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GRAVITY MODELLING OF THE ARNEA GRANITE AND ITS CONTINUATION BELOW THE MYGDONIA GRABEN SEDIMENTS

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ABSTRACT.

An investigation of the gravity field in the vicinity of the Arnea granite is presented . Laboratory density measurements of rock samples and reported seismic velocities converted to density indicate a density contrast of -0.1Mg/m^3 between granitic and basement rocks. The gravity effect of the Mygdonia graben sedimentary fill is calculated and subracted from the observed field. 2-D and 3-D gravity modelling of the Arnea granite suggests a thickness of about 5km. Gravity modelling also suggests its continuation to the north under the Mygdonia graben at a depth of 1km below surface.

ΠΕΡΙΛΗΨΗ

Το βαρυτικό πεδίο στην περιοχή του γρανίτη της Αρναιας και τη Μυγδόνια λεκάνη μελετάται στην παρούσα εργασία. Εργαστηριακές μετρήσεις πυκνότητας και σεισμικές ταχύτητες υποδεικνύουν ότι η αντίθεση πυκνότητας μεταξύ γρανιτών και υποβάθρου είναι περίπου -0.1 γρ/κυβ.εκ. Η επίδραση των ιζημάτων της Μυγδόνιας λεκάνης στο βαρυτικό πεδίο της περιοχής υπολογίστηκε και αφαιρέθηκε απ΄αυτό. Δύο και τριών διαστάσεων βαρυτικά μοντέλα ερμηνείας υποδεικνύουν ότι ο γρανίτης της Αρναιας έχει πάχος περίπου 5χλμ. Η ερμηνεία επίσης υποδεικνύει τη συνέχεια των ίδιων γρανιτικών πετρωμάτων κάτω από τη Μυγδονία λεκάνη σε βάθος περίπου 1χλμ.

Βαρυτική ερμηνεία του γρανίτη της Αρναιας και της συνέχειας του κάτω από τα ιζήματα της Μυγδονίας λεκάνης.
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1. Introduction

Granitic rocks outcrop in various places within the Serbomacedonian massif (Fig 1). This study presents the results from a geophysical investigation of the Arnea granite (Fig. 1).

Density measurements on rock samples from the granitic outcrops and the host metamorphic rocks (Kiriakidis 1984) and seismic velocities converted to densities (Makris and Muller, 1977) predict a significant density contrast between the two rock types. Since the gravity method is normally used to detect density inhomogeneities within the earth's crust it was employed to investigate the volume of low density rocks which is indicated by the presence of low Bouguer gravity values.

However the presence of the granite is not the sole cause of the low gravity values in the area under study. Noegene sediments of the Mygdonia basin (Psilovikos, 1977) with their low density, as indicated by NetLeton density profile (Kiriakidis , 1984) and density logging (DEP, personal communication, 1985), contribute to the low Bouguer gravity values. The amount of this contribution can be calculated, since the shape of the Mygdonia basin is well known (Thanasoulas, 1983) , and subtracted from the Bouguer gravity map thus producing a "stripped"Bouguer anomaly map of the outcropping Arnea granite. Two-dimensional interpretation carried out by Kiriakidis (1984) on a well defined negative residual gravity anomaly along a gravity line crossing the Arnea granite indicates that the granite itself has a limited thickness of 4.7. Km. Using the results obtained from this interpretation as a guide, a 3-D gravity interpretation of the low Bouguer gravity values present in the "stripped"map is performed and the model produced provides evidence for the presence of a low density body whose outcrop coincides with the Arnea granite.

2. Geology

The Serbomacedonian massif which is part of the Internal Hellenides is thrust on to the Vardar Zone to the west and backthrust on to the Rhodope zone to the East.

Two metamorphic sequences constitute the Palaeozoic crystalline basement of the Serbomacedonian massif. A lower sequence composed of about 3km of gneiss ana marble occupies the easternmost part of the Chalkidhiki area, and an upper sequence composed of gneiss, schists and metamorphosed basic igneous rocks (Kockell et al 1977) occupies the westernmost part.

A Triassic to Jurassic neritic and pelagic continental margin and turbiditic sequence comprises the Svoula formation (Fig.1) of the Circum Rhodope belt situated to the west of the Serbomacedonian massif (Kauffmann et al, 1976)

Granitic rocks outcrop within the metamorphic Serbomacedonian massif. The Arnea unit (fig.1) is mainly composed of granite and is considered to be Mesozoic in age. K/Ar dating of the Arnea granite yields an age of 140 Ma (Marakis, 1970) and Ar-Ar dating produces an age of 136 Ma (De Wet and Miller, 1987).

