JOURNAL OF THE BALKAN GEOPHYSICAL SOCIETY, Vol. 1, No 3, August 1998, p. 44-52, 11 figs.

Three-dimensional magnetic model of amphibolite complex in Taskesti area, Mudurnu valley, North-West Turkey

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(Received 9 May 1998; accepted 16 July 1998)

Abstract : *The North Anatolian Fault Zone (NAFZ) crosses almost the whole northern part of Turkey. The active tectonism of NAFZ causes major earthquakes. Some big earthquakes originated from the NAFZ caused loss of lifes and properties. The movements of the fault create stress and strain in the surrounding area. Varying tectonic stress on blocks generates changes of the magnetization due to the magneto-elastic rock properties. In this paper, the previously modeled amphibolite complex that poduce the magnetic anomaly in Mudurnu valley, between Adapazari and Bolu, around Taskesti has been remodeled by an automatic three-dimensional modeling method. The new model suggests a magnetized body extending from near surface to the depth of 1.2 km having a susceptibility value of 22 x* 10^{-2}*(SI). The parameters of the new 3-D model improve the interpretation of tectonomagnetic signals.*

Key Words: *Amphibolite complex, Free air correction, Three-dimensional magnetic model.*

INTRODUCTION

The Adapazari - Mudurnu valley region of Turkey have complex geological structures that generated by the branches of the NAFZ. The area has been studied by many researchers to investigate fault movement and surface geology for earthquake prediction (e.g. Sipahioglu, 1984; Uhrenbacher, 1988; Uhrenbacher and Reiprich, 1991; Orbay et al., 1994; Reiprich et al., 1995). A simplified geological map of the research area modified from Uhrenbacher (1988) is shown in Fig. 1.

The continuous seismic activities around the NAFZ cause earthquakes. The fault movement causes stress changes in the rocks resulting piezomagnetic effects in amphibolites that are measurable on the surface as tectonomagnetic signals. Repeated measurements has been performed for the past 10 years and continuous measurements have been recorded in the past 3 years. For proper interpretation of these signals by using the amphibolite complex as a Natural Geomagnetic Stress Sensor, Uhrenbacher (1988) modeled the same body in three dimensions. However, he did not include the magnetic negative anomalous area in the complex, probably, because of the high and rough topography in the northern part of the magnetic body.

New profile measurements were taken during the summer of 1995 around the northern part of the amphibolite complex in order to cover the complete anomalous region. In total 344 data were measured and included to the previous measurements. Former and new profile measurements are shown in Fig. 2.

FREE AIR CORRECTION

The average height of the previous measurements is about 550 m above the sea level. Therefore, a free air correction was applied to new profile measurements in the north.

The change in the regional field was calculated by synthesizing International Geomagnetic Reference Field (IGRF) values at Çakillar base station. The IGRF is a mathematical representation of the Earth's main field due to sources in the core (Dobrin and Savit, 1988), whereas any continuation data is an indirect representation. The IGRF was calculated using a computer program developed by Baldwin and Langel (1993). The Çakillar base station is located at latitude

