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Possibility of deep gabbroic rocks, east of Tuz Lake, central Turkey, interpreted from aeromagnetic data*

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Abstract: *In the east of Tuz lake, gabbroic rocks are observed as small outcrops from the surface geology. Regional aeromagnetic data measured by the Canadian Aero Service (CAS) show strong anomalies in the region. Gabbroic rocks are the only magnetized rocks in the region. However, surface exposures of the gabbroic rocks do not seem to have adequate size and extension to explain such magnetic anomalies of high amplitudes.*

High-and low-pass filtered aeromagnetic anomalies were calculated by using the cut-off wavenumbers obtained from the azimuthally-averaged power spectra. Two-dimensional models were constructed from the high and low-pass filtered anomalies with the control of the power spectrum depth estimates. The two-dimensional model produced from the low-pass filtered anomalies suggests the existence of a conical shaped, deeply buried, body. The bottom of the body extends down to deeper levels of the upper crust. Pseudogravity anomalies and maxima of the horizontal gradient of the low pass-pass filtered anomalies were produced. A three-dimensional model was also constructed by employing an automated method. This model resembles the two-dimensional model produced from the low-pass filtered anomalies.

Key Words: *Gabbroic Rocks, Aeromagnetic Data, Central Turkey*

INTRODUCTION

In central Turkey, gabbroic rocks outcrop in many places. Most of the gabbroic rocks were identified as ophiolites of the Neotethyan ocean floor by some researchers (i.e. Göncüoglu et al. 1991, 1992; Göncüoglu and Tureli, 1994). It has been shown for the first time that the bodies causing aeromagnetic anomalies have deep roots around Keskin and Kaman towns, in Kirikkale (Ates, 1995). Shortly after this, it was understood that the body that cause the gravity anomaly centered on [32°45', 37°45'] (known as Konya anomaly) would have a deep root. This was proved during a test run of newly purchased instruments with applications on the Transient Electromagnetic (TEM) and Controlled Source Audio-Frequency Magnetotelluric (CSAMT) methods (pers. comm: T. Tokgoz of General Directorate of Mineral Exploration and Research, Ankara). Moreover, two-dimensional magnetic modelling of gabbroic rocks at the north of the presently studied area have shown that gabbroic rocks have small exposures on the surface, but their extension continue (Kadioglu, et al. 1998) in the deeper parts.

In this paper, deep relation of small surface outcrops of gabbroic rocks (Figs.1 and 2) with respect to an aeromagnetic anomaly (Fig.3) centered on [38°41', 33°56'] is investigated.

REGIONAL TECTONICS AND GEOLOGY OF THE AREA

The research area is situated at the east of the Tuz Lake. Regional tectonic features of the area are shown in a simplified tectonic map (Fig.1) reproduced from Ketin (1966) and Kadioglu, et al. (1998). The tectonic map also shows major suture zones in central Turkey. The research area, shown by the red box, appears to be far away from any of the sutures. A simplified geological map of the study area from Atabey (1989); Atabey and Uygun (1989) is shown in Figure 2. The surface geology shows that the region is dominantly covered by very young sedimentary units in the south, west and northwest. Granitic rocks are exposed at the center, east and southeast of the area. Large pieces of

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marbles can be seen near the granitic rocks. A few small sized gabbroic outcrops can be observed in the east of the area.

DATA ANALYSIS

Aeromagnetic data were collected in the Central Anatolian Crystalline Complex (CACC) around the supposed ophiolitic belt by the Canadian Aero Service (CAS) (Hutchison, et al. 1962). The data were obtained at a mean terrain clearance of 150 m above the surface along flight lines spaced 1 km apart. A constant value of 45,000 nT was removed from the surveyed data and the survey results were displayed as anomaly maps of 1:25,000 scale. Anomalies of the study area shown in the geological map (Fig. 2) are given in Figure 3 in the form of an analogue map.

Data processing by geophysical methods

The anologue aeromagnetic anomalies (Fig. 3) were digitized using a digitizer and then the data were transferred to a computer for digital processing. 4847 data points were obtained in total from the anologue anomalies. The data were gridded at 0.25 km intervals in a 13 × 13 km area using a Kriging gridding routine to construct a data matrix of 53 × 53 = 2809. The number of the gridded data are less than the number of the digitized data. Thus, we may assume that the gridded data set wholly represents the anologue map. The contoured aeromagnetic anomaly map (Fig. 4) appears to be polarized along the Earth's natural magnetic field indicating that remanent magnetization may not exist .

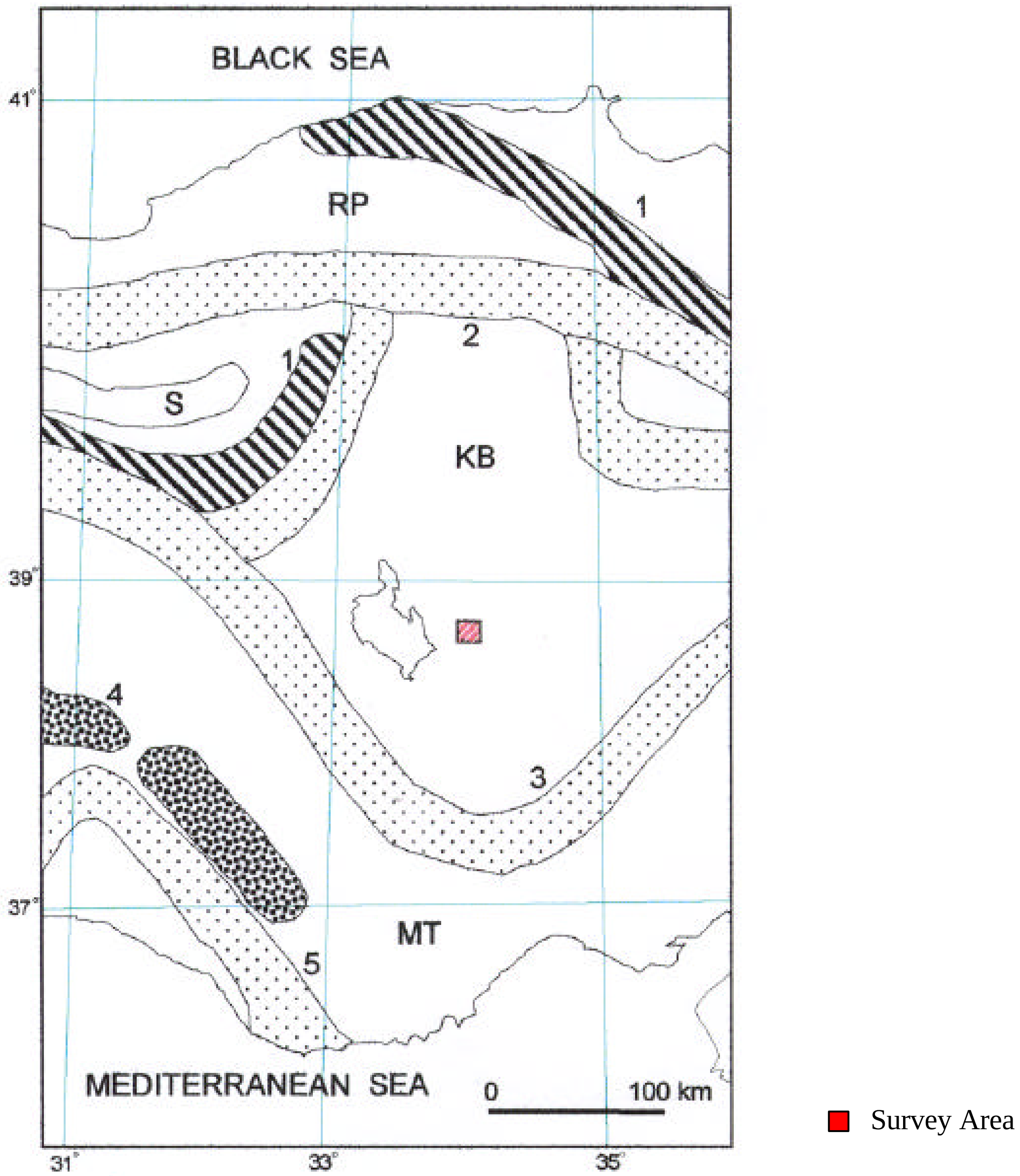

FIG. 1. Regional tectonic setting and location of the area (simplified from Ketin, (1966); Kadioglu et al. (1998)). Red coloured box shows the area of study. (1. Main Paleo-Tethys Suture, 2. Intra Pontide Suture, 3. Inner Tauride Suture, 4. Pan-African Suture, 5. Antalya Suture) (RP: Rhodop-Pontide Fragment; KB: Kirsehir Block; S: Sakarya Continent; MT: Menderes-Taurus Platform).