The Sithonia granite was once considered to have the same age as the Arnea body (Sapountzis et al 1977). However recent dating of the former, and associated aplites, using the Rb/Sr method gives an age of approximately 51 Ma (early Eocene) (Christofides et al, in prep).

The Mygdonia basin (Psilovikos , 1977) was developed during the Neogene and the accumulated sediments are subdivided into three main groups:the Promygdonian group (conglomerates, sands and sills) of Late Miocene-Early Pleistocene age and two groups of the Mygdonia system of Middle-Late Pleistocene and Holocene age.

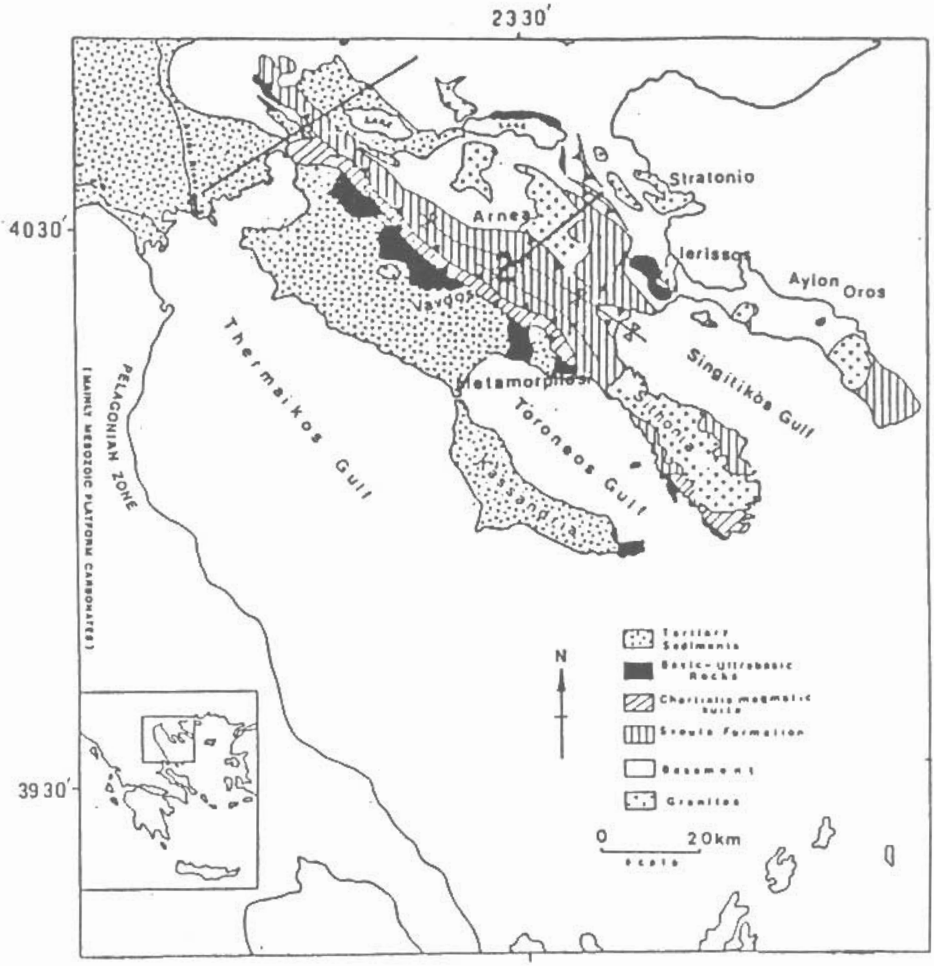


Fig. 1. Outline geological map of the study area.

Σχ.1. Γεωλογικός χάρτης της ευρύτερης περιοχής.

3. The Geophysical Data

The Bouguer gravity map used in this study is the final product of a major geophysical project conducted by Brooks and Kiriakidis (Kiriakidis, 1984) covering the entire Chalkidiki area and part of the N.Aegean. The accuracy of the gravity measurements is ± 0.3 mGal Part of the project involves establishing gravity stations along profiles crossing the northern edge of Mygdonia graben and the Arnea granite (Fig 1).

