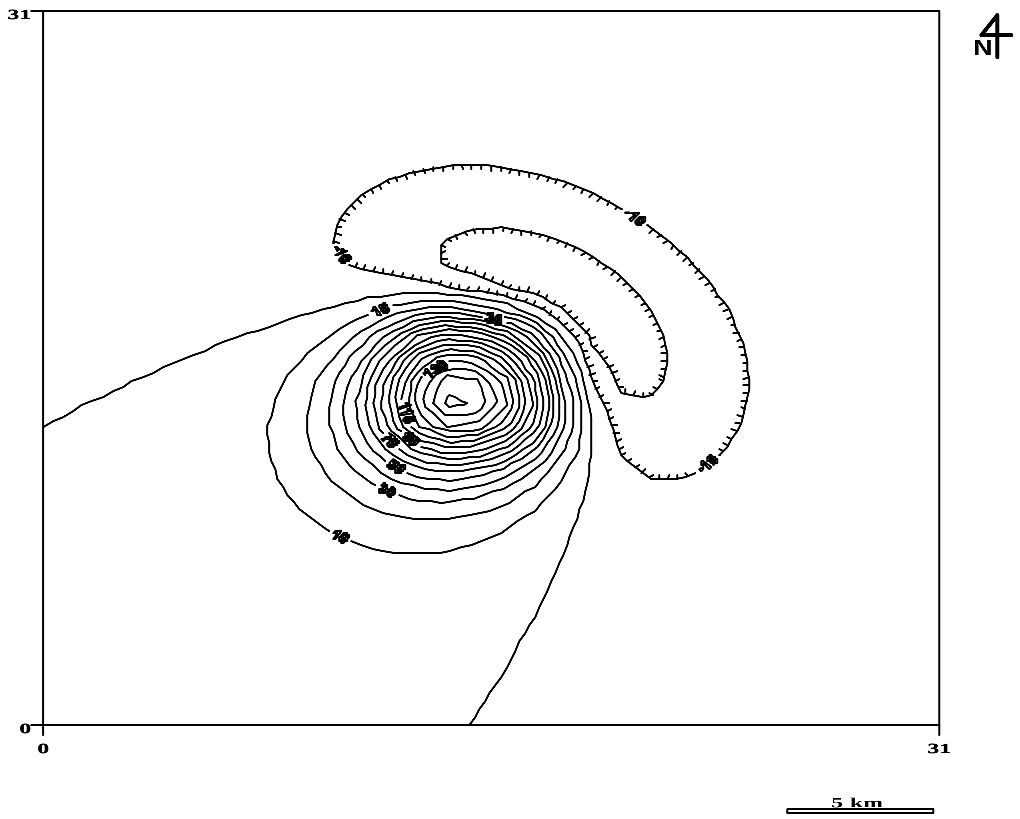

FIG. 2: Magnetic anomaly (nT) of the prism model shown in Figure 1. Contour interval is 10 nT.