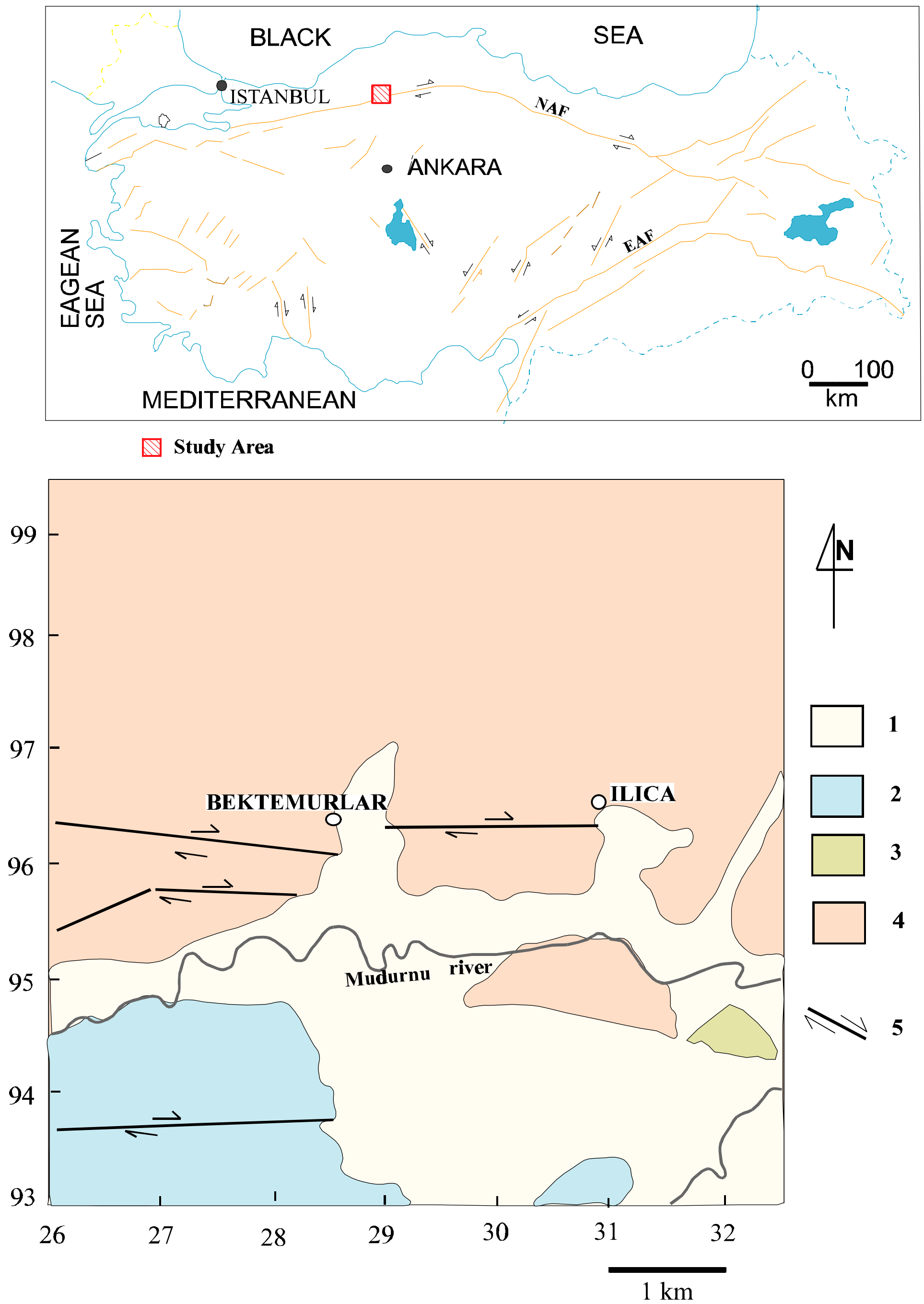

FIG. 1. Simplified geological map of the area (modified from Uhrenbacher, 1988). (1) Neogene cover units, (2) undifferentiated metamorphic rocks, (3) marble, (4) amphibolites, (5) fault.

of 40° 34' 00" and longitude of 30° 48' 87". The IGRF calculations were done at a height of 500 m and 1500 m above sea level. The IGRF gradient was calculated approximately as 0.0233 nT/m. This value represents the dipole and multipole regional gradient, up to a spatial wavelength of 4000 km, although local effects are not included in the IGRF calculation. This value is also in close agreement with Kertz's (1971) calculation which is 0.0247 nT/m for the gradient of the dipole component. The value of 0.0233 nT/m was used to calculate the free air correction for the new measurements above 550 m.

The top of the magnetized part of the amphibolite complex lies at about 550 m. In the north, the topographic height reaches to a level of 700 to 900 meters above the sea level. However, the rocks of this area are almost non-magnetic. The main magnetic element is the amphibolitic complex at the 550 m topographic elevation. Therefore, the terrain effect in the northern part of the area was neglected.

A total magnetic field anomaly map, compiled as described above, is shown in Fig. 3. The data were gridded by using Krigging gridding method as a square matrix. The matrix size is 34 x 34 points (4.25

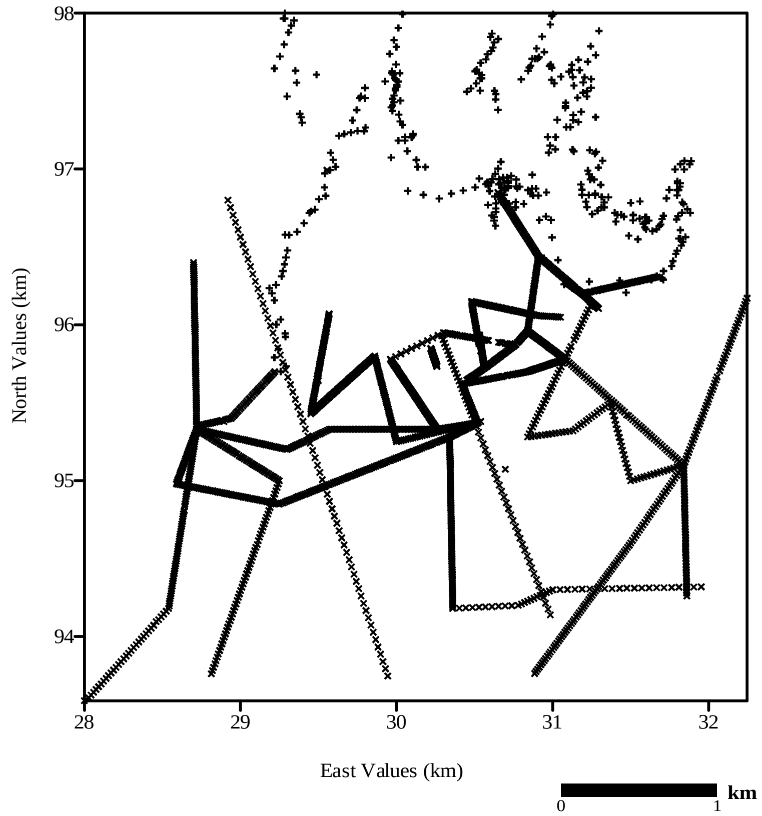

FIG. 2. Base map showing the locations of the data points. Old and new data are shown by (x) and (+) signs, respectively.