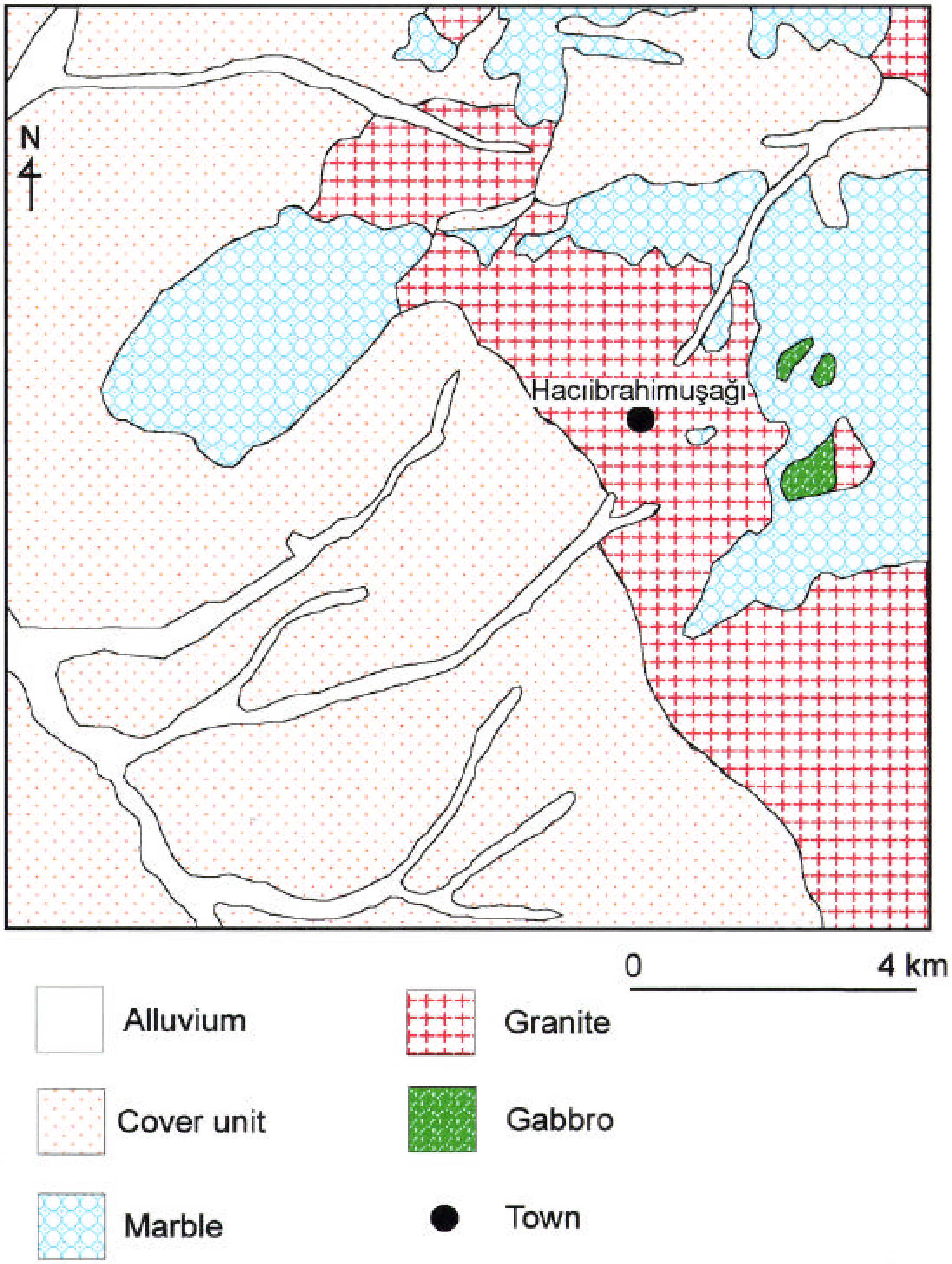

FIG. 2. Simplified geological map of the study area (map simplified from Atabey (1989); Atabey and Uygun (1989)).

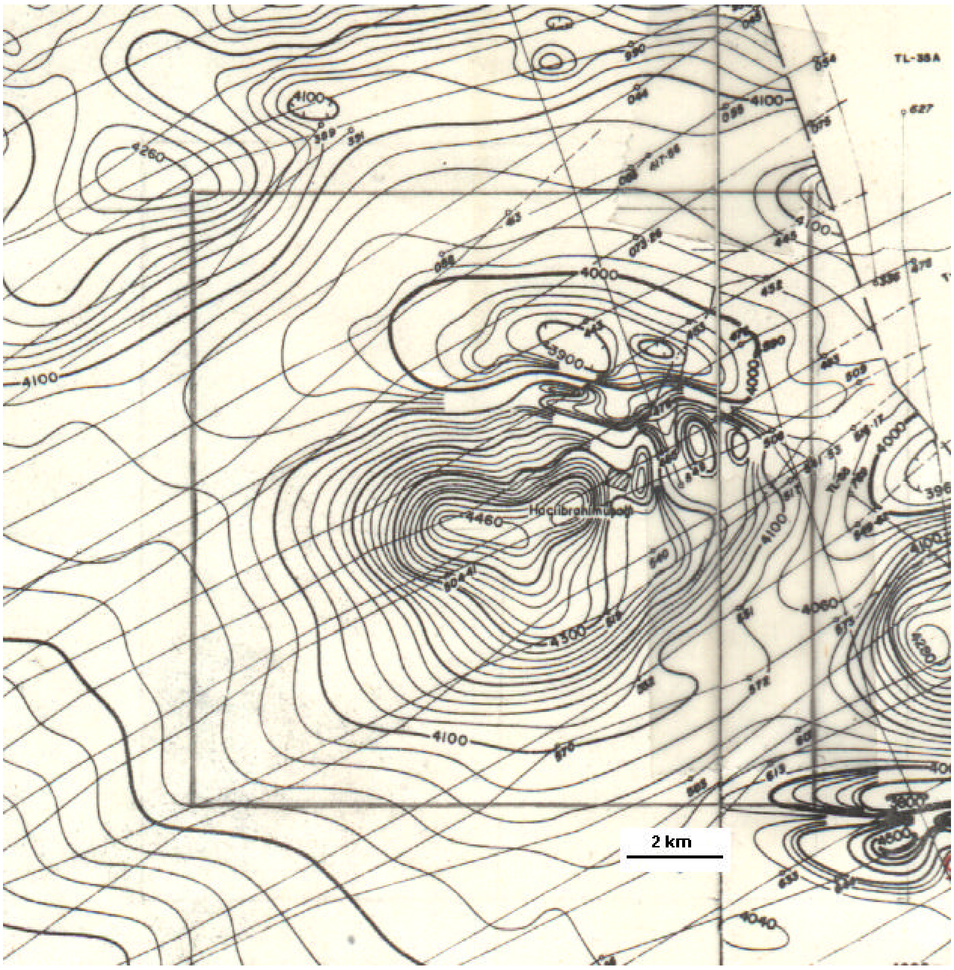

FIG. 3. Aeromagnetic anomalies surveyed by the Canadian Aero Service (Hutchison et al. (1962)). Contour interval is 20 nT.