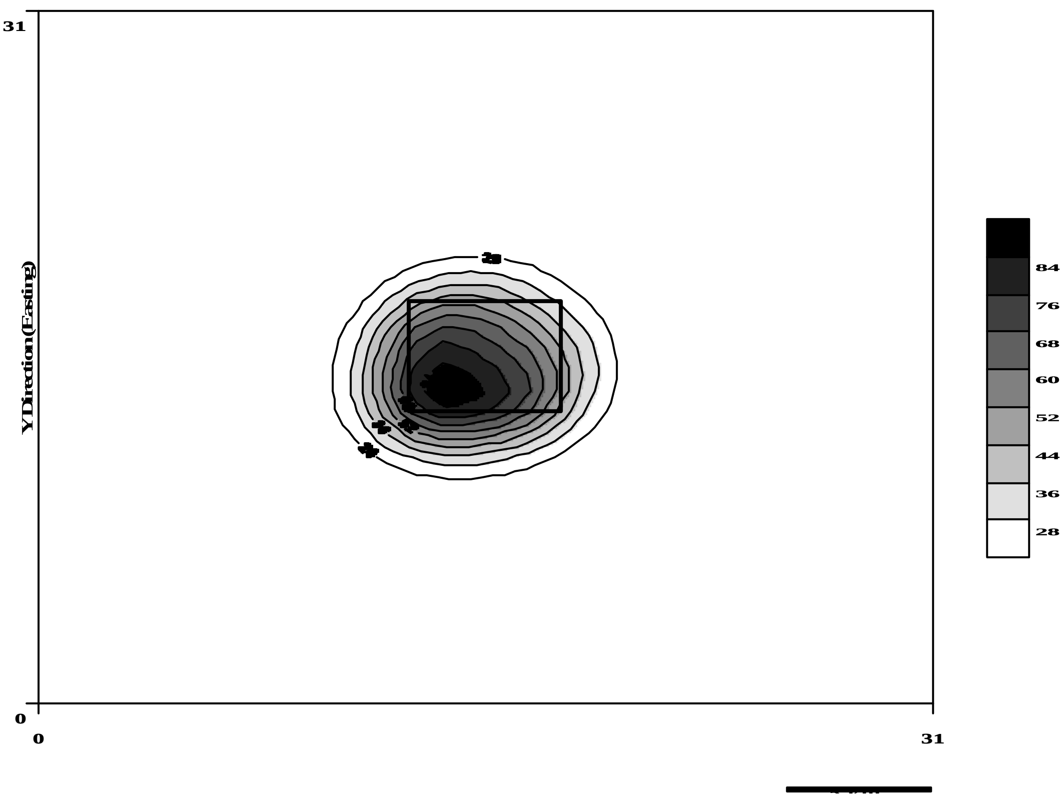

FIG. 3: The analytic signal of the magnetic anomaly of Figure 2. Bold lines show plan view of the causative body.