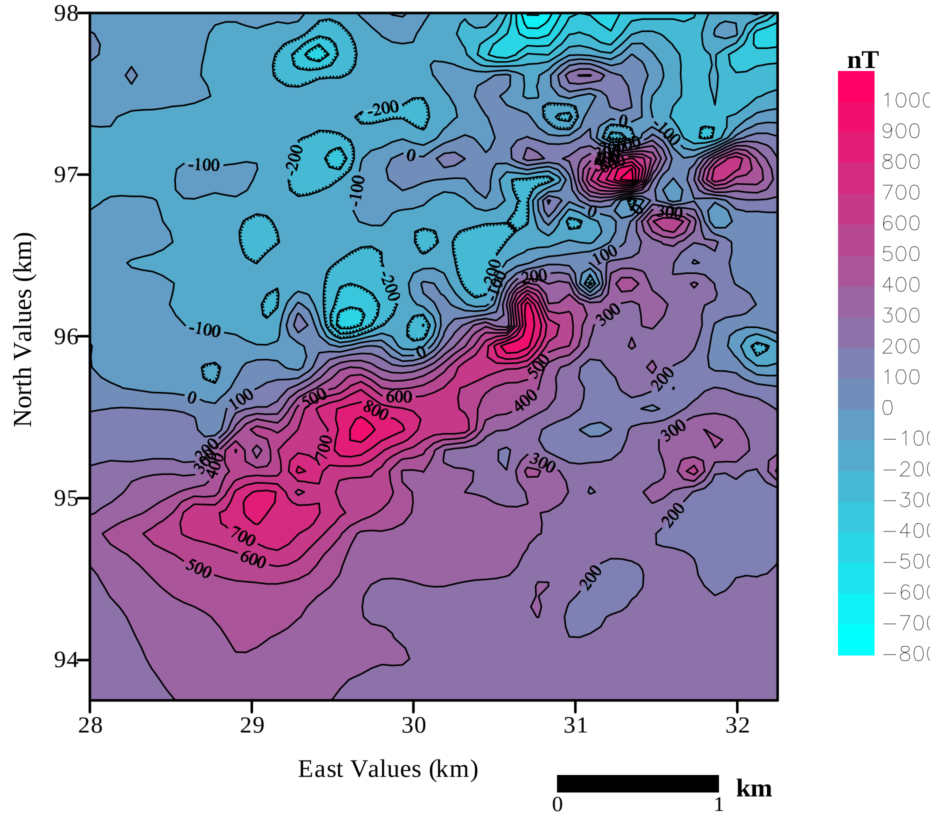

FIG.3. Gridded total component magnetic anomalies. Contour interval= 100 nT.

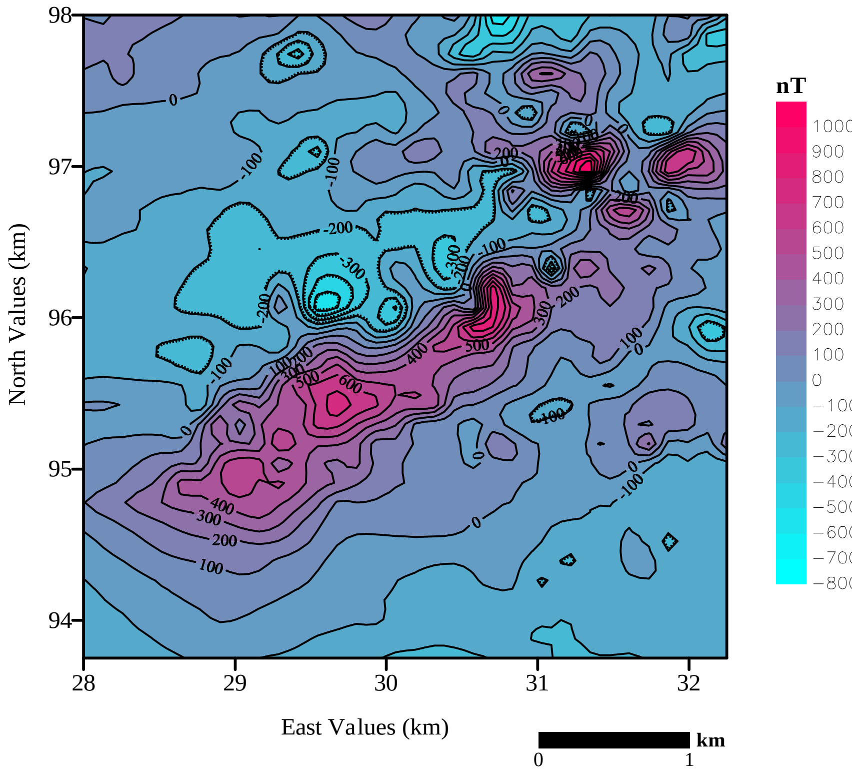

FIG. 4. Linear trend removed magnetic anomalies. Contour interval = 100 nT.