A regional planar trend was removed from the aeromagnetic data shown in Figure 4 to strengten the near surface effects. The regional planar trend removed from the magnetic anomaly map residual field is shown in Figure 5. The azimuthally-averaged power spectrum method of Spector and Grant (1970) was applied to the data in order to determine the top of source bodies causing magnetic anomalies. The logarithm of power spectra plotted versus wavenumber (Fig.6) could be fitted to two dominant lines. The steepest line yields at a depth of 1.69 km for the top of the anomalous body. Therefore, it can be considered as a deep body. Presence of shallow units can be inferred from the less steep line which gives a depth of 0.29 km from surface. The cut-off wavenumber obtained from the intersection of the two lines, is 0.37 k (2.70 λ). The residual aeromagnetic anomalies were high-pass filtered by using the cut-off wavenumber. The high-pass filtered aeromagnetic map shows concentric circular shaped anomalies (Fig.7). The amplitude of the circular anomalies is higher in the north than elsewhere suggesting a strong possibility of the existence of near surface gabbroic rocks in the surveyed area. It can also be suggested that, in SW, under the sedimentary cover, gabbroic rocks may exist beneath the circular shapes. The residual aeromagnetic anomalies in Figure 5 were low-pass filtered using the above mentioned cut off wavenumber. The low-pass filtered aeromagnetic anomalies are shown in Figure 8. The low-pass filtering was necessary to remove near surface effects. It can be concluded that the low-pass filtered aeromagnetic anomalies originate from a deep source that is larger than the surface outcrops.

Using a computer program written by Blakely and Simpson (1986), the pseudogravity anomalies (Fig.9) were produced from the low-pass filtered aeromagnetic anomalies using the parameters of the Earth's natural magnetic field (inclination and declination angles of 55° and 4°, respectively). Shape analysis suggests that the pseudogravity transformation is successful and the causative body does not seem to have the effect of any remanent magnetization. Blakely and Simpson's (1986) algorithm allows the calculation of maxima of the horizontal gradient of pseudogravity anomalies. Maxima shows various density and magnetization boundaries of formations that cause gravity and magnetic anomalies. Maxima give good results on abrupt or near vertical contacts. The maxima map produced by this way is shown in Figure 10.

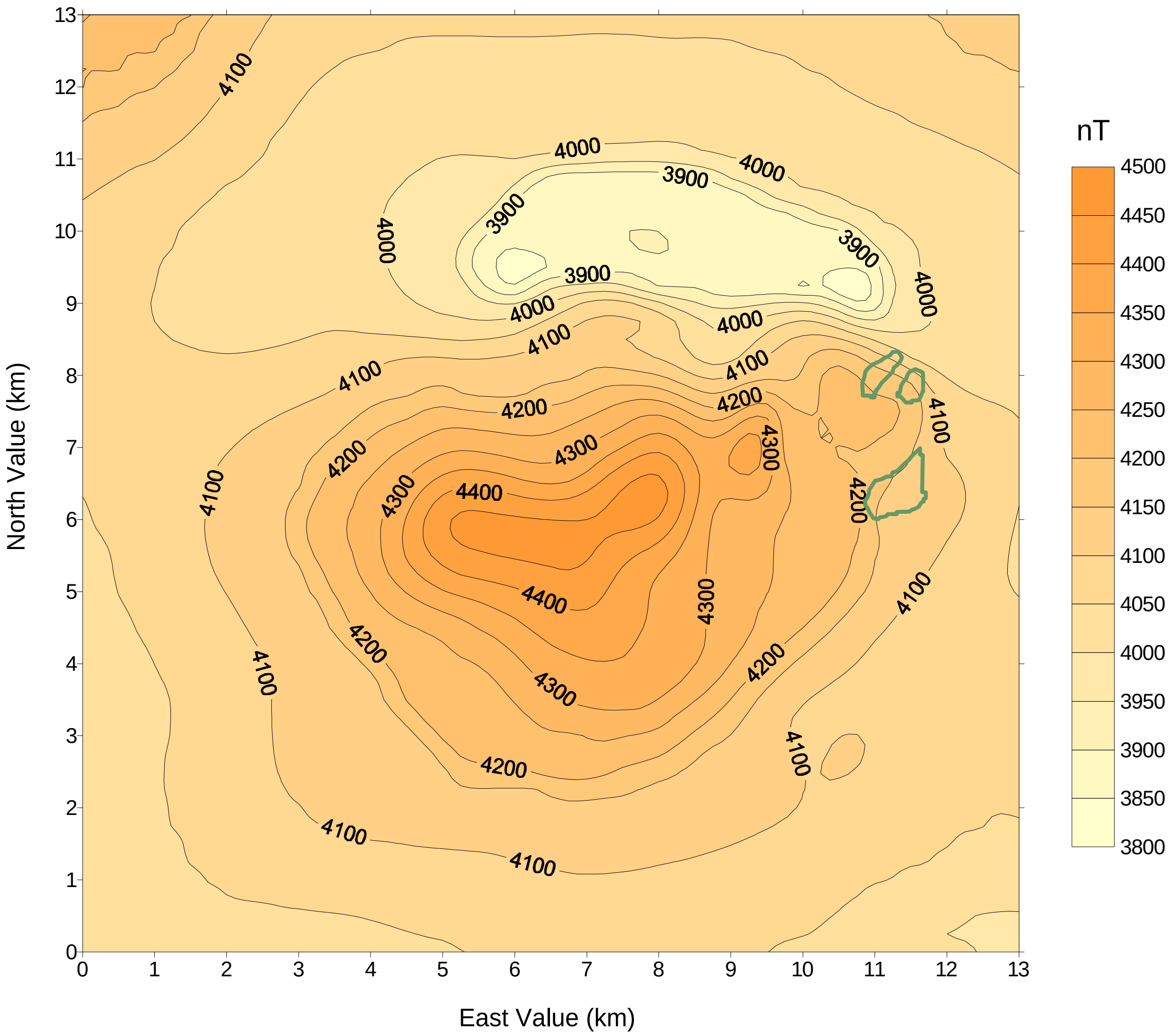

FIG. 4. Computer generated aeromagnetic anomalies digitized from the anomalies shown in Figure 3. Contour interval is 50 nT. Dark green coloured annotations show the outcrops of the gabbroic rocks at the surface.

