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Analysis of geomagnetic field anomalies in the Leptokarya area, NE Greece

A. Stampolidis, G. N. Tsokas, D. Panagiotopoulos, D. Kondopoulou and A. Savvaidis

Geophysical Laboratory, Aristotle University of Thessaloniki, 54006 Thessaloniki, GREECE.

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Abstract*: Plutonic rocks intrude the metamorphic basement rocks of the Rhodope massif. Aeromagnetic data from a 1966 survey of Macedonia and Thrace were recompiled, processed and used in the present study to interpret the anomalies associated with the Leptokarya granite. The data were inverted by means of a terracing technique that defines separate domains of uniform distribution of physical properties causing magnetic anomalies.*

The anomalies were separated in the wavenumber domain. The sources of the short-wavelength anomalies were interpreted as granitic domes. The aeromagnetic data were differentially upward continued to the constant altitude of 3275 m. The magnetic field produced from this procedure was used to interpret the long-wavelength part of the Leptokarya anomalies.

Key Words*: AeromagneticInterpretation, Leptokaria, NE Greece.*

INTRODUCTION

The Eastern Rhodope Massif (NE Greece) consists mainly of metamorphic rocks belonging to the amphibolite-gneiss series (Zachos and Dimadis, 1983; Mposkos, 1986; Billett and Nesbitt, 1986). Plutonic rocks outcrop inside the Kirki and Esimi volcanosedimentary basin, as well as at the surrounding metamorphic basement rocks of the Rhodope massif (Fig. 1). These intrusions are aligned in a SW-NE trending belt which is about 20 km long. The most important outcrop is located close to the village of Leptokarya.

The outcrop is petrologically classified as monzodiorite (Katirtsoglou *et al*, 1981; Eleftheriadis *et al*, 1989, Mavroudchiev *et al*, 1993), though earlier it was described as a granodioritic composition (Maratos and Andropoulos, 1964). This is the largest plutonic body in the Eastern Rhodope Massif with a surface outcrop of approximately 15 km^2. Radiometric dating by using the K/Ar method on biotite has given an Oligocene age (~28 Ma) for the Leptokarya plutonic body (Bitzios, 1973).

Spais (1987) made measurements on the magnetic properties of drilled specimens from the Leptokarya intrusion. Magnetic susceptibility values were calculated for 135 specimens on 9 locations. The mean value of magnetic susceptibility is $k = 38.5 \pm 10.4 \times 10^{-3}$ (SI). Measurements of NRM intensities and directions (inclination and declination) were made on 43 oriented samples. NRM intensities were found to be within the range of 26 to 2259 mA/m with a mean value of 620 mA/m, while inclination and declination showed large scattering with a site mean direction D = 21.6° and I = 30.2°. The average Königsberger ratio calculated by using susceptibility values and NRM intensities from 36 specimens was found to be 0.30 ± 0.13 (Maltezou, 1987). This suggests predominance of induced magnetization which was used in the present study.

Maltezou (1987) and Maltezou and Brooks (1989) studied the Leptokarya intrusion by geophysical means and produced a two-dimensional model of the pluton. Depending on the regional field removed, they claimed that the maximum depth to the base of the pluton was between 400 and 1200 m.

DATA USED

The aeromagnetic data used here were produced in 1966 during a campaign of the ABEM-Elektrisk Malmetning Company on behalf of IGME (ABEM, 1967). Flight lines were flown in the WSW-ENE direction, perpendicular to the regional strike of the Hellenides. They were spaced 0.8 km apart and tie lines were flown at a spacing of 30 Km. A constant clearance altitude of 275 ± 75 m above the ground level was maintained throughout the survey.