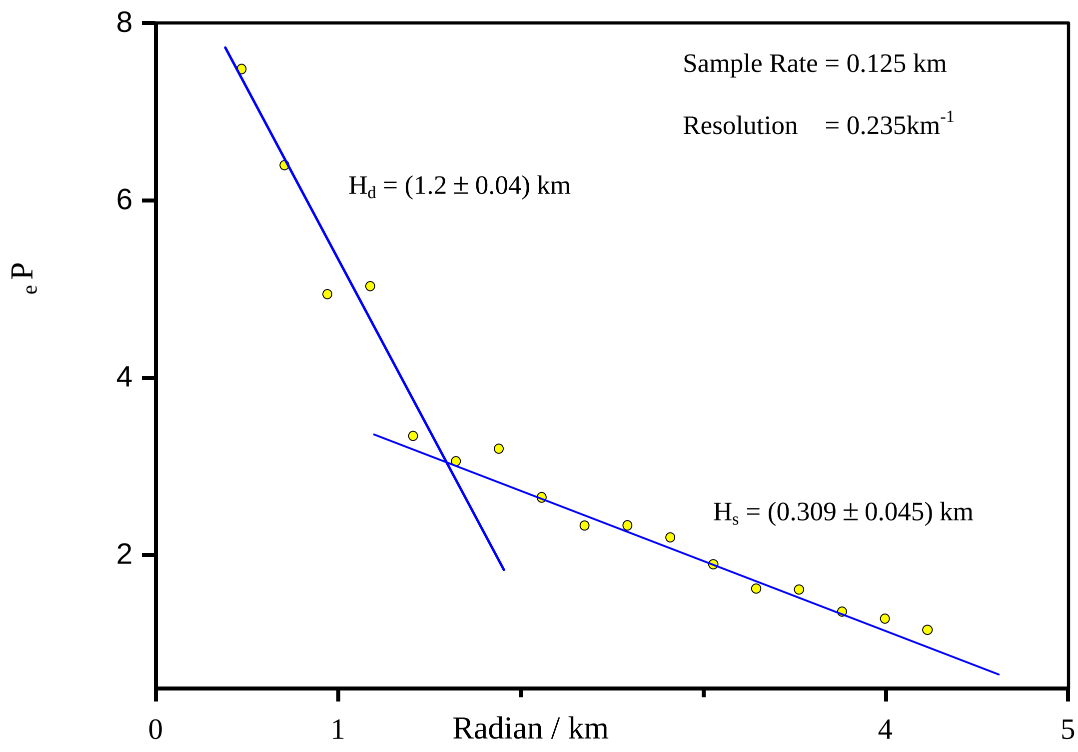

FIG. 5. Power spectra plot. Wavenumber versus the logarithm of power.