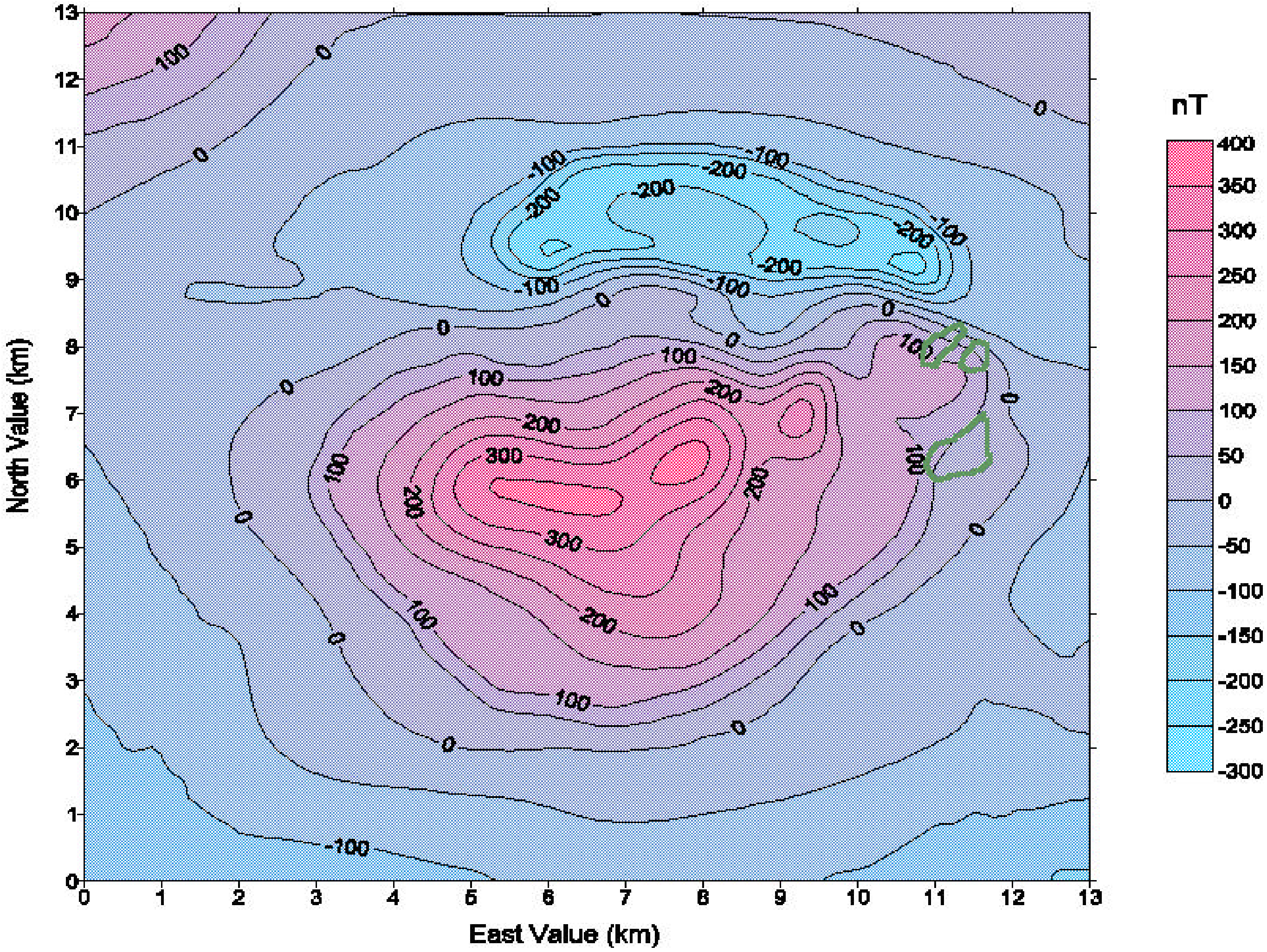

FIG. 5. Planar trend removed aeromagnetic anomalies. Contour interval is 50 nT. Dark green coloured annotations show the outcrops of the gabbroic rocks at the surface.

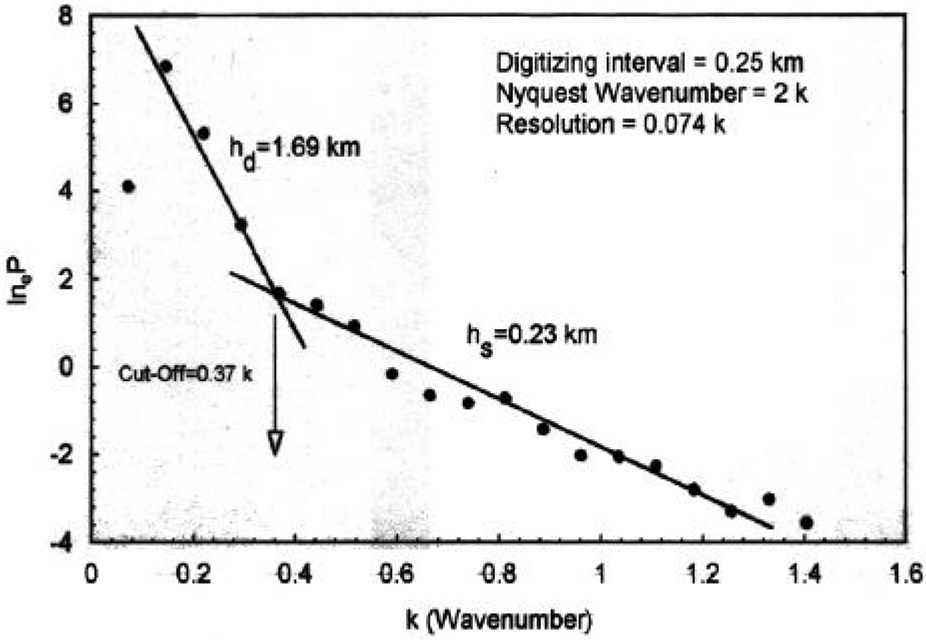

FIG. 6. Azimuthally averaged power spectrum of the planar trend removed aeromagnetic anomalies. Arrow shows the cut-off wavenumber of 0.37 k. h_d and h_s are the deep and shallow source bodies, respectively.