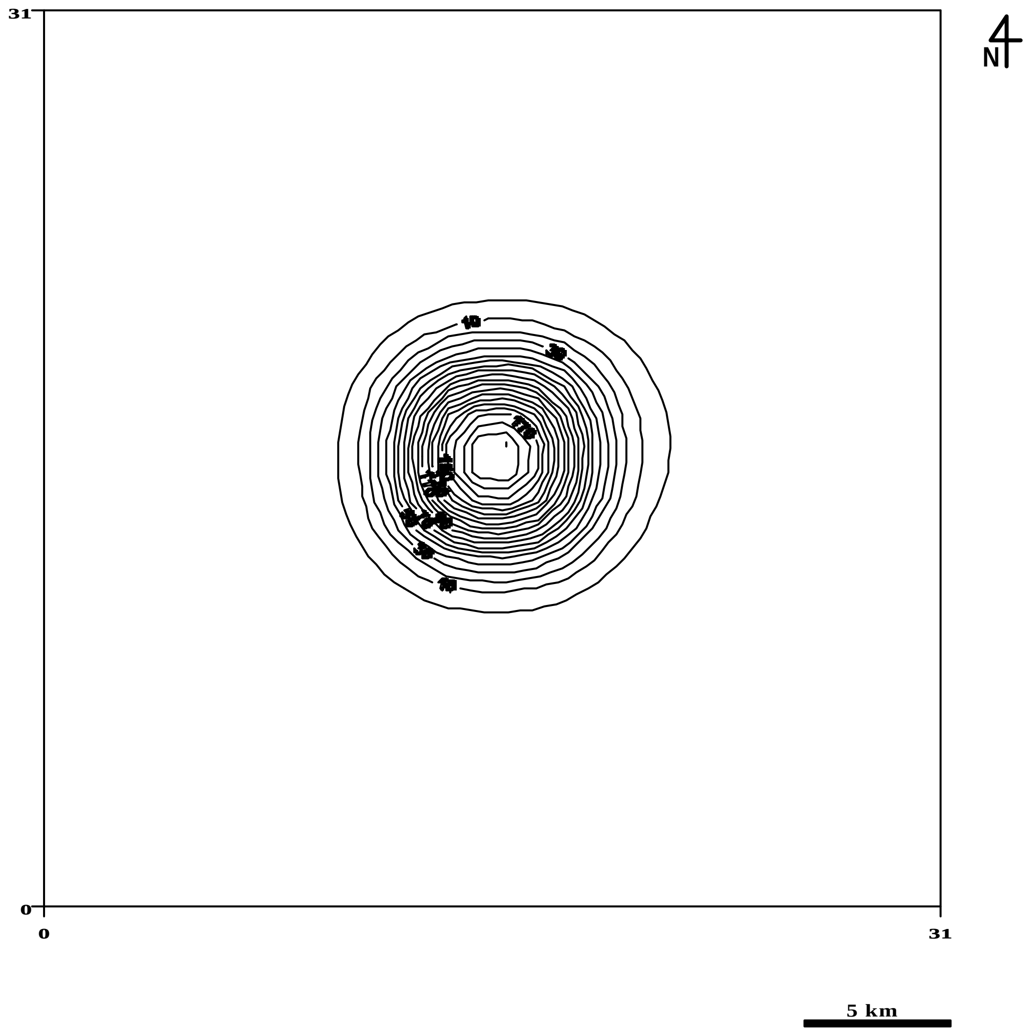

FIG. 4. Reduced to the pole magnetic anomaly. Contour interval is 10 nT.

3. CASE STUDY

The magnetic anomaly map of Turkey (Ates et al., 1999) exhibits strong anomalies in the central-northern Turkey, mainly elongated in E-W direction at about, $39^\circ 40'$ of latitude between the meridian 34°E and 35°E. In this area, the regional geology (inferred from the geological map of Turkey) (Bingol, 1989; Ketin, 1963) shows wide spread young cover units, outcrops of granitic and small gabbroic rocks (Figs. 6 and 7). Aeromagnetic data were obtained in digital form from the General Directorate of the Mineral Research and Exploration (MTA) of Turkey in 2.5 km grid interval. International Geomagnetic Reference Field (IGRF) was removed from the original data using a computer program supplied by Baldwin and Langel (1993). The data processed in this way were contoured to produce the anomaly map shown of Figure 8. This aeromagnetic anomaly map displays strong positive anomalies up to 700 nT along E-W direction flanked in the north and south with minor negative anomalies suggesting, thus, that the magnetization of the causative rocks is near vertical (i.e: the inclination of the body magnetization is 90°). The aeromagnetic anomalies reduced to the pole are also using inclination and declination angles for the Earth's magnetic field 55°N and 4°E, respectively. Reduced to the pole anomaly computed, is shown in Figure 9. It has a similarity with the aeromagnetic anomalies shown in Figure 8. It can be thus, suggested, that the 90° inclination of the body magnetization was justifiable. The analytic signal of reduced to the pole anomaly was produced according to Blakely (1995), and it is shown in Figure 10.

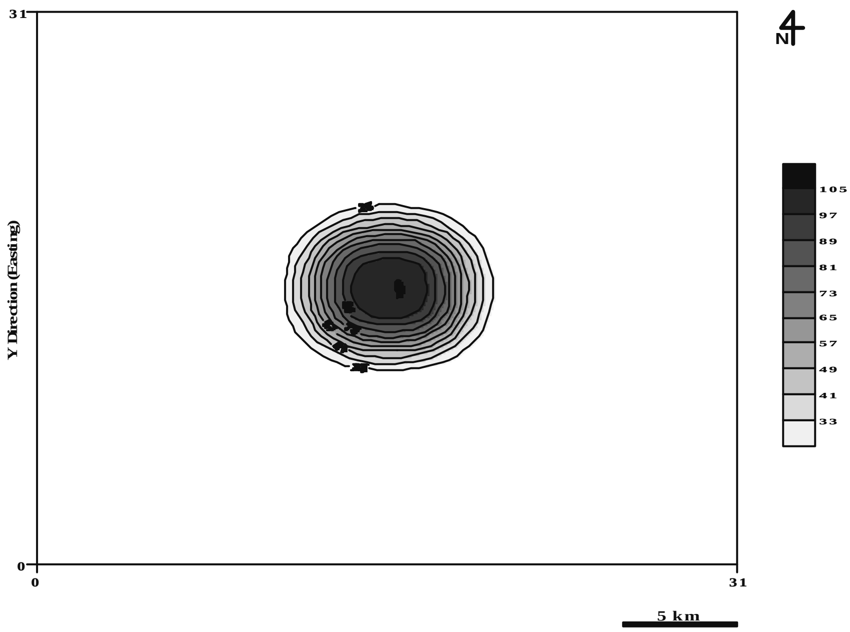

FIG. 5: The analytic signal of reduced to the pole magnetic anomaly. Bold line shows the location of plan view of the model