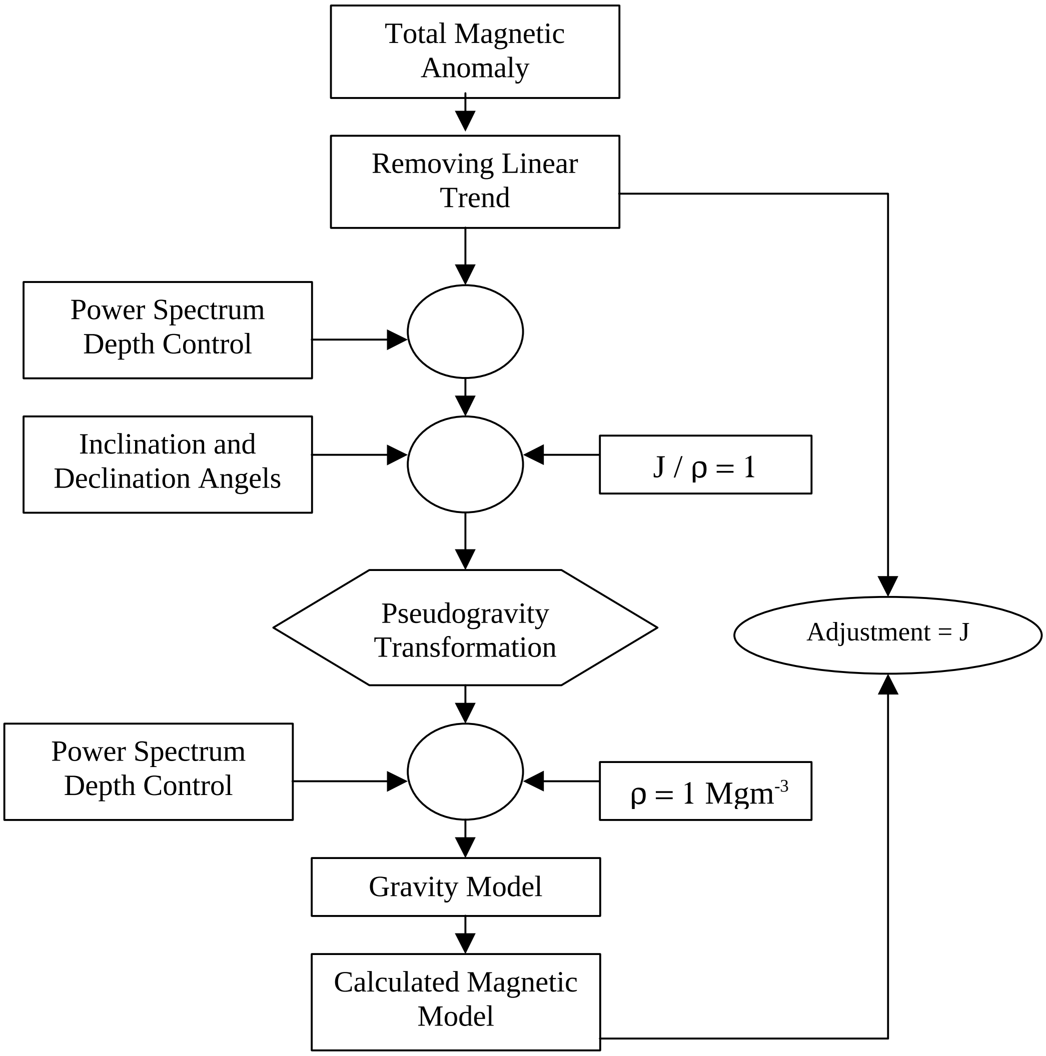

FIG. 6. Steps of automatic three dimensional modeling.

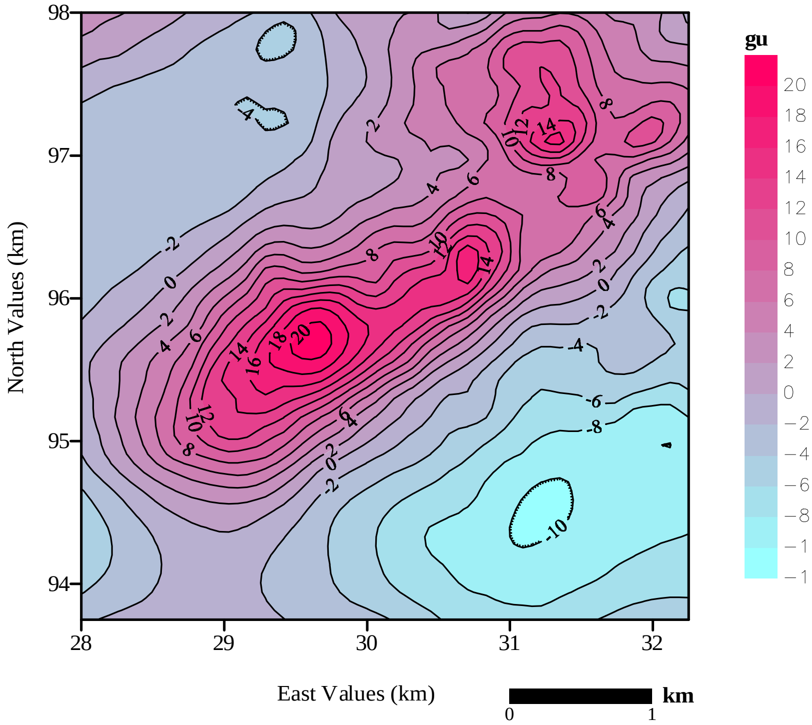

FIG. 7. Pseudogravity anomaly map of Taskesti amphibolite complex.