Kiriakidis (1984) showed that an analytically determined second order polynomial adequately represents the regional gravity field, based on:
1) The comparison of the graphically determined regional field along gravity profile line 2 with the analytically determined regional gravity field,
2) The residual Bouguer anomaly due to the Vavdos ophiolite as deduced from individual gravity lines after subtraction of a graphically determinated regional field in comparison with the residual anomaly as determinated by the analytically calculated regional field.
The residual gravity field to this second order polynomial is shown in fig.2. A dominant feature is a 20Km wide belt of negative anomalies trending NW-SE which coincides roughly with the outcropping Arnea and Sithonia granites (Fig. 2, Anomalies A,B,C,).

Kiriakidis (1984) listed laboratory density measurements on rock samples from Serbomacedonian basement and from the Arnea and Sithonia granites. Rock samples of Serbomacedonian gneiss from 22 sites in the vicinity of the Mygdonia graben and Arnea granite yield a mean density of 2.65±0.1 Mg/m^3.

Granitic samples from 9 sites along the road from Poliyiros to Arnea (Fig.1) yield a mean density of 2.59±0.09 Mg/m^3 for the Arnea granite.

Regarding the density of the Mygdonia graben sediments the information available was derived from a Nettleton density profile on sediments from the nearby Axios basin reported by Kiriakidis (1984). Information exists also on the velocities of the sediments in the same basin from commercial boreholes (DEP,pers communication, 1982;Kiriakidis, in press). This information shows that the first 0.5Km of the recent sediments has a mean velocity of 2.1 Km/s. Converting this velocity to density using Nafe-Drake Birch curves a value of 2.1 Mg/m^3 is derived. This value is in good agreement with the 2.15 Mg/m^3 that was derived from the Nettleton density profile.

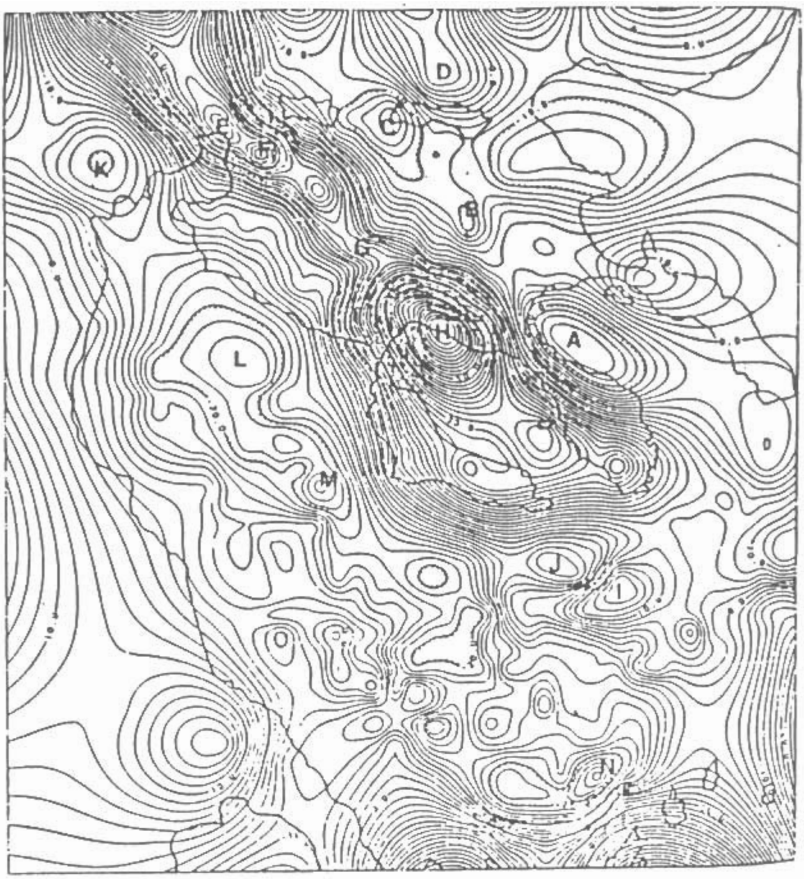
Information on the mean seismic velocity of the Serbomacedonian metamorphic basement is reported in Makris and Muller (1977) who give a velocity of 6.0 Km/s for the basement in the vicinity of the Arnea granite. Conversion of this velocity to density using Nafe-Drake and Birch curves gives a value of 2.78 Mg/m^3 for the basement.