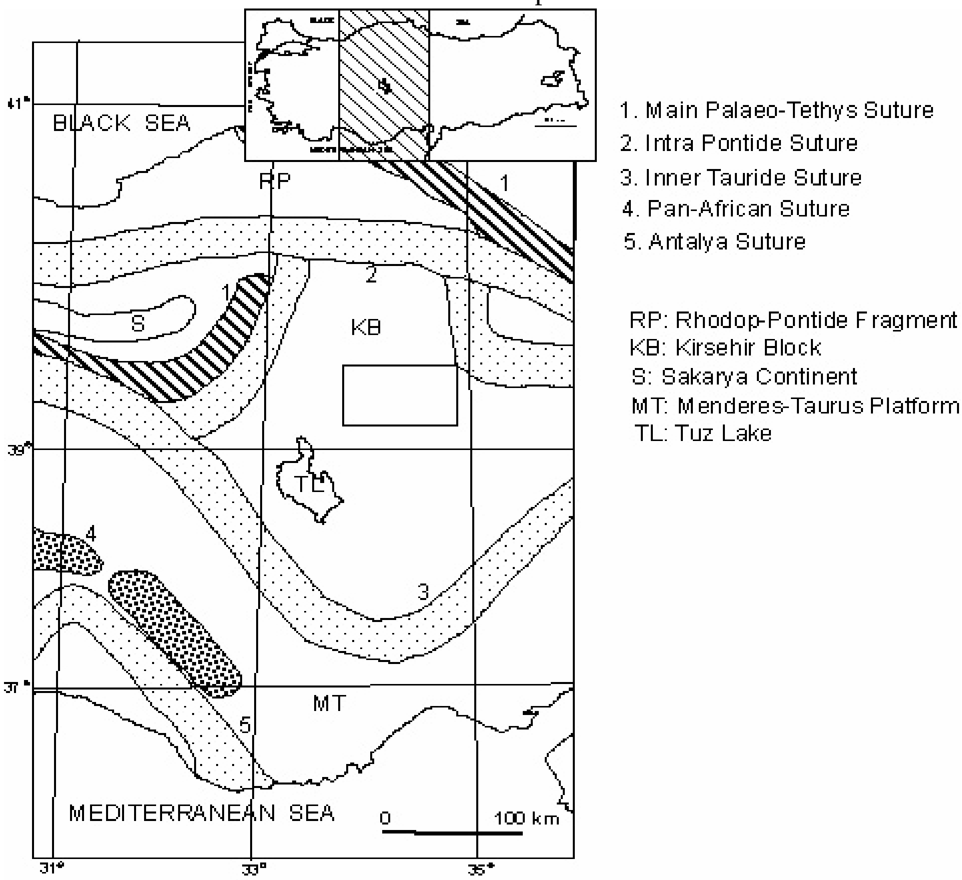

FIG. 6: Location and tectonic map of the surroundings of the study area. The rectangle shows the study area.