Stampolidis (1999) digitized the original hardcopy profiles. The total field magnetic profiles obtained were subjected to a series of corrections. The DGRF model (1966.5) was deduced from the data, also applying the

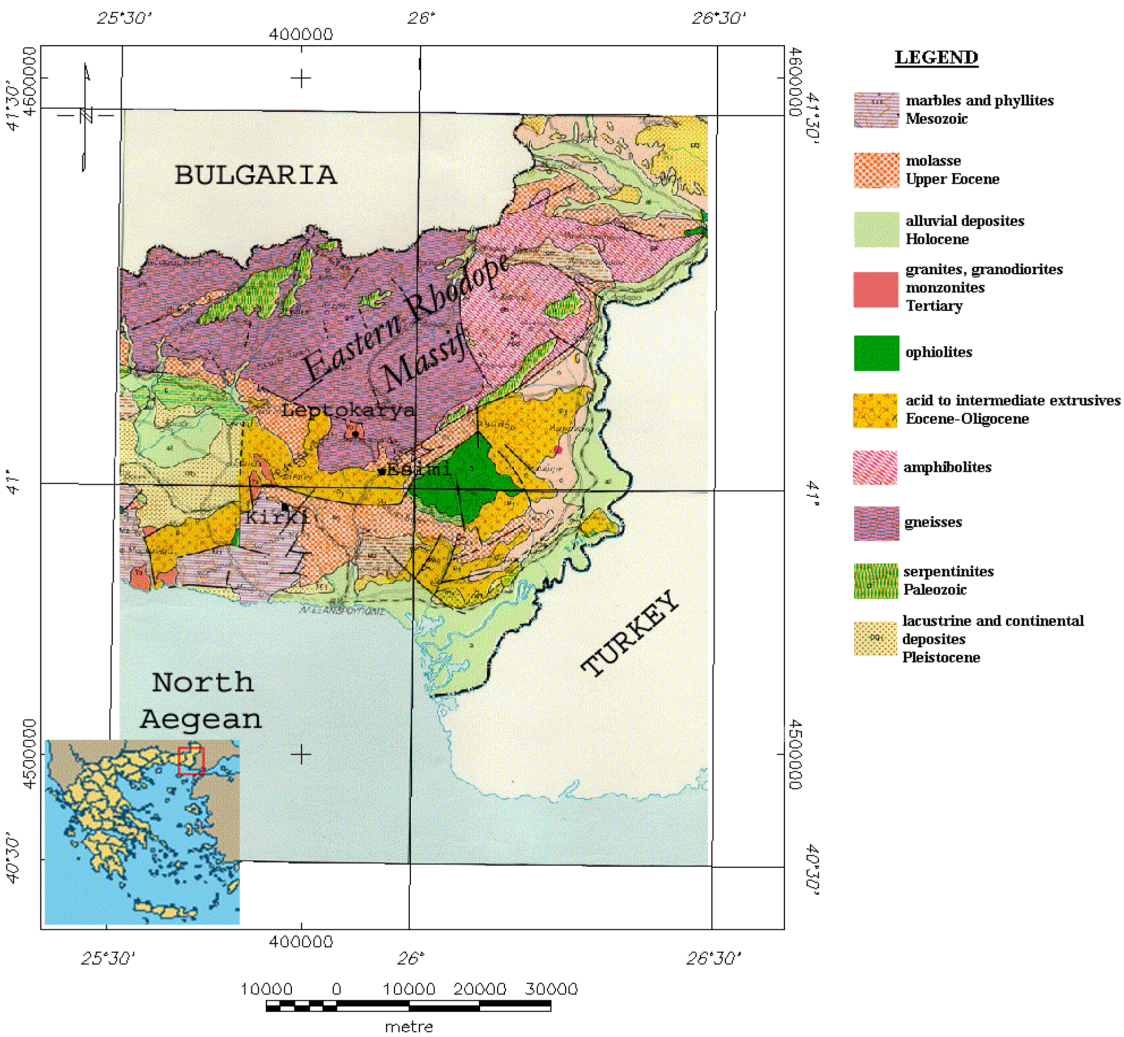

FIG. 1. Geological map of the Eastern Rhodope massif (scale 1:500.000). The location of the Leptokarya intrusion is also visible.

lag and heading corrections. Next, tie line leveling was performed and finally microleveling was applied in order to remove the high frequency noise from the magnetic data. The magnetic data were transformed into the wavenumber domain. Reduction to the north magnetic pole was performed at the first stage of processing the aeromagnetic data. The reduced to the north-pole total field magnetic anomaly map of the Eastern Rhodopes is shown in Figure 2. Remanence is assumed to be negligible as mentioned above. The outcrop of the Leptokarya pluton is associated with a pronounced anomaly.

