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Tittel
A Gravity Study of the Råna Nickeliferous Norite-Periodotite Intrusion, Nordland, Norway

Forfatter	Dato	År	Bedrift (Oppdragsgiver og/eller oppdragstaker)
Sindre Atle, Boyd Rognvald, Mathiesen Carl O.	04.01	1980	NGU

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Fagområde	Dokument type	Forekomster (forekomst, gruvefelt, undersøkelsesfelt)
Geofysikk Geologi		Råna Bruvannsfeltet
Råstoffgruppe	**Råstofftype**	
Malm/metall	Ni,Cu	

Sammendrag, innholdsfortegnelse eller innholdsbeskrivelse

En geologisk beskrivelse der det blir pekt på at mineraliseringen vanligvis er knyttet opp til periodotitten. Gravimetriske målinger er benyttet som et hjelpemiddel for å framskaffe en modell av intrusjonen og videre finne større, potensielt mineraliserte periodotitt-kropper.
Målingene tyder på en intrusjon som er i størrelsesorden 2,5 km dyp og har en akse som stuper mot NV. Intrusjonen er grunnere i sør og østlige deler og har lite periodotitt. mot nord og vest øker antagelig andelen periodotitt mot dypet.

NORGES GEOLOGISKE UNDERSØKELSE
4.1.1980 RB/Amb

C22

A GRAVITY STUDY OF THE RÅNA NICKELIFEROUS NORITE-PERIDOTITE INTRUSION, NORDLAND, NORWAY.

Atle Sindre, Rognvald Boyd and Carl O.Mathiesen.

Sindre, Atle, Boyd, Rognvald and Mathiesen, Carl O. 1980: A gravity study of the Råna nickeliferous norite-peridotite intrusion, Nordland, Norway.

ABSTRACT.

The Råna intrusion consists of a quartz-norite core and norite peripheral zone; the latter containing bands and lenses of pyroxenite and peridotite. Mineralization is associated generally with peridotite but only one deposit of substantial size is known. The intrusion has been deformed by the last two phases of the Scandinavian orogeny and has a complex structure.

Gravimetric measurements have been used as an aid in constructing a model for the intrusion and to attempt to localize large, potentially mineralized, peridotite bodies. The study suggests that the intrusion has a depth of the order of 2,5 km or less and that its axis plunges northwestwards. Model interpretations indicate that the southern and eastern parts of the intrusion are relatively shallow (less than or equal to 1 km) and contain relatively little peridotite at depth. The body is deepest in the north-west and in this area contains a higher proportion of peridotite which probably increases with depth.

INTRODUCTION

The Råna mafic intrusion lies on the south side of Ofotfjord in the northermost part of the county of Nordland in northern Norway and 20 km southwest of the iron-ore port of Narvik (Fig.1). The area has been known for its nickel mineralization since the early part of the century (Foslie, 1921) but the most detailed investigations have been carried out within the last decade, some of the general geological results having been reported by Boyd & Mathiesen (1979) (Fig. 2).

The intrusion forms a positive feature in the topography with extensive areas at an altitude of 700 m or more while the country rock to the north, east and west lies at 450 m or less. Above 700 m the terrain is alpine with a number of peaks at over 1300 m and several small glaciers. The recent investigations have included colour aerial photography of the whole area and the photogrammetric construction of topographic maps at a scale of 1:10,000, the latter forming an essential basis for the detailed geological and gravimetric mapping. Extensive use of helicopter support has enabled a more complete and logistically rational survey than would otherwise have been possible.

As part of a nationwide survey, gravimetric measurements at a density of one per 100 km^2 were carried out over the area by the Geographical Survey of Norway (NGO, 1979). The results are shown in Fig.3 which shows no positive anomaly over the Råna intrusion, the measurements having been too sparse.