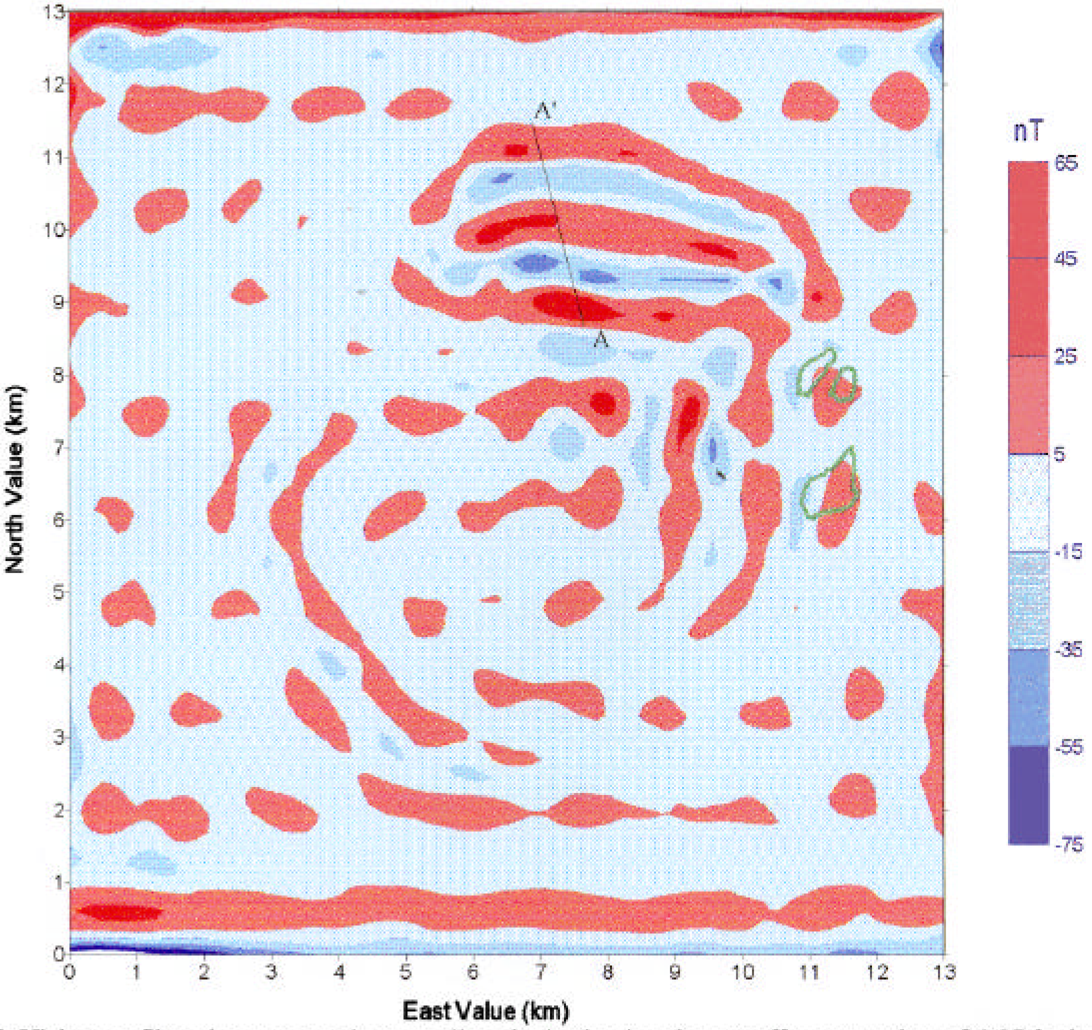

FIG. 7. High-pass filtered aeromagnetic anomalies obtained using the cut-off wavenumber of 0.37 k shown in Figure.6. Contour interval is 20 nT. Dark green coloured annotations show the outcrops of the gabbroic rocks at the surface.

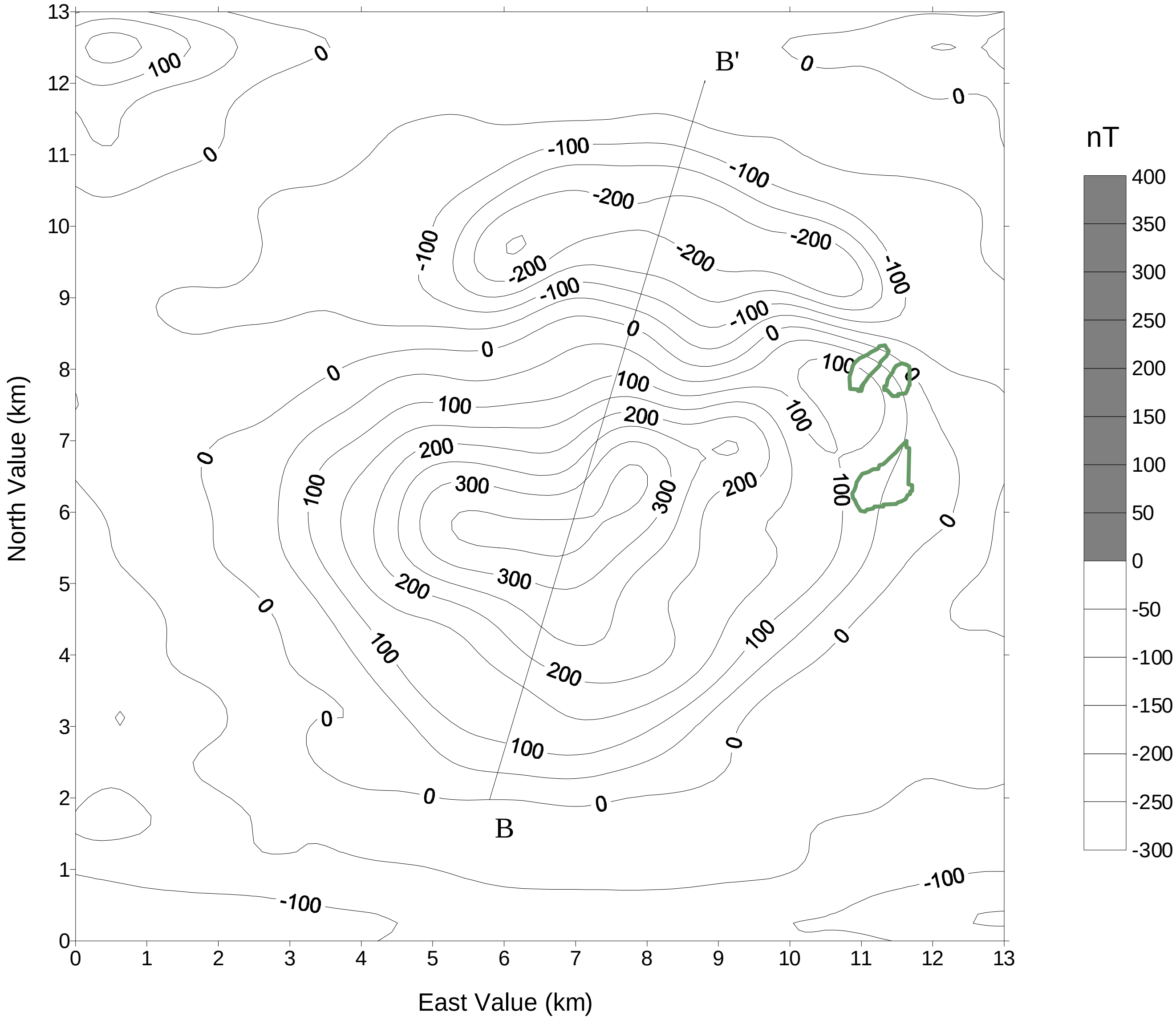

FIG. 8. Low-pass filtered aeromagnetic anomalies obtained using the cut-off wavenumber of 0.37 k shown in Figure.6. Contour interval is 50 nT. Dark green coloured annotations show the outcrops of the gabbroic rocks at the surface.