PROCESSING OF THE MAGNETIC DATA

The data processing was carried out by using both the Potential Field Geophysical Software available to the public from USGS (Philips, 1997) and the OASIS montaj™ Data Processing and Analysis system (Geosoft, 1997).

In order to interpret the aeromagnetic anomaly associated with the Leptokarya intrusion, part of the magnetic field including these magnetic anomalies was subtracted from the reduced to the pole magnetic field in Figure 2. A first-degree regional field was calculated and subtracted from this data set. Figure 3 shows the residual anomaly of the Leptokarya intrusion along with the regional field. The residual field consists of the anomalies (A1a, b, c, d) coinciding with the intrusive exposures of the Leptokarya body, and anomalies (A2a, b, c, d) coinciding with the extrusive volcanic bodies in the Kirki-Esimi basin. Anomalies A1a occupy the area where the pluton outcrops and has a maximum amplitude of 206 nT. Anomaly A1b is the widest and has a maximum amplitude of 182 nT. Anomaly A1c is the most intense with a maximum amplitude of 354 nT, whereas A1d is the weakest (~140 nT).

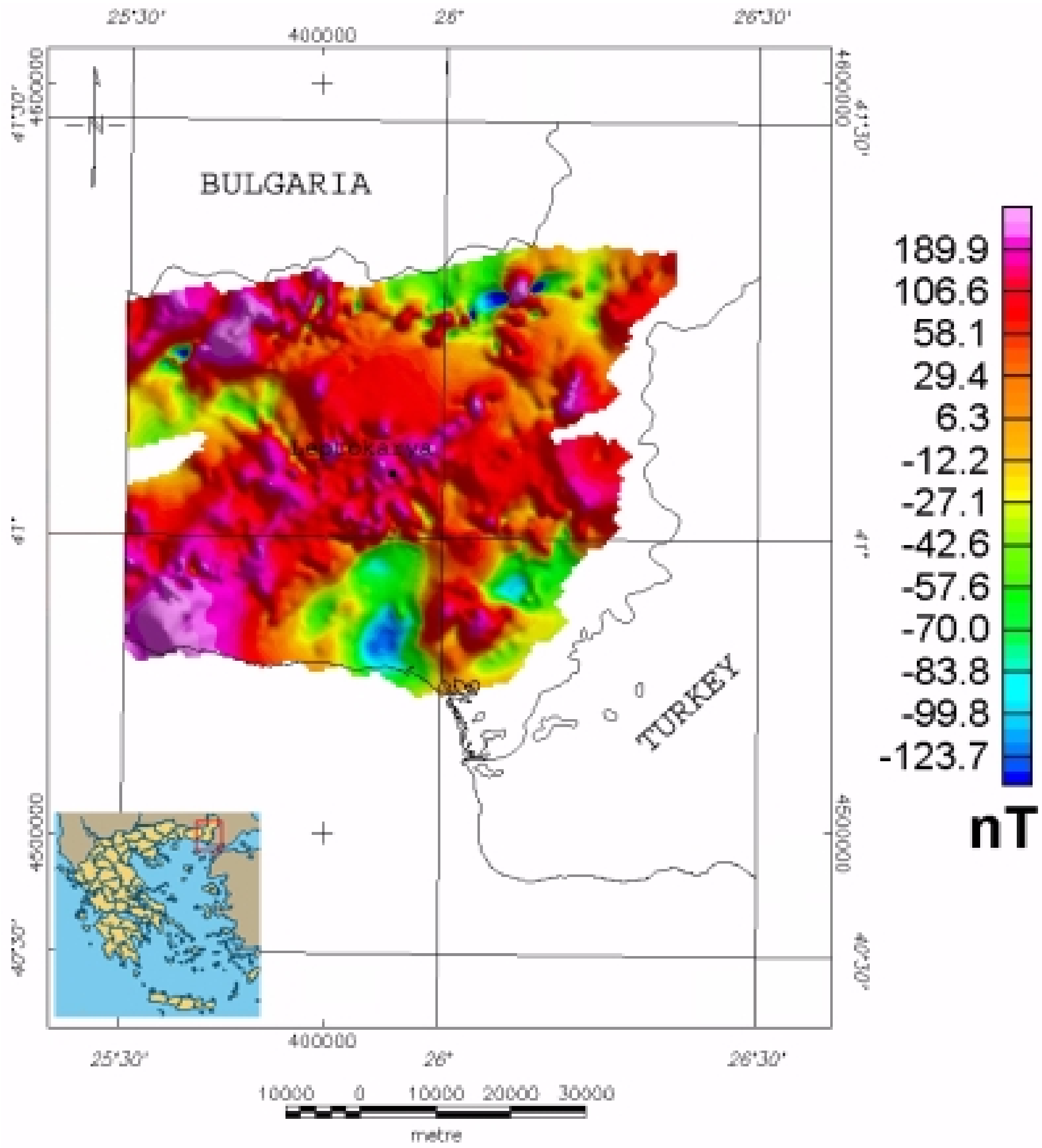

FIG. 2. Total field reduced to the pole anomaly map of the Eastern Rhodopes.

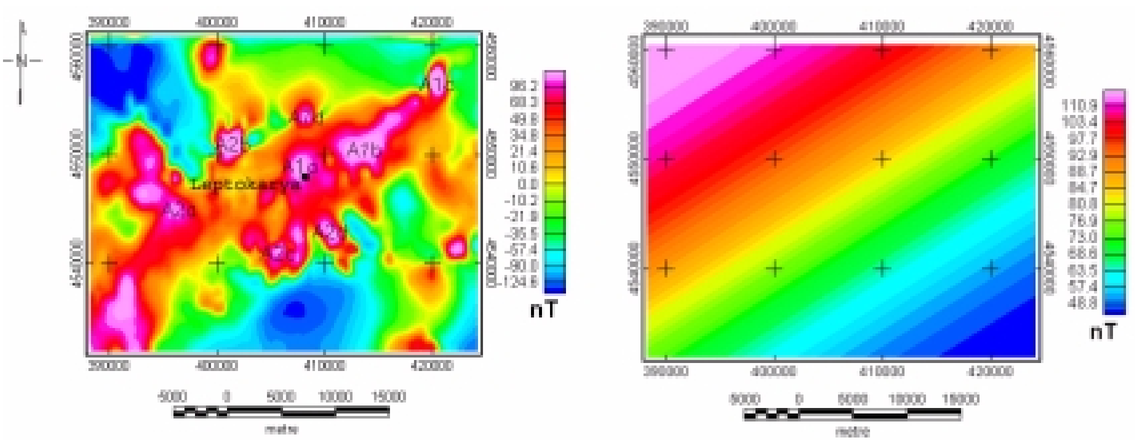

FIG. 3. The residual field of Leptokarya reduced to the North Pole to the right and the regional field to the left. The maps deal with a particular bit extracted from the data in Figure 2.