A reconnaissance gravimetric survey was carried out by the Geological Survey of Norway (NGU) in 1976 and was followed up in 1977 with a detailed survey using a helicopter and boats to reach areas not easily accessible by car or on foot. Gravity was measured at 330 stations both within intrusion and in a wide area around it: the average density of points is c. 1/km^2.

GEOLOGY

The contry rocks of the Råna mass belong to the Narvik Group (Gustavson, 1972) and are mainly two-mica gneisses. They form part of the Caledonian orogenic belt and have been subjected to at least four fold phases and to metamorphism at garnet-amphibolite facies conditions. The country rocks have a metamorphic age of 400±16 m.y. while intrusion itself has been dated at 400 m.y. on the basis of Rb/Sr whole rock and mineral isochrons (Roddick, 1977).

The intrusion itself has a core of quartz-norite and a perperal zone of norite which contains irregular bands and lenses of peridotite (the main host rock for mineralization) and pyroxenite (Fig.2). The ultramafic rocks are not evenly distributed round the periphery of the intrusion, being concentrated in the northern and southern parts of the periphery where they tend to occur in greatest volume close the outer margins of the intrusion. Two roughly synformal outliers are present at the southern margin, one of them, on mountain Tverrfjell (Fig.2), being the only area in the intrusion in which magmatic banding on scales below 100 m occurs frequently. Particularly in the southeastern part of the main body of the intrusion subhorizontal granitic or trondhjemitic pegmatites are common. These may reach a thickness of 50 m and may have a combined thickness of up to 200 m in the visible section

The surface geology of the intrusion suggests the general form of an inverted cone with contacts on the northern and northwestern margins dipping steeply outwards while the southern and eastern contacts dip inwards at moderate angles. The surface distribution of rock types and comparison with many well-described layered intrusions suggests the possibility that deeper levels of the intrusion could be expected to have a higher proportion of peridotite.

The only known deposit of significance in the intrusion occurs near the northwestern margin, north of the lake Bruvann (Fig.2). The deposit contains 43 million metric tons with 0.33% sulphide nickel, 0.08% copper and 0.15% cobalt almost the entire mineralization occurring as a dissemination of pyrrhotite+pentlandite+chalcopyrite+pyrite interstitial to olivine and orthopyroxene in peridotite. The Bruvann deposit lies in a part of the intrusion called the Arneshesten block which has been thrust upwards towards the southeast in relation to the rest of the intrusion (Boyd & Mathiesen, 1979). That this block contains a relatively high proportion of peridotite, including the only major mineralized body in the intrusion found to date tends to confirm the suggestion that the proportion of peridotite and possibly the ore potential increase downwards. Without the means to carry out an exceedingly expensive deep drilling programme geophysical methods offered the only possibility for confirming or supporting this hypothesis.

Cap /Methods, correction procedures, etc.

The specific gravity of selected samples from within the intrusion was measured at 20°C after one day's saturation in water in order to fill cracks and pores (Table 1). The samples are thought to be representative except in the case of quartz-norite: several of the quartz-norite samples tested come from Eiterdal (Fig.2) and contain a higher proportion of normative quartz than is present elsewhere in the core of the intrusion. For this reason the density used for quartz-norite is 2.88 g/cm^3. For the surrounding gneisses the figure of 2.73 g/cm^3 (Brooks, 1970) was used to calculate density contrasts. The rocks within the intrusion thus have specific gravities 0.15 - 0.50 g/cm^3 greater than that of quartz-mica gneiss which makes up the bulk of the country rock.

For the Bouguer and terrain corrections a value of 2.67 g/cm^3 was employed: this figure is in general use in Norway to enable direct comparison of Bouguer anomaly maps to be made (see discussion by Ramberg, 1976). These corrections were made using a computer programme written by Mathiesen (1976) while corrections for the dept of water in Storvatn were made manually by the method of Hammer (1939). The data were thereafter corrected for regional variations using the NGO map (Fig.3) to obtain a residual anomaly map (Fig.4) on which a zeroanomaly level was chosen by inspection.