On the basis of the above, the following densities were selected for the purpose of the gravity interpretation.

1. Basement:2.74 Mg/m^3
2. Granite:2.60 Mg/m^3
3. The Mygdonia basin sediments:2.15 Mg/m^3

4. Gravity Interpretation

Results from a gravity profile interpreted by Kiriakidis (1984) are presented. This profile (Fig.1 Line 2) is perpendicular to the trend of the negative gravity belt shown in Fig. 2 . Gravity stations along this profile line are spaced 1 Km apart. The geology along the line comprises Svoula formation sediments to the SW in contact with the Arnea granite.



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0 20km

Fig. 2. Residual anomaly corresponding to the second order polynomial. Contour interval 2mGal.

Σχ.2. Υπολειπόμενη βαρυτική ανωμαλία που αντιστοιχεί σε γενικό πεδίο 2ου βαθμού. Ισοδιάσταση καμπυλών 2mGal.

The granite itself appears to be thrust on to the Vertiskos Unit to the NE (Kockel et al 1977;Filbrandt, 1986).

The gravity interpretation model along line 2 is shown in Fig. 3.
A density contrast of 0.10 Mg/m^3 has been adopted. The granitic body is modelled to have its southwesterly boundary dipping at 70° to the SW, while its northeasterly boundary is interpreted to dip at 50° to the SW.
The angles and direction of dips are in good agreement with field observations reported by Filbrandt (1986) and Sakellariou (pers. communication, 1988). The thickness of the body is 4.7 km and its lower contact has been modelled as a flat surface.

A computer program was used by Kiriakidis (1984), based on Talwani and Ewing's (1965) equations, to perform the 3-D gravity interpretation. The residual gravity field in the vicinity of the Mygdonia graben and the Arnea granite is shown in Fig. 4.

A belt of negative gravity values trending NW-SE and having a local minimum of 15 mGal is observed. The minimum is located in the Mygdonia graben to the southwest of Volvi lake. An anomaly of - 12 mGal is observed over the Arnea granite, in good agreement with the residual anomaly shown in profile line 2. A local maximum of about 3 mGal to the north of Volvi lake is attributed to the presence of amphibolitic rocks.

The negative part of the residual field is attributed to the combined effect of the Mygdonia sediments and the granitic rocks. To separate these two negative gravity effects that of the Mygdonia sediments was calculated. The geometry of the sedimentary fill in the Mygdonia graben was investigated by Thanasoulas (1983) using electrical methods. The 3-D interpretation program was used to predict the gravity effect of the sediments adopting a density contrast of 0.55 Mg/m^3 on a grid with a 4km mesh. This density contrast is well constained by seismic velocities converted to densities and also density logging in the nearby Axios basin (D.E.P. personal communication). The 3-D gravity model of the Mygdonia sediments and its calculated gravity effect are shown in Fig. 5a and 5b respectively. The gravity effect of the sediments shown in Fig. 5b was subtracted from the residual to the 2nd order field shown in Fig. 4 and the resultant "stripped"gravity map is shown in Fig. 6.

Comparing fig 6 with fig 4 it can be seen that the belt of negative anomalies still exists but its trend is rotated towards the north. Also the minimum at the southwest edge of Volvi lake has been decreased in surfase area. A significant point on the "stripped" map of fig. 6 is that there are no negative gravity values left over Langhadhas lake. The area covered by positive gravity values over tha amphibolitic rocks to the north of Volvi lake has been increased.

The presence of the negative gravity belt is indicative of a body with lower density than the background uppercrustal density.

This belt of negative anomalies is interpeted in terms of a 3-D body having a density contrast of -0.1 Mg/m^3 with the metamorphic basement, as shown in fig. 7.

The body shown in fig. 7 is separated into two units. The upper unit includes the surface expression of the Arnea granite. It has a thickness of 1 km and its areal extent is the same as that of the Arnea granite, as mapped by Kockel et al (1977).

The lower unit has a thickness of 4km with flat upper and lower surfaces. Its width is 40km at the northern edge and 15 km at the southern. The gravity field produced by this body is shown in fig. 8.