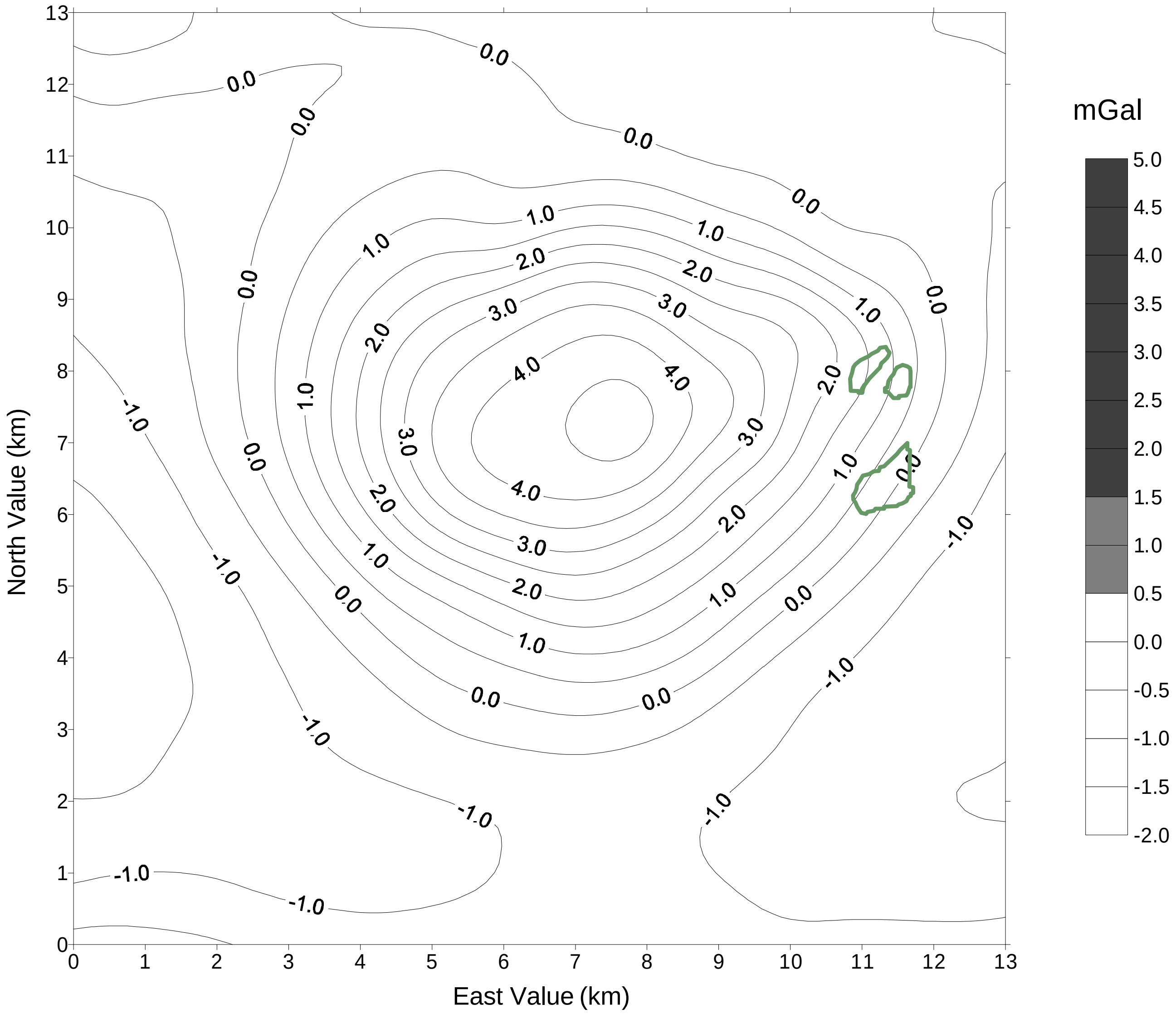

FIG. 9. Pseudogravity transformed anomalies obtained from the planar trend removed aeromagnetic anomalies shown in Figure 5. Transformation was carried out assuming the body was magnetized only by induced magnetization. The ratio of density to intensity of magnetization is unity. Contour interval is 0.5 mGal. Dark green coloured annotations show the outcrops of the gabbroic rocks at the surface.

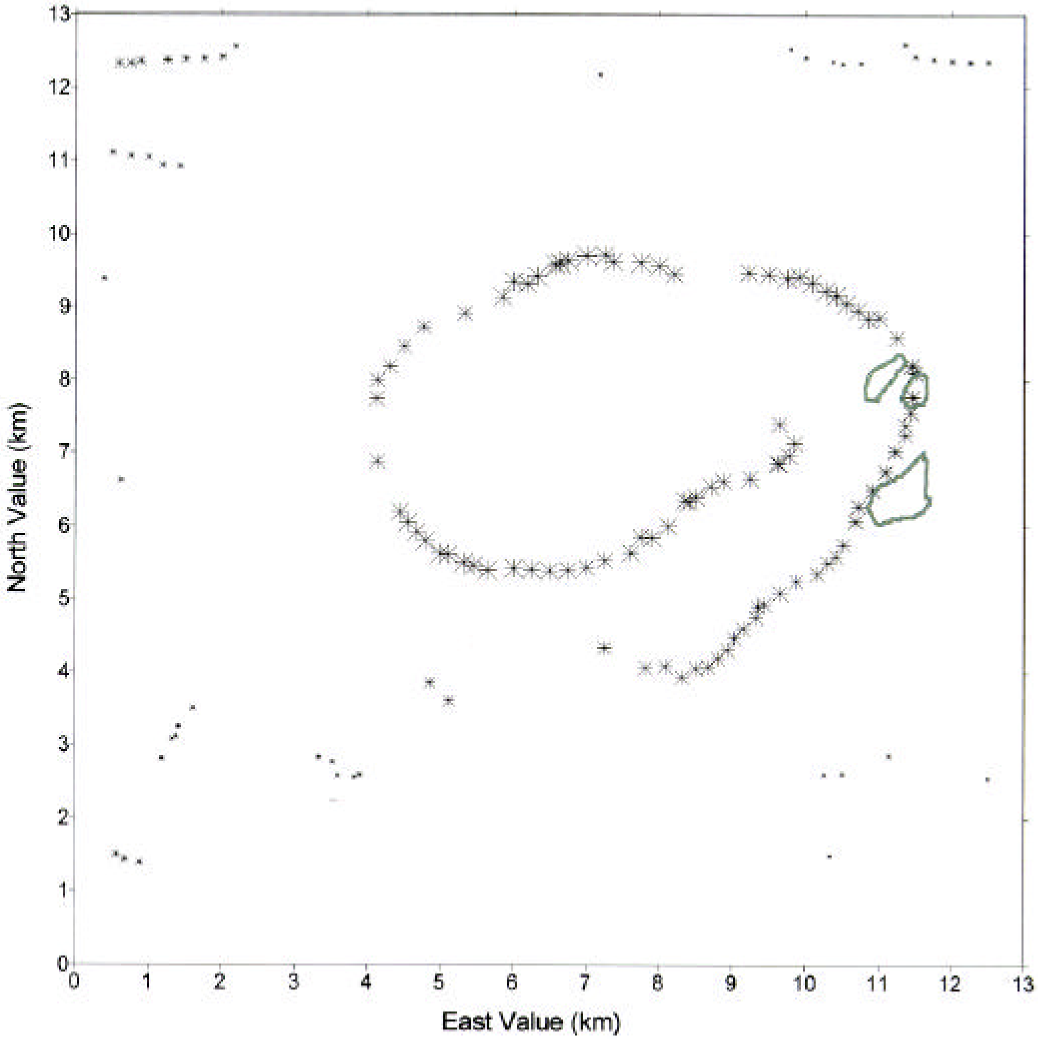

FIG. 10. Locations of maxima of the horizontal gradient of the pseudogravity anomalies shown in Figure 9. The size of the asterisks is proportional to the magnitude of the horizontal gradient. Large asterisks signs show the principal boundary of the causative body. Dark green coloured annotations show the outcrops of the gabbroic rocks at the surface.