Detailed gravimetric surveys in the areas of such extreme terrain as Råna became feasible only with the advent of computerized correction. Large areas have terrain corrections of c. 30 mGal but nevertheless the points which have the highest terrain corrections fall naturally into the anomaly picture - a fact which points to efficiency of the correction programme.

Application of a general Bouguer correction for gneiss as opposed to the densities of the rocks occurring locally within the intrusion has resulted in a Bouguer anomaly map which reflects the effect of all rocks in the intrusion, including those above sea level. The maximum error involved in the use of 2.67 g/cm^3 instead of 2.73 g/cm^3 is +3.3 mGal. Conversely the use of 2.67 g/cm^3 in terrain corrections instead of a combination of densities has involved a maximum of -3.6 mGal such that the two errors tend to cancel each other.

The altitude determinations at most of the stations have been determined photogrammetrically with an accuracy of $\pm$2m: this results in an error of $\pm$0.4 mGal in the residual anomaly map.

It is thought highly unlikely that selection of the zero anomaly level by inspection has resulted in an error exceeding 1,5 mGal or 10% of the average anomaly.

Three profiles across the residual anomaly map (Fig.6) were selected to give approximate symmetry in the area of each profile and to intersect prominent features in the intrusion. Models for each profile were erected using a computer programme written by . As ultramafic rocks occur in varying proportions in norite it was found necessary in model construction to employ 'mixed rocks', norite and peridotite in the proportions 7:1 and 2:3. In erecting the models the geology on the surface along each profile was used as a starting point. Attention was paid to the agreement of each profile with the other two at their points of intersection and to topographic variation along each profile (bearing in mind that the effect of the density contrast between mafic rocks and geniss above sea level remains).

The models (Fig.7) consist of a series of horizontal prisms with rectangular cross-sections. Fig. 7 incorporates schematic profiles showing the models readjusted for topography.

RESULTS AND PROFILE INTERPRETATION

Fig. 5 demonstrates the marked gravity anomaly resulting from the Råna intrusion. The margins of the anomaly over the main body of the intrusion show close coincidence with the known surface contacts of the intrusion. This indicates the following:

1) that the intrusion extends for a short distance out under Ofotfjord.
2) that the outliner on Tverrfjell and possibly that on Kvanåkertind (Fig.2), south of the main intrusion, are isolated from it at depth as well as on the surface.
3) that the embayment in the contact south of Bruvann (Fig.2) which is related to the upthrusting of the Arneshesten block to the southeast extends to some depth but is underlain by mafic rocks.

A major feature of the residual anomaly map (Fig.5) is the negative anomaly extending northwards along Storvatn. Although gneiss with a northward dipping foliation is exposed as far north as the O E-W profile (Fig.2) on the western side of Storvatn, little is known of the geology at lake level on the eastern side of the lake because of the cover of scree, especially between Eiterdal and Kringelvann (5500E 2500N). The gravity picture suggests the existence of a tongue of gneiss extending northwards along the lake. Its presence could be controlled by faulting or folding. The latter alternative is tentatively preferred because: 1) N-S faults and fractures have been exploited locally to form prominent topographic features elsewhere in the intrusion but not of the order of magnitude of Råndal and Storvatn, 2) no significant displacement of the main outer contacts of the intrusion is seen and 3) exposed evidence tends to favour the fold hypothesis.

The southermost anomaly on the western side of Storvatn appears to be unrelated to the mafic rocks of the intrusion.

Numerous models could give theoretical anomalies corresponding to the selected profiles (Fig.7) but those presented here are regarded as approximations to be most probable form of anomaly. The range of possibilities is limited by the necessary conformity of the models to the surface geology and to each other.