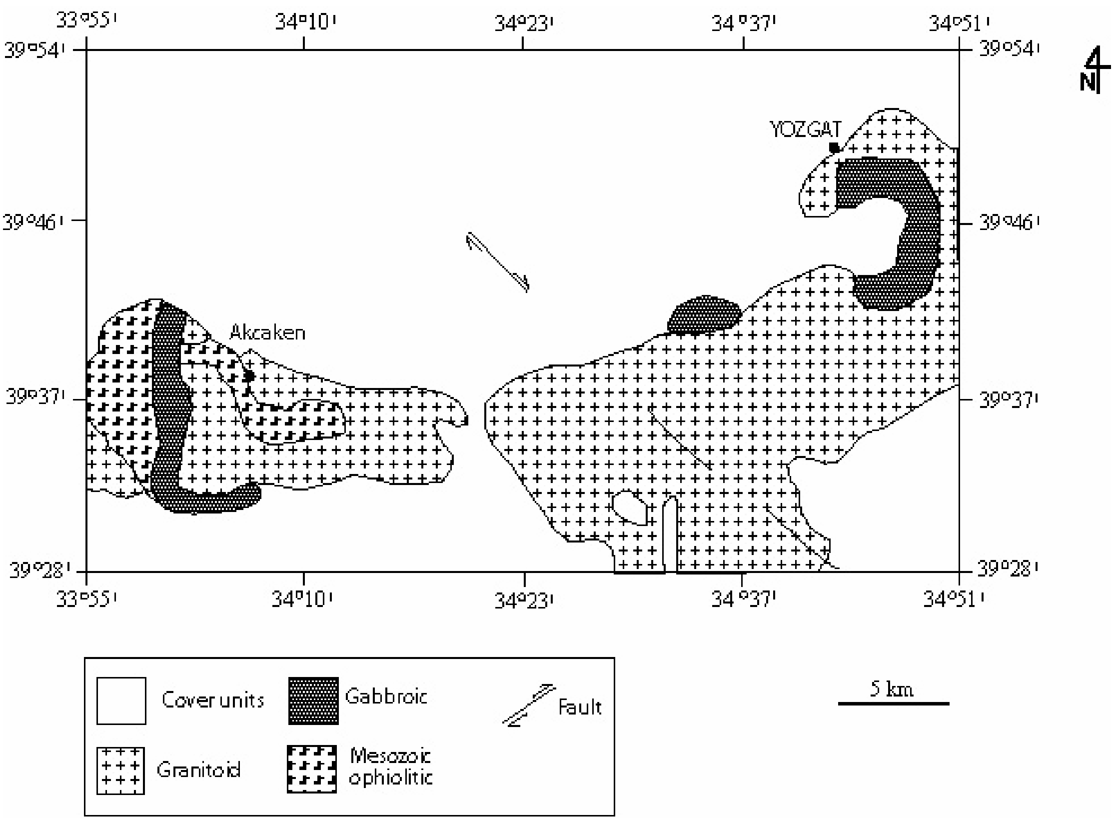

FIG. 7: Simplified geological map of the studied area (enclosed by the box of Figure 6).