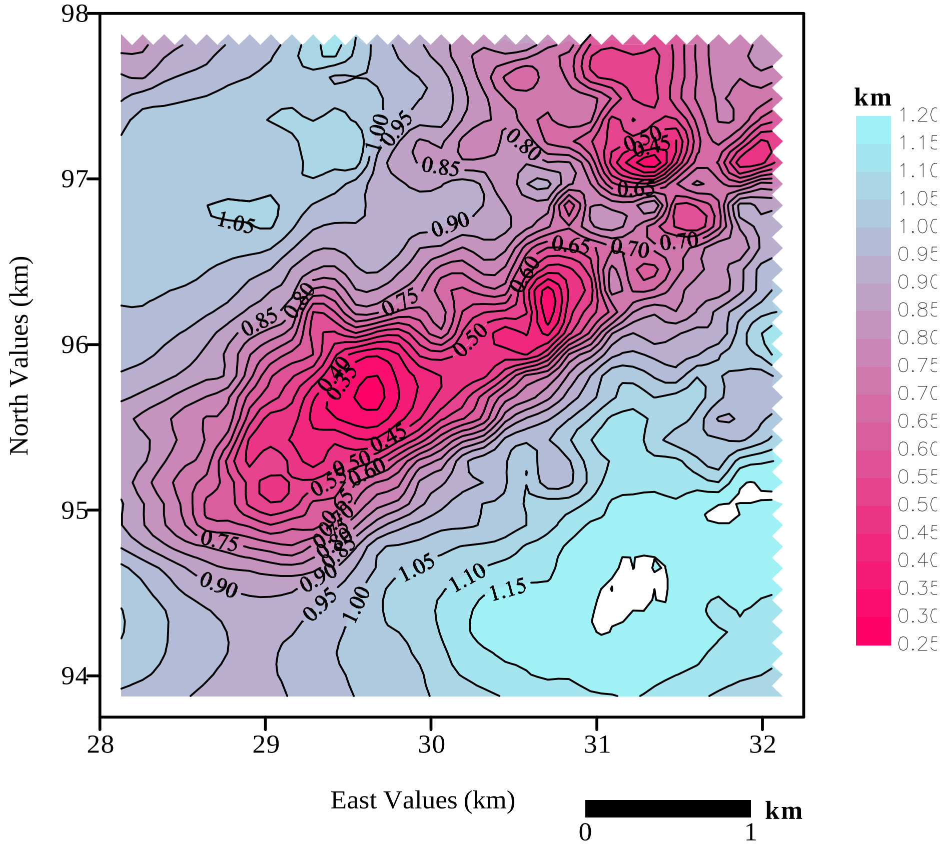

FIG. 8. Three-dimensional model of Taskesti amphibolite complex. Contour interval = 0.05 km.

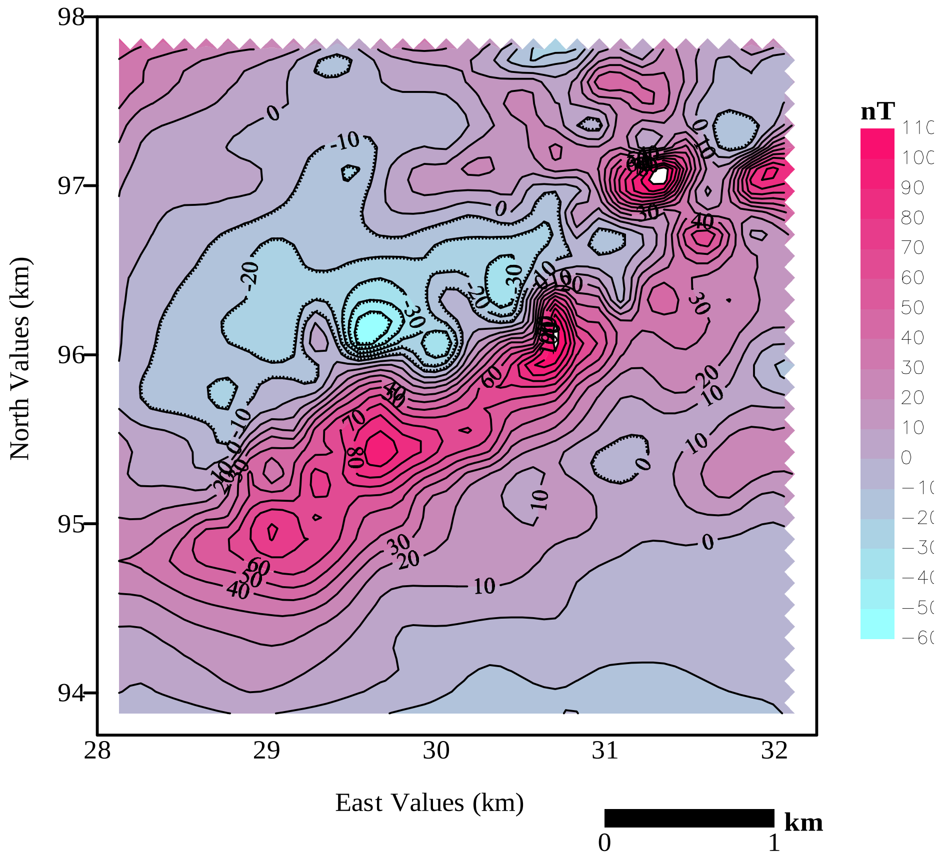

FIG. 9. Reproduction of magnetic anomaly map from the model shown in Fig.8. Contour interval = 10 nT.