The models suggest a maximum depth for the intrusion of the order of 2.5 km at its northwestern extremity. The contact at the northern mergin appears, in general, to dip steeply northwards or northwestwards to a depth of at least 1.5 km below the surface but may locally (Profile C) flatten out below this depth. The southern and eastern contacts appear to have shallower dips, towards the north and west respectively. The models suggest that the hypothetical country rock antiform extends into the northern third of Storvatn. The Tverrfjell outlier probably does not extend down to sea level while much of the eastermost part of the intrusion appears to be quite shallow.

As to the distribution of rock types within the intrusion the interpretation indicate that the ultramafic rocks tend to be concentrated in the northern part of the intrusion and at deeper levels. The interpretation given for Profile C suggests that the norite peripheral zone is discontinuous or absent under much of the eastern part of the intrusion: alternatively if the norite zone, with or without peridotite is present then the intrusion must be considerably thinner. If the selected interpretation is correct, it is probable that the base of the intrusion in this area is tectonic and connected to the prominent belt of foliated metanorite and gneiss north of the Tverrfjell outlier.

In general in considering the profile interpretations it must be noted that the present form of the intrusion shows the effects of two phases of folding and at least local thrusting on the primary geometry of the body. Thus the northwesternmost parts of each profile intersect the thrust zone between the Arneshesten block and the rest of the intrusion, and other lesser tectonic discontinuities.

While the gravity results have not proved to be of direct use in exploration for mineralized peridotite at present (no large near-surface peridotites have been revealed) they have enabled an extension, refinement and correction of the previous model (Boyd & Mathiesen, 1979). This along with an improved knowledge of the distribution of rock types at depth in the intrusion has importance for an assessment of the long-term resource potential of the area.

ACKNOWLEDGEMENTS

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TABLE 1

Average densites of rocks from the Råna area, and density sontrasts to the surrounding gneiss.

Rock type	Number of samples	Meandensity g/cm^3	Standard deviation	Contrast to gneiss g/cm^3
Norite	6	2,97	0,07	0,24
Quartz norite	4	2,83	0,01	0,10
Peridotite	9	3,23	0,13	0,50
Gneiss (Brooks,1970)		2,73		0
Quartz norite		2,88		0,15
Norite with 12,5% peridotite		3,00		0,27
Norite with 60% peridotite		3,13		0,40

TEXT FOR FIGURES

Fig.1: Map of Norway showing the location of the Råna intrusion.

Fig.2: Geological map of the Råna intrusion.

Fig.3: Regional Bouguer anomaly map (scale 1:500,000) based on data from the Geographical Survey of Norway (1979).

Fig.4: Bouguer anomaly map of the Råna area (scale 1:200,00).

Fig.5: Map showing residual gravity anomaly and geology of the Råna area.

Fig.6: Map showing residual gravity anomaly and the horizontal projections of the prisms involved in the model interpretations (scale 1:100,000).

Fig.7A,B & C: Each figure shows a gravity profile as measured across the intrusion, a geological model built up of prisms with densities approcimating those of the rocks in the intrusion, a theoretical gravity profile which the model would generate and a schematic geological profile based on the model (scale 1:100,000).