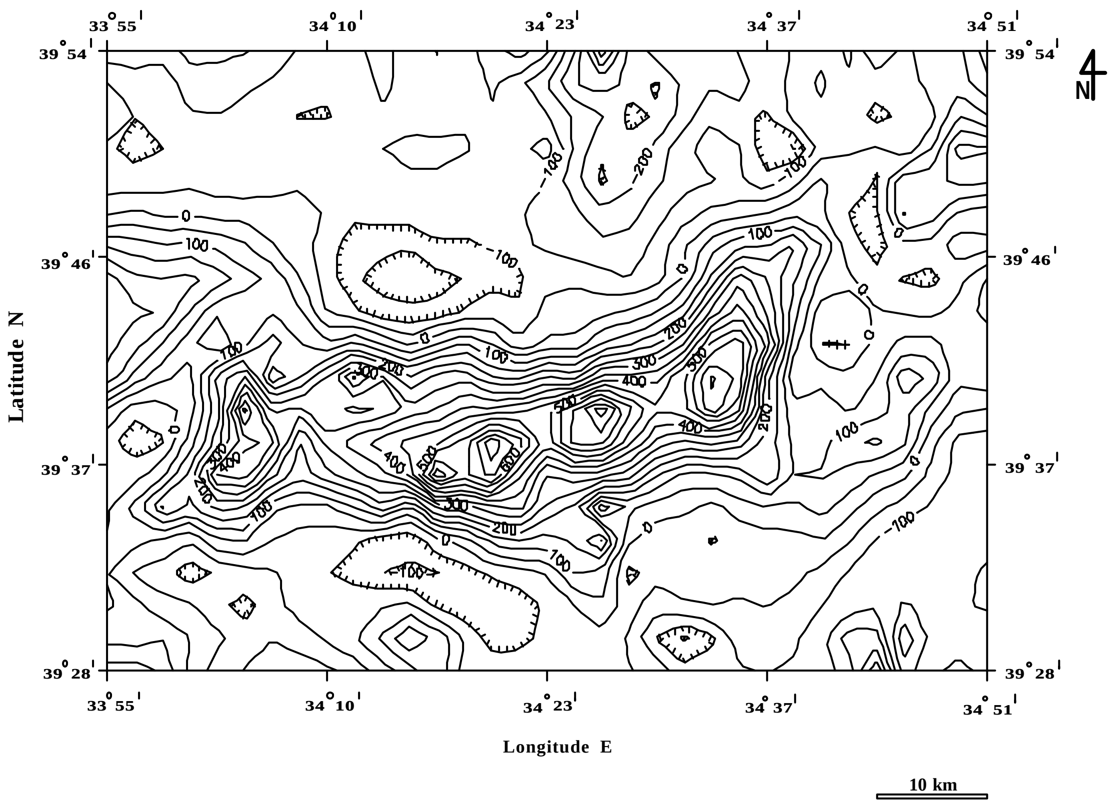

FIG.8: Aeromagnetic anomaly map near the towns of Yozgat and Akcakent in the central northern Turkey. Flight height is 600 m above the ground surface.
Contour interval is 50 nT.

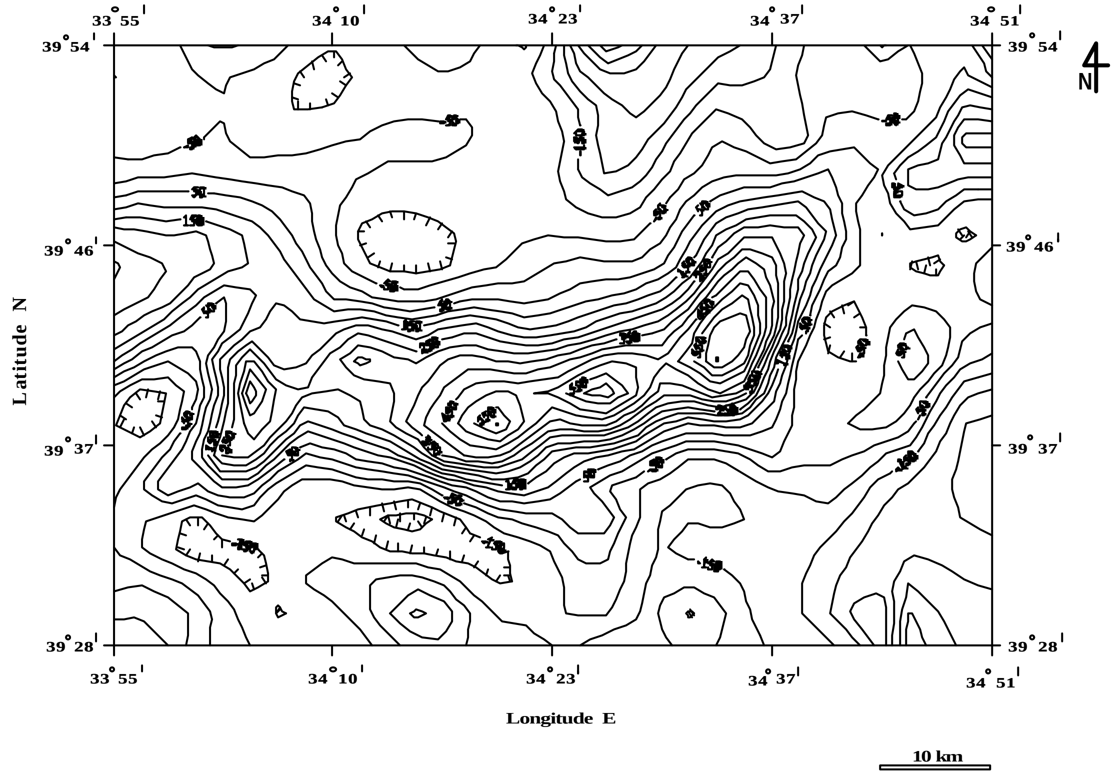

FIG. 9: Reduced to the pole transformation of the aeromagnetic anomaly map of the studied area. Contour interval is 50 nT.