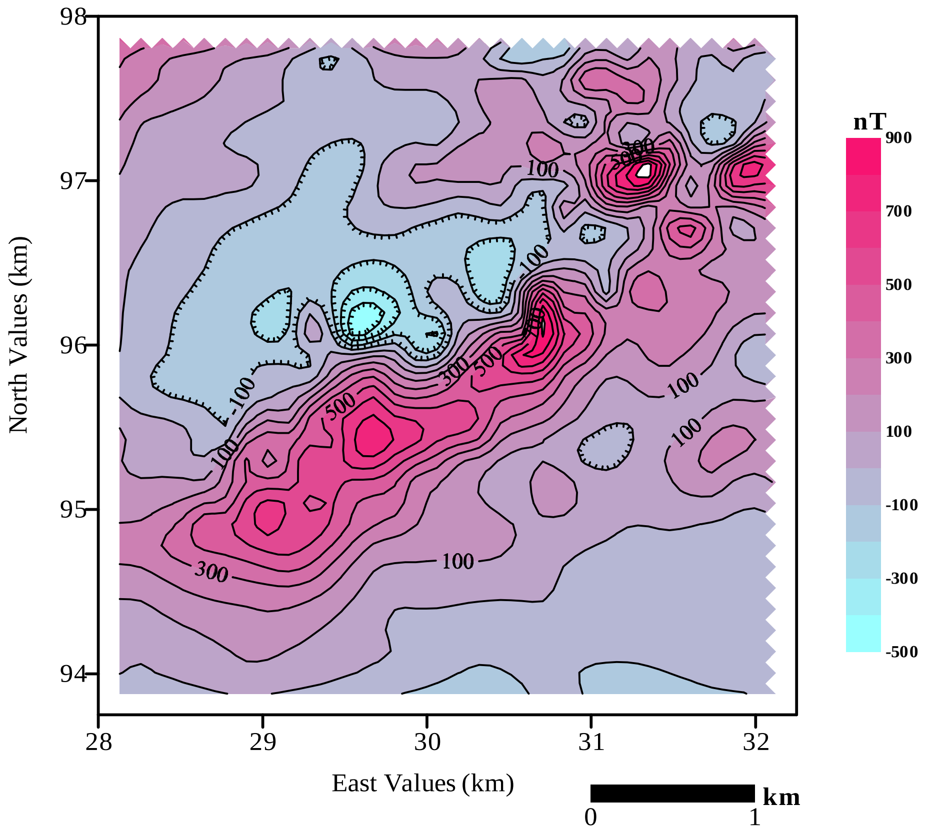

FIG. 10. Scaled magnetic anomaly map. Adjustment factor = 8 Am $^{-1}$. Contour interval = 100 nT.

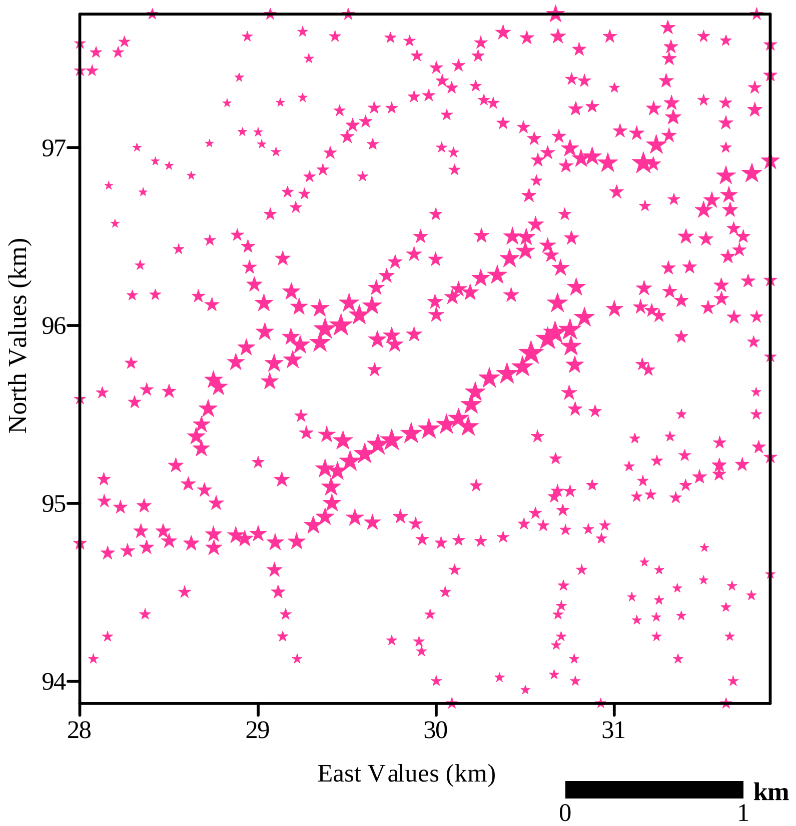

FIG. 11. Locations of the maxima of the horizontal gradient of pseudogravity for the Taskesti magnetic anomaly. Size of stars is proportional to the magnitude of the gradient.

x 4.25 km²), on a UTM geodetic projection. In total, 2.627 data points were used for gridding.

POWER SPECTRUM ANALYSIS AND FILTERING

Prior to the power spectrum calculation, a linear trend was removed from the anomalies shown in Fig. 3 and the results are shown in Fig. 4.