FIG. 1

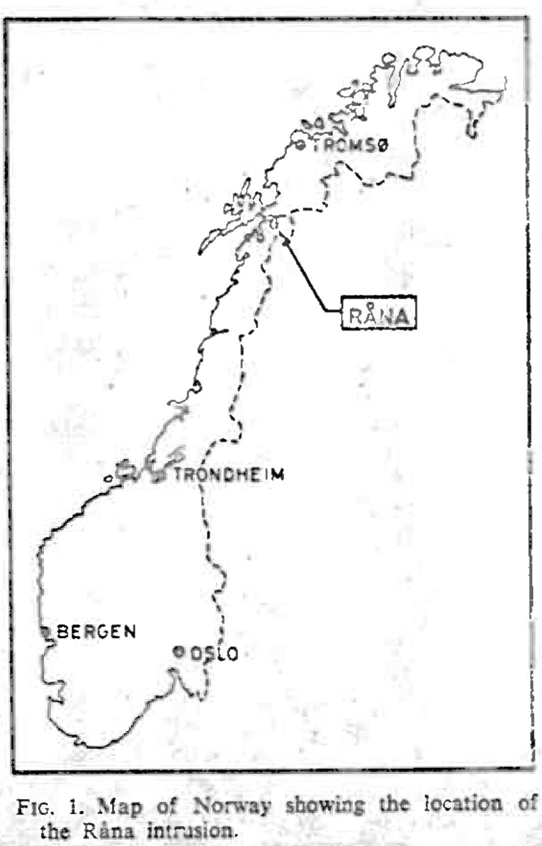
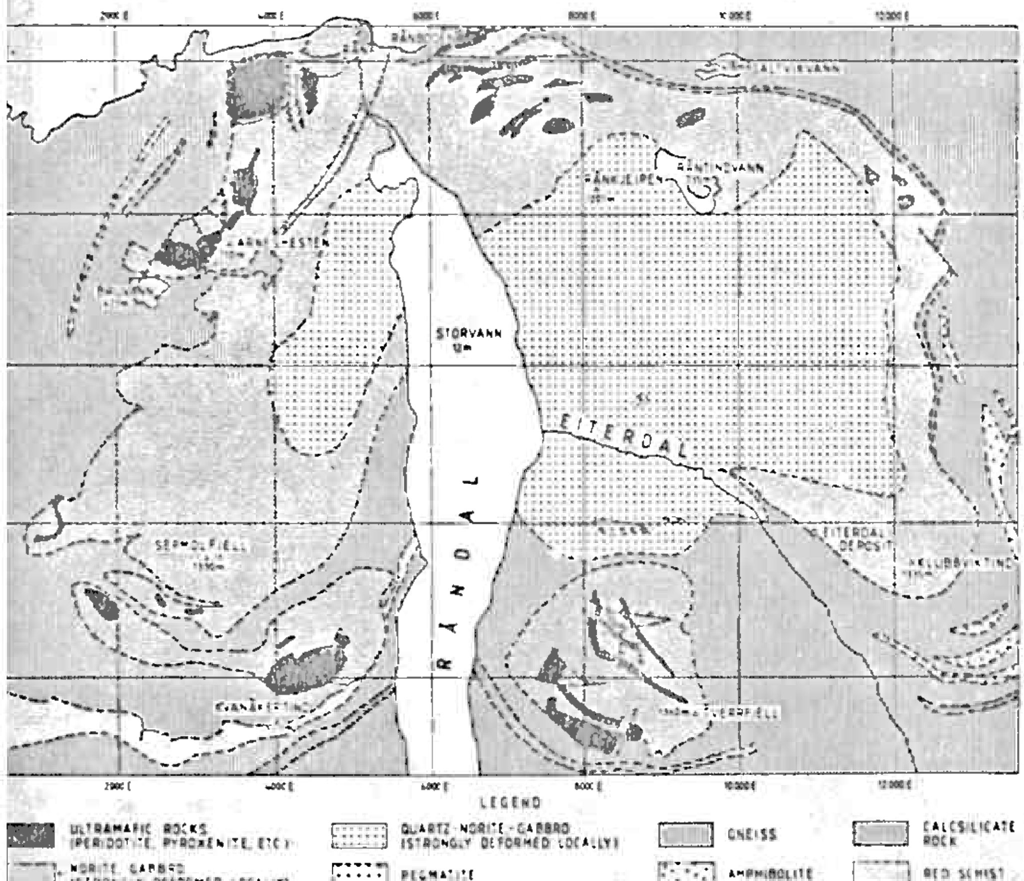


FIG. 1. Map of Norway showing the location of the Råna intrusion.