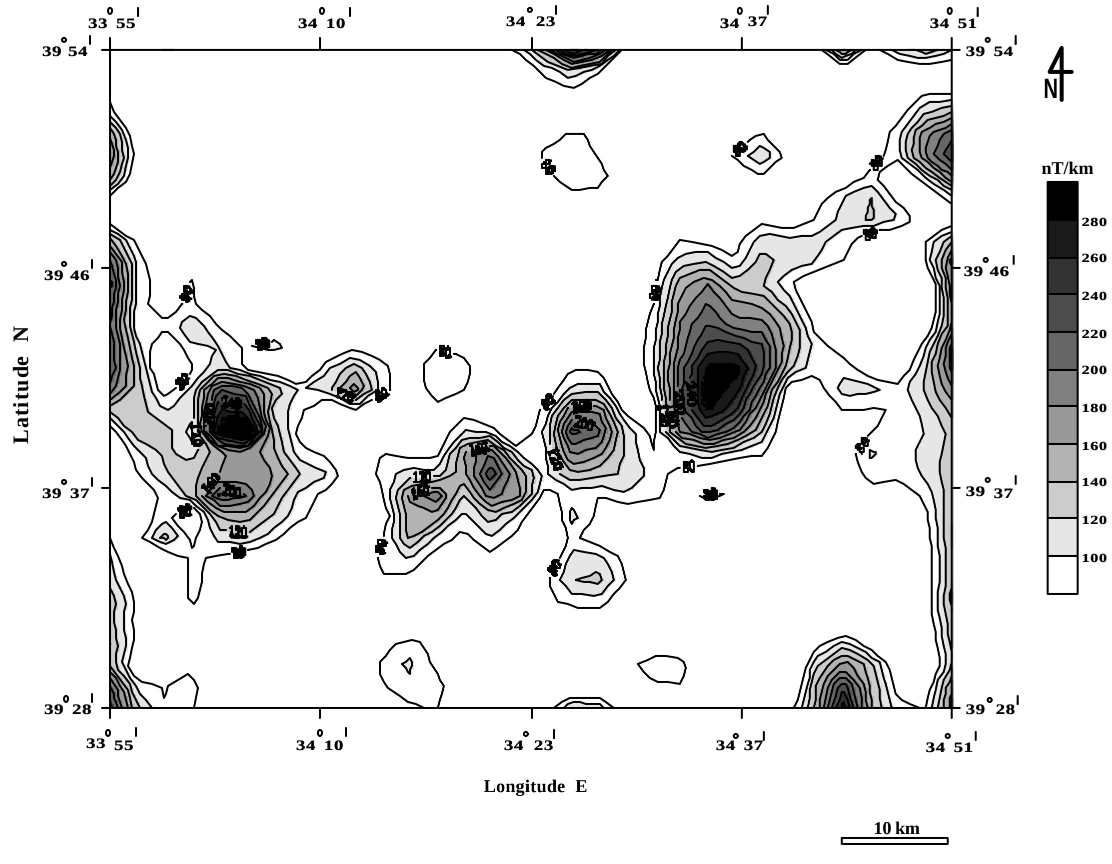

FIG. 10: The analytic signal of reduced to the pole anomalies shown in Figure 9.

Rock type	Location	No. of samples	Maximum susceptibility ($\times 10^{-3}$ SI)
Granitoid	Yozgat	3	1.15
Gabbroic	Yozgat	4	41.10
Gabbroic	Akcakent	3	6.30

CONCLUSIONS

The analytic signal transformation of a synthetic magnetic anomaly to which reduced to the pole data was produced better results than when performed to the total field anomaly directly.

Analytic signal method was applied to reduced to the pole aeromagnetic data of a region near Yozgat and Akcakent towns, in the central-northern Turkey. The regional geology does not show an obvious cause of the anomalies as their location is close to the contact of granitoid and cover units.

Rock samples were collected from the outcrops of the granitoids and gabbros, near towns of Akcakent and Yozgat, to assess the cause of the strong magnetization. Susceptibility measurement were carried out on rock samples using a KT-6 Kappameter, and they are listed in Table. 1. Granitoid rock samples have a mean susceptibility of 1.15×10^{-3} SI, while gabbroic rocks show the maximum susceptibility of 41.10×10^{-3} SI. It can thus be suggested that the gabbroic rocks buried under the cover units are responsible for the magnetic anomalies. Such buried masses of gabbroic bodies are not uncommon in central Turkey. For example Ates (1999); Kadioglu et al., (1998) showed the possibility of existence of deeply buried gabbroic bodies southwards of the studied area, resulted by past subduction.

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