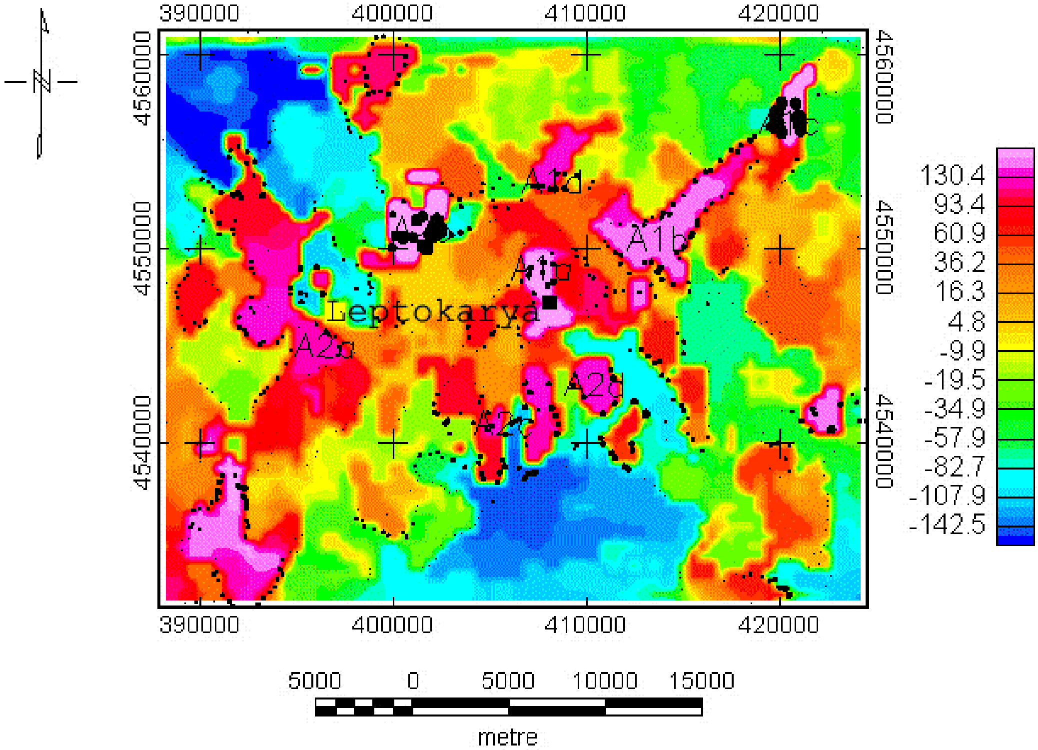

FIG. 4. The "terraced" magnetic field of Leptokarya. The units are arbitrary. The thickness of dots is indicative of the amplitude of the horizontal gradient maxima.

Horizontal gradient maxima were used to reveal the horizontal boundaries of the sources. According to Blakely and Simpson (1986) and Grauch and Cordell (1987) the maximum values of the horizontal gradient will be located near the vertical sides. Cordell and McCafferty (1989) presented an iterative method for transforming the potential field data into uniform domains separated by abrupt domain boundaries. The method was called "terracing" for obvious reasons and comprises a mapping of the physical property causing the anomalous field. Although the method is directly applicable to the gravity field data, the magnetic data should be subjected to pseudogravity transform first. The terracing method is used in conjunction with the horizontal gradient maxima to delineate the body boundaries. Figure 4 shows the "terraced" magnetic field along with the maxima of the horizontal gradient.

Enhancement techniques were applied to the data in order to enhance certain characteristics of the sources thus facilitating the overall interpretation (Blakely, 1995). The first and second vertical derivatives were calculated (Fig. 5). The effect of shallow sources is enhanced in these maps. Magnetic anomalies were separated in the wavenumber domain (Fig. 6). The high-pass filtered field (Fig. 6a) resembles the first vertical gradient field (Fig. 4a), while the shape of the mid-pass filtered magnetic field (Fig. 6b) coincides with the residual anomaly (Fig. 3a). The low-pass filtered map (Fig. 6c) enhances the deep sources of the magnetic field.

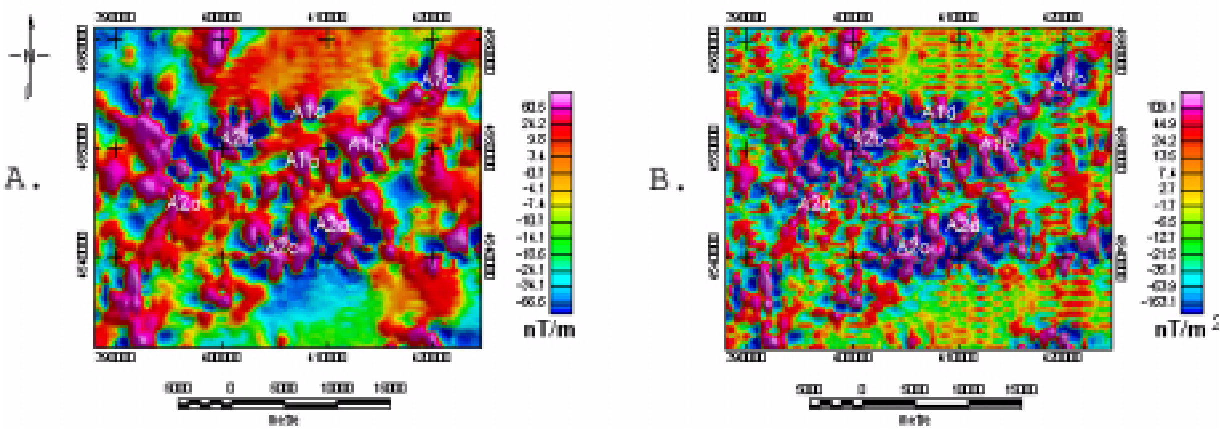

FIG. 5. First vertical derivative (a) and second vertical derivative of the total field anomaly (b) (Fig. 2).