The azimutally-averaged power spectrum suggested by (Spector and Grant, 1970) was applied to the anomalies shown in Fig. 4 and Fig. 5. The logarithmic power spectrum plotted versus wavenumber.

Two straight lines can be distinguished in Fig. 5. These lines considered to be related to the disturbing bodies. The line that has high slope gives 300 m for the depth of the deep source. This body appears to be the amphibolitic complex to be modeled.

THREE DIMENSIONAL MODELING

Kearey (1991) introduced a new method of modeling aeromagnetic anomalies. This method is also used by Ates and Kearey (1993), Ates and Kearey (1995) and Ates et al. (1997) to model aeromagnetic anomalies in southern England and in Western Turkey. Fig. 6 shows the flow chart of the automatic three-dimensional modeling shows the flow chart of the automatic three-dimensional modeling.

Pseudogravity transformation was applied to the anomalies shown in Fig. 4 using a computer program provided by Blakely and Simpson (1986). The angle of natural induced magnetization (I = 55º, D = + 4º) was used to carry out the transformation. The intensity of magnetization (J) to density (ρ) ratio is assumed to be unity. The resulted pseudogravity anomaly map is shown in Fig. 7.

Using a computer program developed by Cordell and Henderson (1968), pseudogravity anomalies were modelled based on the power spectrum depth estimate. The three-dimensional automatic modelling was calculated by means of successive approximations. The causative body can be assumed to be flat-topped, flat-bottomed or symmetrical about a horizon-tal plane. In this case causative body is assumed to be flat-bottomed. An initial approximation of structure is calculated by means of the Bouguer slab relationship. The gravity field of this slab was calculated at each grid point. The ratio of observed to calculate gravity was used to modify the first and successive models until a good agreement is reached. The bottom depth of the body was varied until the top of the body reaches to 0.3 km as suggested by the power spectrum. In this case the bottom of the body was fixed at 1.2 km below the surface. The model is shown in Fig. 8. Magnetic anomalies of the model were produced by using a computer program coded by Kearey (1977) that applies Goodacre's (1973) algorithm (Fig. 9). The anomalies in Fig. 9 were scaled to make comparable the magnetic anomalies with the trend-removed anomalies shown in Fig. 4. The correspond-ing magnetic anomaly map is shown in Fig. 10.

The Earth's field intensity is approximately 36.6 Am^{-1}. In the area, this produces a susceptibility of 22 x 10^{-2} (SI) for the magnetized part of the amphibolite complex. The method developed by Blakely and Simpson (1986), that locates the edges of anomalous bodies is applied to the anomalies shown in Fig. 4 as the third step. At this stage, maxima of the horizontal gradients are calculated. Maxima are displayed as stars and star sizes are assigned to the magnitude of the horizontal gradients. Locations of the maxima of the horizontal gradient map are shown in Fig. 11.

CONCLUSIONS

Bottom depth of the model is 1.2 km from the surface. This indicates a causative body with a more limited thickness than that of the Uhrenbacher's (1988) model. This was probably because, his model was constructed on the assumption that the bottom depth of the prisms extend to infinity. The calculated and adjusted magnetic anomalies in Fig. 10 give a remarkably good fit to the magnetic anomalies shown in Fig. 4. However, there are some discrepancies in details. This may be caused by remanent magnetization.

The susceptibility of the main amphibolitic complex is 22 x 10^{-2} (SI). Although the amphibolite outcrops, it is likely to be weathered. It is possible to find robust amphibole rocks at depth. Former laboratory studies on rock-samples collected on the surface, i.e. the weathered layer, obtained an average value of $20x10^{-3} \pm 11$ (SI) (Uhrenbacher, 1988). The higher susceptibilities of the deeper rocks are in good agreement with the new results. It leads to a higher internal stress sensitivity of the amphibolite complex, acting as a natural geomagnetic stress sensor. The results of laboratory measurements on rock samples give induced intensity, 0.8 ± 0.44 A/m and natural remanent magnetization (I NRM), 0.28 ± 0.28 A/m (Uhrenbacher,1988). These values of approximately 1.1 Am^{-1} is much lower than those of calculated by us.

The thickness of sediment in the south can be inferred from Fig. 8 to be 1.15 km. The biggest stars indicate the outline of the top of the main magnetized amphibolite complex, which lies at a topographic height of approximately 550 meters.

ACKNOWLEDGMENT

We thank to R. O. Hansen and an anonymous referee for their critical comments on the manuscript and also editors A. T. Basokur and G. Tsokas for their helps. We would like to thank GeoForschungs-Zentrum of Potsdam, Germany and Earthquake Research Department of Ankara, Turkey. Part of this project was sponsored by TÜBITAK, Project No: YDABÇAG-293. We extend our thanks to Y.K. Kadioglu of Geological Engineering Department at the Ankara University, for his help on the geology of the area. This is a contribution to the Turkish-German Joint Project on Earthquake Research.

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