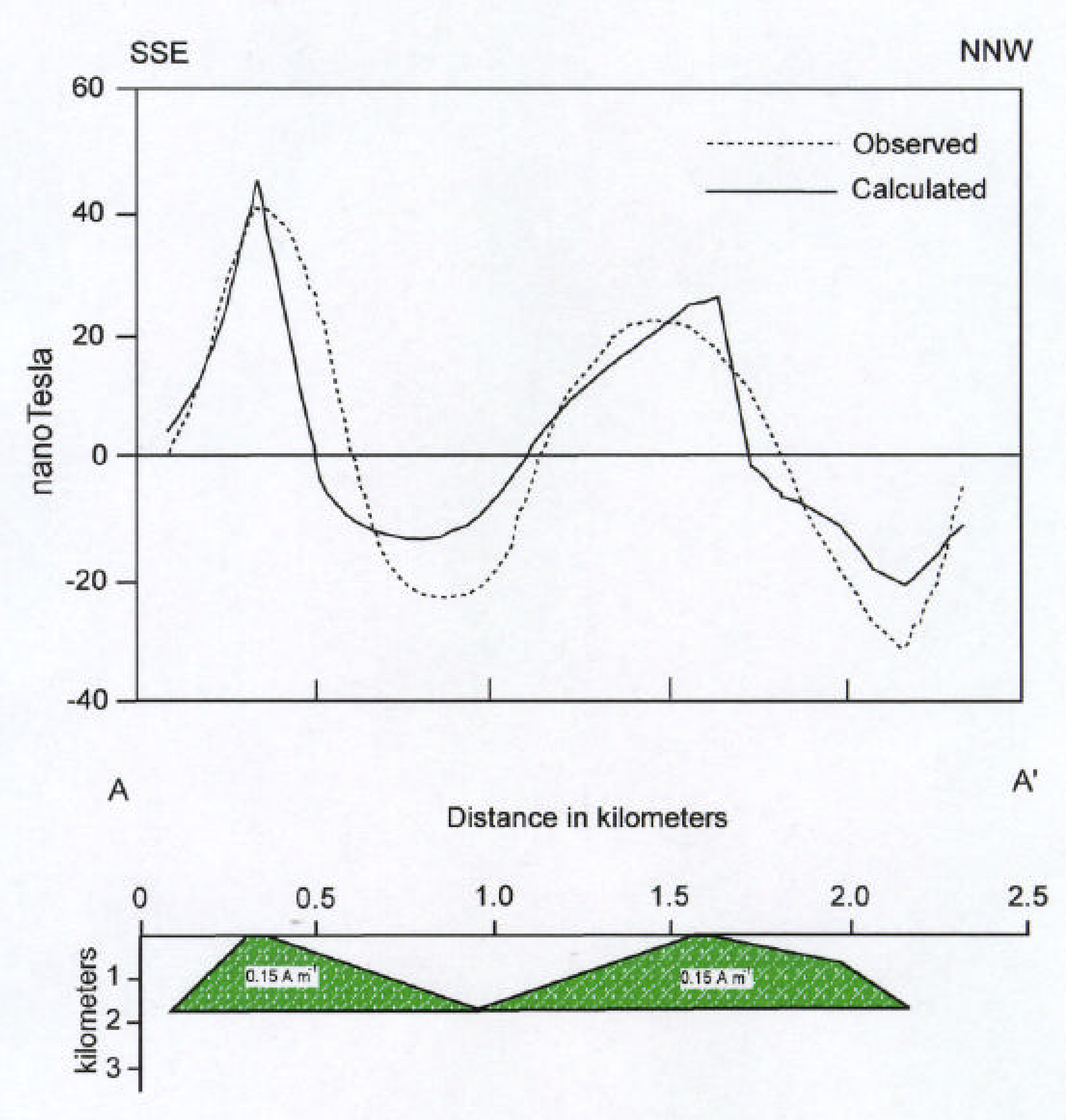

FIG. 11. Two-dimensional magnetic anomaly model along profile AA' shown in high-pass filtered anomalies in Figure 7.

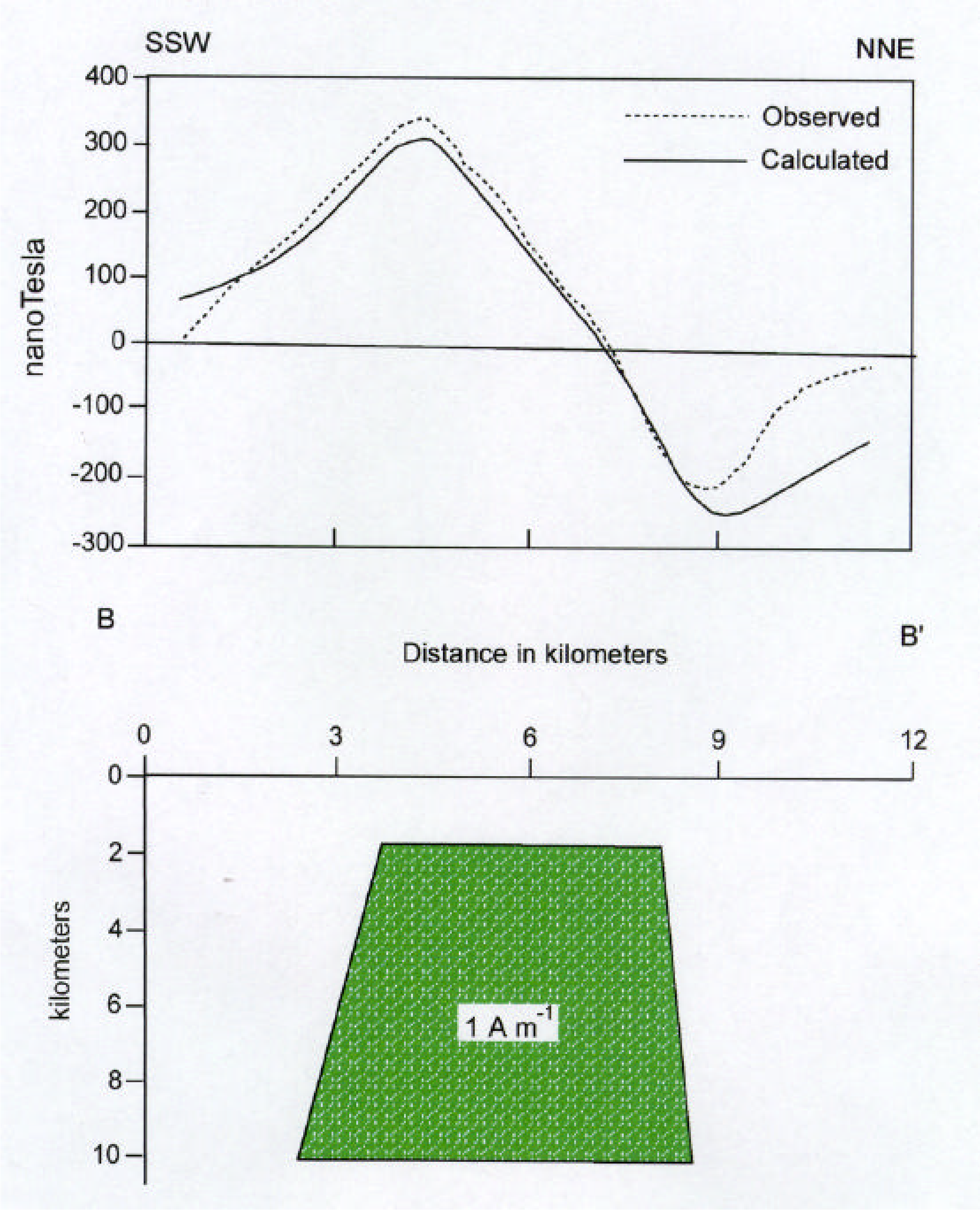

FIG. 12. Two-dimensional magnetic anomaly model along profile BB' shown in low-pass filtered anomalies in Figure 8.