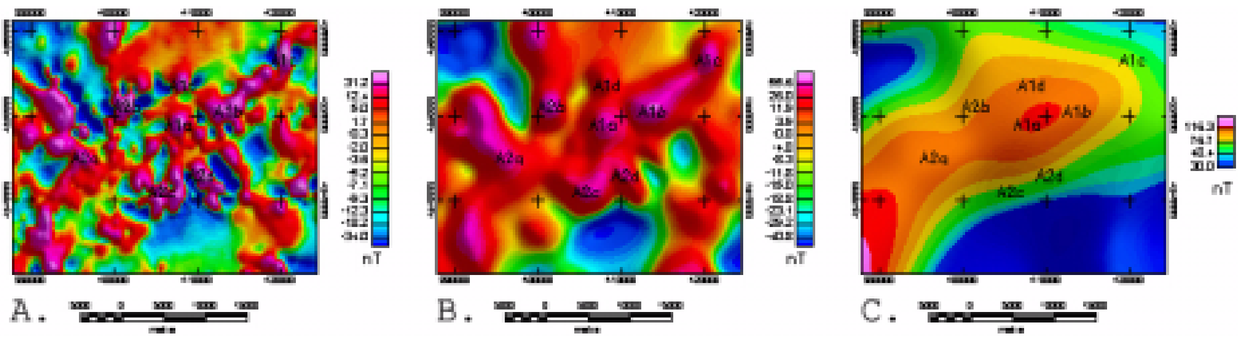

FIG. 6. High-pass filter (a), band-pass filter (b), low-pass filter (c) of the total field anomaly map in Figure 2.

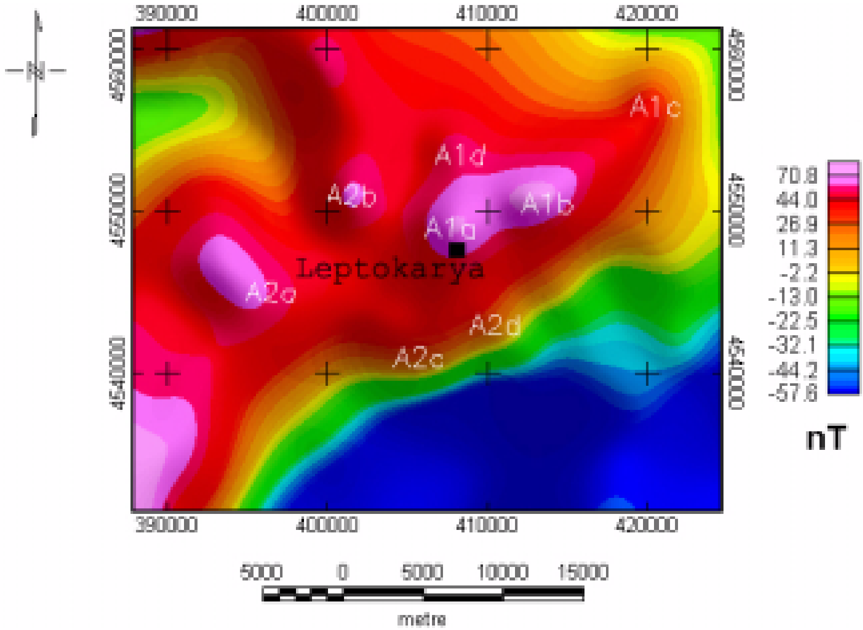

FIG. 7. Differential upward continued magnetic field to the barometric altitude of 3275 m.

The magnetic field was differentially upward continued to 3.275 km above sea level (Fig. 7), using the method of Ivan (1994). Comparing this map with the low-pass filtered map (Fig. 6c), we can conclude that the deep part of the Leptokarya body is located mainly under anomalies A1a and A1b.