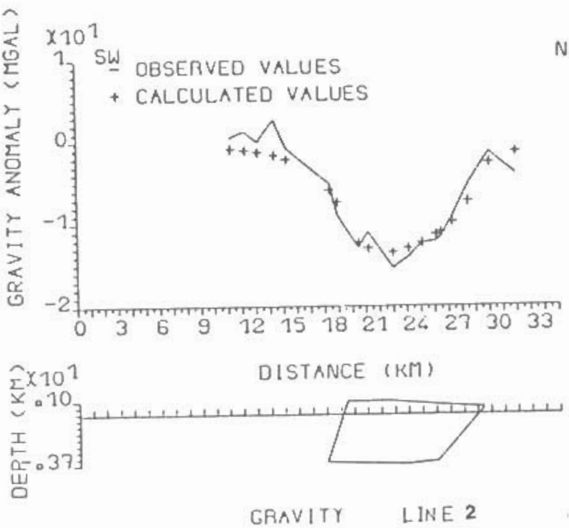
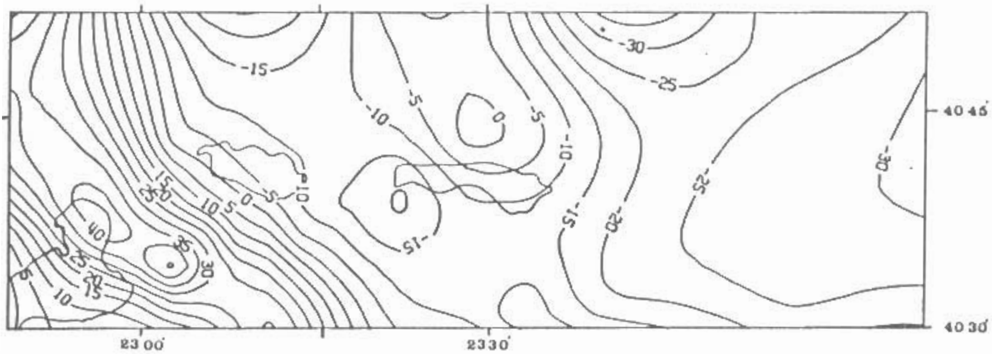


Fig.3. The interpretation model of the Arnea granite
Σχ.3. Το μοντέλο ερμηνείας του γρανίτη της Αρναίας.



Multiplying factor 1.

Fig.4. The residual gravity field in the area under study.
Σχ.4. Το υπολειπόμενο βαρυτικό πεδίο στην περιοχή έρευνας.

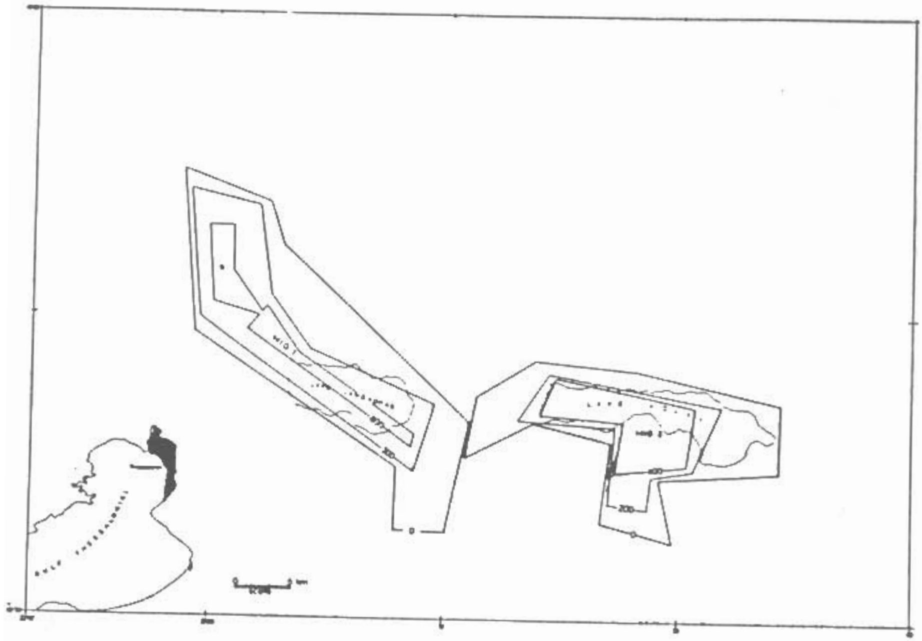


Fig.5.a) The depth and lateral extent of the Mygdonia graben sediments as revealed from electrical soundings.

Σχ.5.α) Η χωρική κατανομή των ιζημάτων της Μυγδόνιας λεκάνης όπως υπολογίζονται από τις γεωηλεκτρικές βυθοσκοπήσεις.