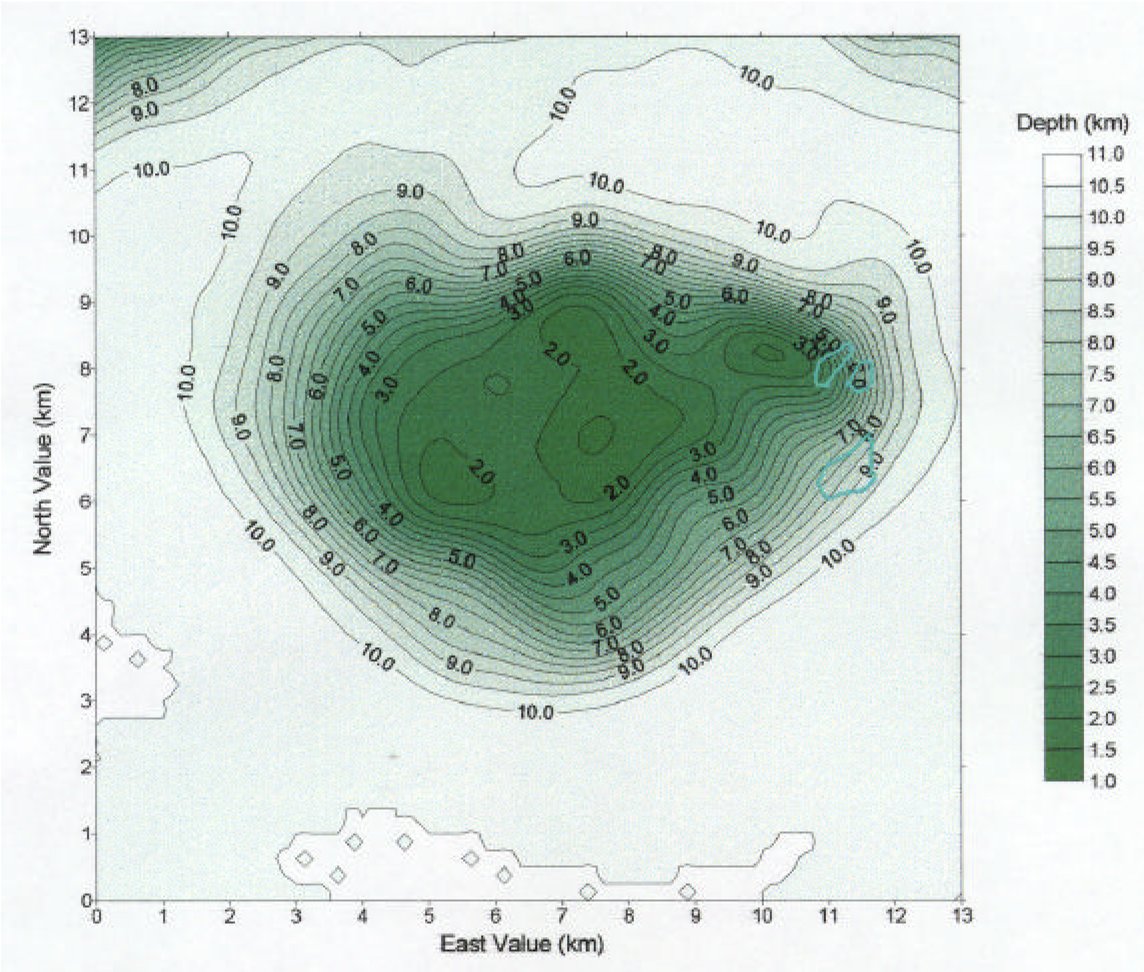

FIG. 13. Three-dimensional magnetic anomaly model, utilising Cordell and Henderson (1968) iterative algorithm, of pseudogravity anomalies shown in Figure 9. Density contrast is 0.3 Mg m^{-3}. Contour interval is 0.5 km. Light blue coloured annotations show the outcrops of the gabbroic rocks at the surface.

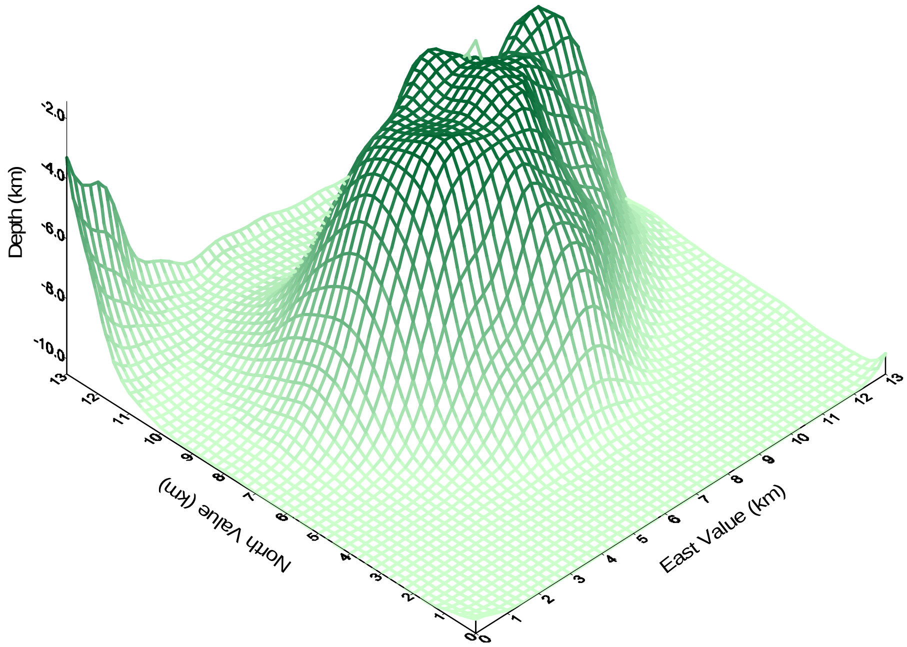

FIG. 14. Isometric projection of the three-dimensional magnetic model shown in Figure 13, viewed from SW.

Two and three-dimensional aeromagnetic models

Two dimensional models were constructed from high and low-pass filtered anomalies along profiles AA' and BB' shown in Figures 11 and 12, respectively. Anomaly profile AA' obtained from the high-pass filtered anomalies simulated by forward modelling. Two bodies with intensity of magnetization of 0.15 A m^{-1} having bottom depths of 1.69 km produced a good fit between the calculated and observed magnetic anomalies along the profile (Fig.11). A two dimensional model was also produced along a profile BB' shown in the low-pass filtered aeromagnetic anomalies (Figure 12). The top of the body was located at a depth of 1.69 km from surface as revealed by the power spectrum. An average intensity of magnetization of 1 A m^{-1} as given in the literature was used to construct the model (Telford, et al. 1990). A good fit between the observed and calculated anomalies was obtained when the bottom of the body was extended to a depth of 10 km below surface.

A three-dimensional model (Fig.13) was constructed from the low-pass filtered pseudogravity anomalies by using the three-dimensional iterative method of Cordell and Henderson (1968). Top of the model was determined from the power spectrum as 1.69 km and bottom of the model was modified until the top of the model reached to 1.69 km depth from surface. The bottom of the model is at 10 km depth from surface at 6 th iteration and the RMS error between the observed and calculated anomalies is 0.25 mGal. A typical density contrast of 0.3 Mg m^{-3} was used in between the gabbroic and surrounding formations (granite and other sedimentary rocks). The model resembles the two-dimensional model presented in Figure 12. An isometric projection of the model is also presented in Figure 14, viewed from SW corner.

CONCLUSIONS

The geological observations, in the study area, are not indicative of a large body which would produce an aeromagnetic anomaly shown in Figure 3. Two and three-dimensional modeling followed by geophysical processes on the aeromagnetic anomalies demonstrate an existence of a large and deeply buried body. There is a good correlation in between the maxima and the annotated surface outcrops of the gabbroic rocks (Fig.10) in the central east of the area. Thus, a speculative connection between the magnetized gabbroic outcrops and the deep magnetic body can be established. If the deep body has no gabbroic origin, then there is a possibility that the aeromagnetic anomalies in Figure 3 may be attributed to the localized mineral zones. There are iron-ore formations about 70 km NNW of the study area, around Kesikköprü-Keskin region in Kirikkale town and some of them are presently excavated (Cihnioglu et al. 1994; Öztürk, 1996).

It would also be highly speculative to identify all the gabbroic formations as ophiolites of the Neotethyan ocean. Shallow gabbroic rocks with intrusive origin may present similarities to the ophiolites due to the effect of the weathering and hydrothermal alteration.

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