INTERPRETATION OF ANOMALOUS MAGNETIC FIELD

The 3-D model of the Leptokarya pluton was constructed using the method of Plouff (1976). Only the induced type of magnetization was assumed, as discussed previously. A constant magnetic susceptibility value of $k = 38.5x10^{-3}$ (SI) is used for the pluton, while the magnetic susceptibility of the surrounding rocks was set to zero.

The height of 275 m above the topography was considered as the measurement level. The horizontal boundaries of the model were revealed by horizontal gradient maxima and terracing techniques. Results from other data enhancement techniques (Figs. 5, 6 and 7) assisted the interpretation. The top surface of the model coincides with the pluton outcrop, while the bottom surface was calculated by the trial and error method.

The 3-D model of the Leptokarya pluton is shown in Figure 8. The model field with its horizontal boundaries is shown in Figure 8a, while its 3-D view is displayed in Figure 8b. The model is composed of four domes. These domes reach the topographic surface or are close to it. The model has its maximum horizontal dimensions at 400 m (ASL), which is 20x8 km^2. The depth to the bottom of the model is 200 m (ASL). According to this model the pluton is about 500 m thick, which is compatible with Maltezou and Brooks's estimate (1989). The shape and thickness of the intrusion can be interpreted as a rootless, laccolithic body like the other plutonic bodies of the Rhodope Massif (Xanthi, Philippi pluton).

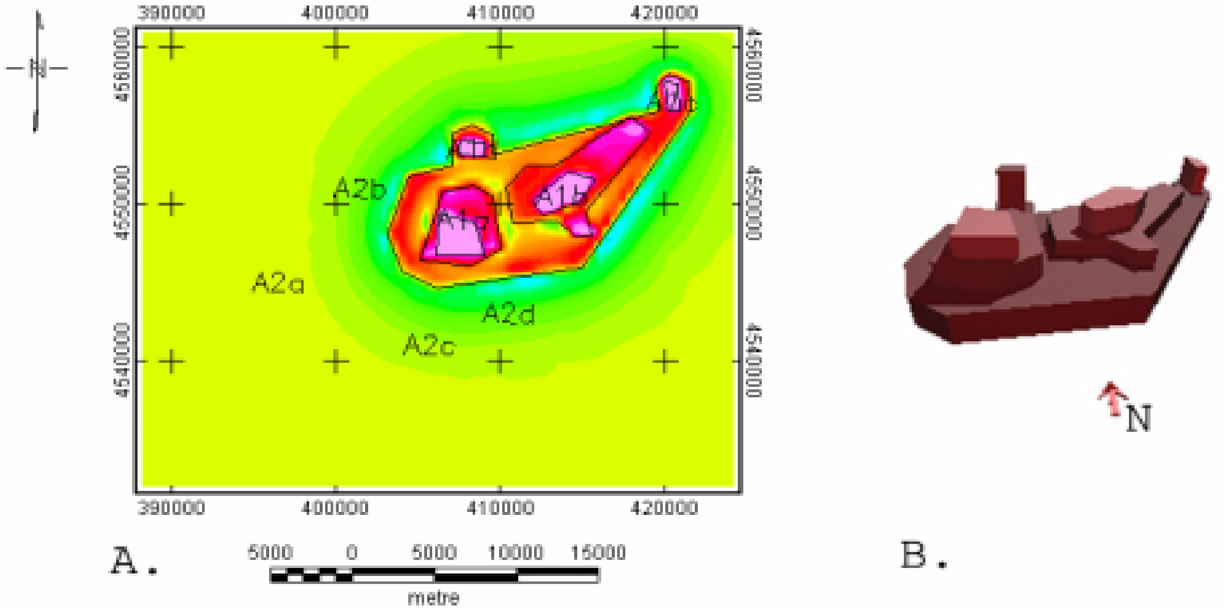

FIG. 8. (a) Magnetic field of the Leptokarya intrusion model along the plan view of the proposed model. (b) 3-D model view of the Leptokarya intrusion.

CONCLUSIONS

According to the proposed model for the Leptokarya intrusion, the pluton forms into a line of SW-NE direction, occupies an area of 20x8 km^2 and has a maximum thickness of 500 m (ASL).

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