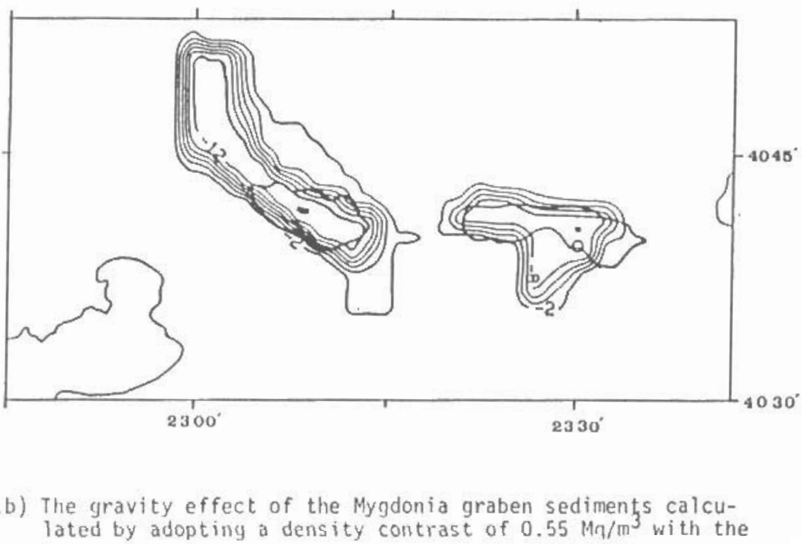


Fig.5.b) The gravity effect of the Mygdonia graben sediments calculated by adopting a density contrast of 0.55 Mg/m^3 with the basement rocks.

Σχ.5.β) Η βαρυτική επίδραση των ιζημάτων της Μυγδονίας λεκάνης υπολογισμένη χρησιμοποιώντας διαφορά πυκνότητας -0.55γρ/κυβ.εκατοστά.

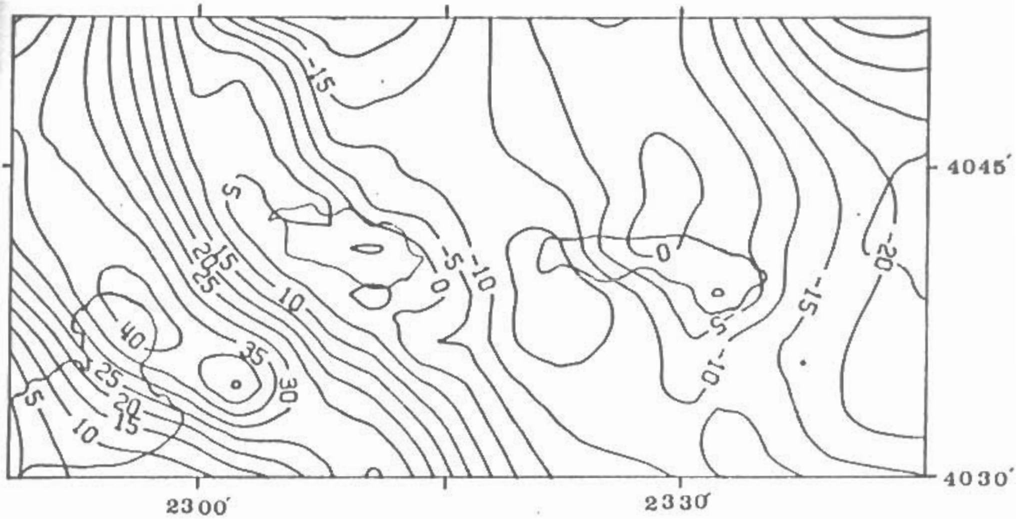


Fig.6. The gravity "stripped map. The gravity effect of the Neogene sediments as shown in Fig.5b has been removed.
Σχ.6. Βαρυτικός χάρτης της περιοχής έρευνας έχοντας αφαιρέσει την επίδραση των ιζημάτων.

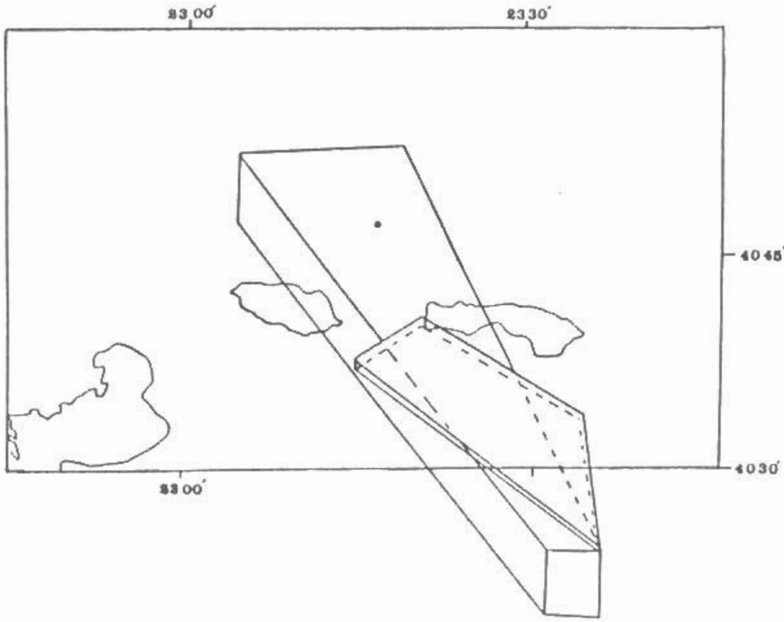


Fig.7 The 3-D shape of the gravity model used to interpret the residual gravity field of Fig.6. For details see the text.
Σχ. 7 Το τριών διαστάσεων σχήμα του σώματος που χρησιμοποιήθηκε για την ερμηνεία του υπολειπόμενου βαρυτικού πεδίου του σχήματος 6.

Comparing fig. 8 and 6 it can be observed that a fairly good fit exists between the amplitudes and shape of the observed negative residual gravity field and the calculated field.

5. Discussion-Conclusions

The examination of the "stripped" residual gravity map shows a belt of negative values with a maximum amplitude of -15mGal. This belt is located above the Arnea granite and extends to the north (Fig. 6).

The belt of negative anomaly can be interpreted in terms of a simple body having a density of 2.6 Mg/m^3 whose shape is shown in fig. 7. Its upper part is coincident with the Arnea granite and it is abruptly terminated by a vertical fault with a downthrow of 1 km located in the area where the 1978 Thessaloniki earthquake occured and which is also shown in the 1:100.000 geological maps (Kockel et al, 1977).

The body which is assumed to represent granitic rocks continues to the north 1 km below surface under the Mygdonia basin sediments and the Serbo-macedonia metamorphic basement. This model is also supported by electrical layer below the crystalline basement in the vicinity of Mygdonia basin. The lower part of the body is interpreted as a flat surface located 5 km below surface.

The two dimensional modelling has shown that both the southwestern and the northeastern boundaries of the body dip to the SW.

A seismic refractionproject would provide more detailed information on the subsurface shape of the Arnea granite.
measurements interpreted by Thanasoulas (1983) who found a higly resistive layer below the crystalline basement in the vicinity of Mygdonia basin. The lower part of the body is interpreted as a flat surface located 5 km below surface.

The two dimensional modelling has shown that both the southwestern and the northeastern boundaries of the body dip to the SW. A seismic refraction project would provide more detailed information on the subsurface shape of the Arnea granite.

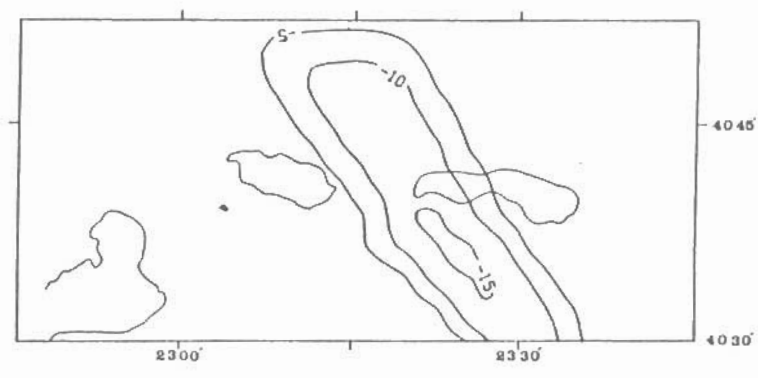


Fig.8. The calculated gravity field of the body shown in Fig. 7. Contour interval 5 mGal.

Σχ.8. Το βαρυτικό πεδίο που παράγεται από το σώμα του σχήματος 7. Ισοδιάσταση καμπύλων 5mGal.

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