FIG. 2



G. 2. Geologic map of the Râna intrusion.

FIG 3

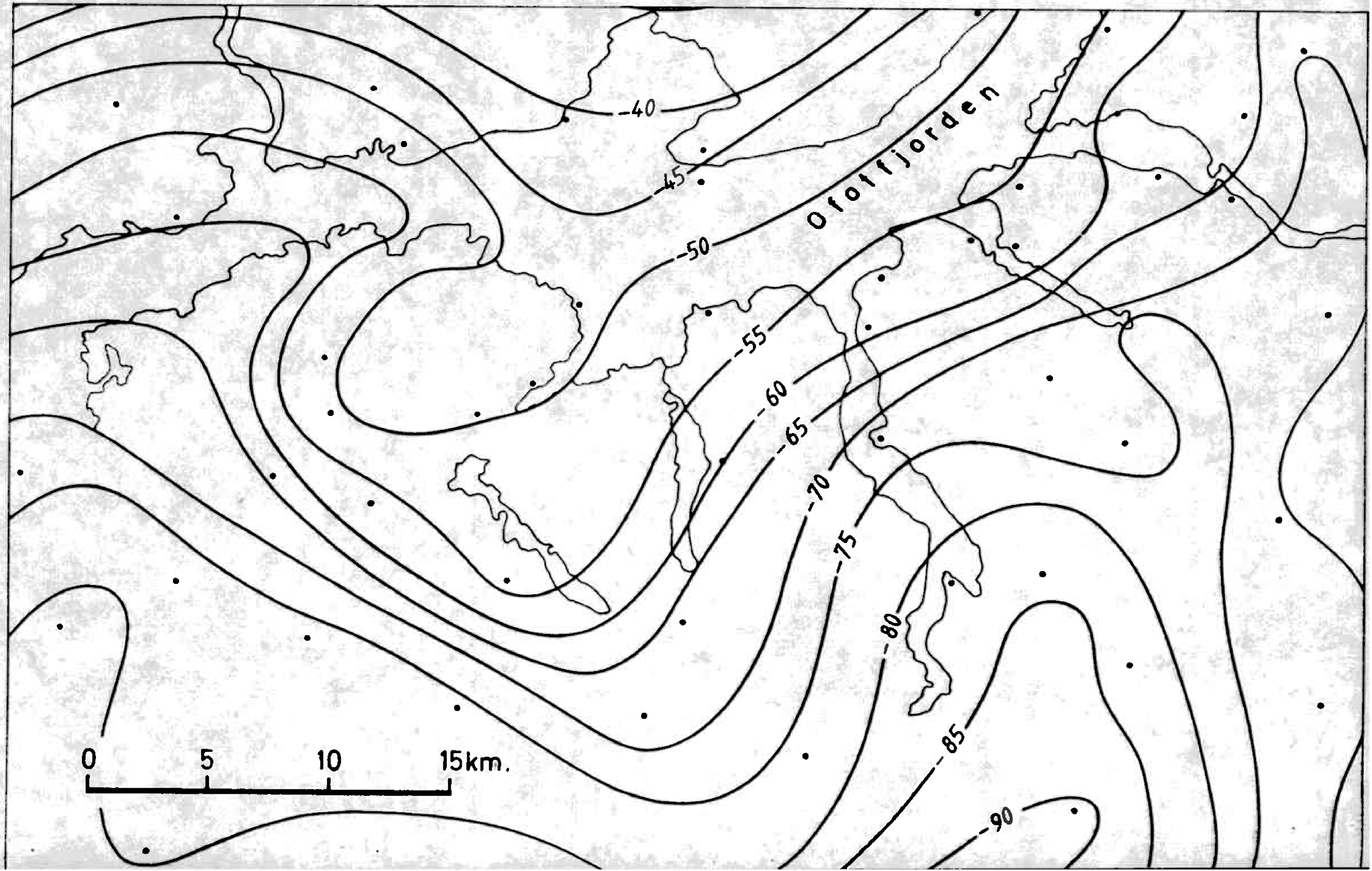


Fig. 4

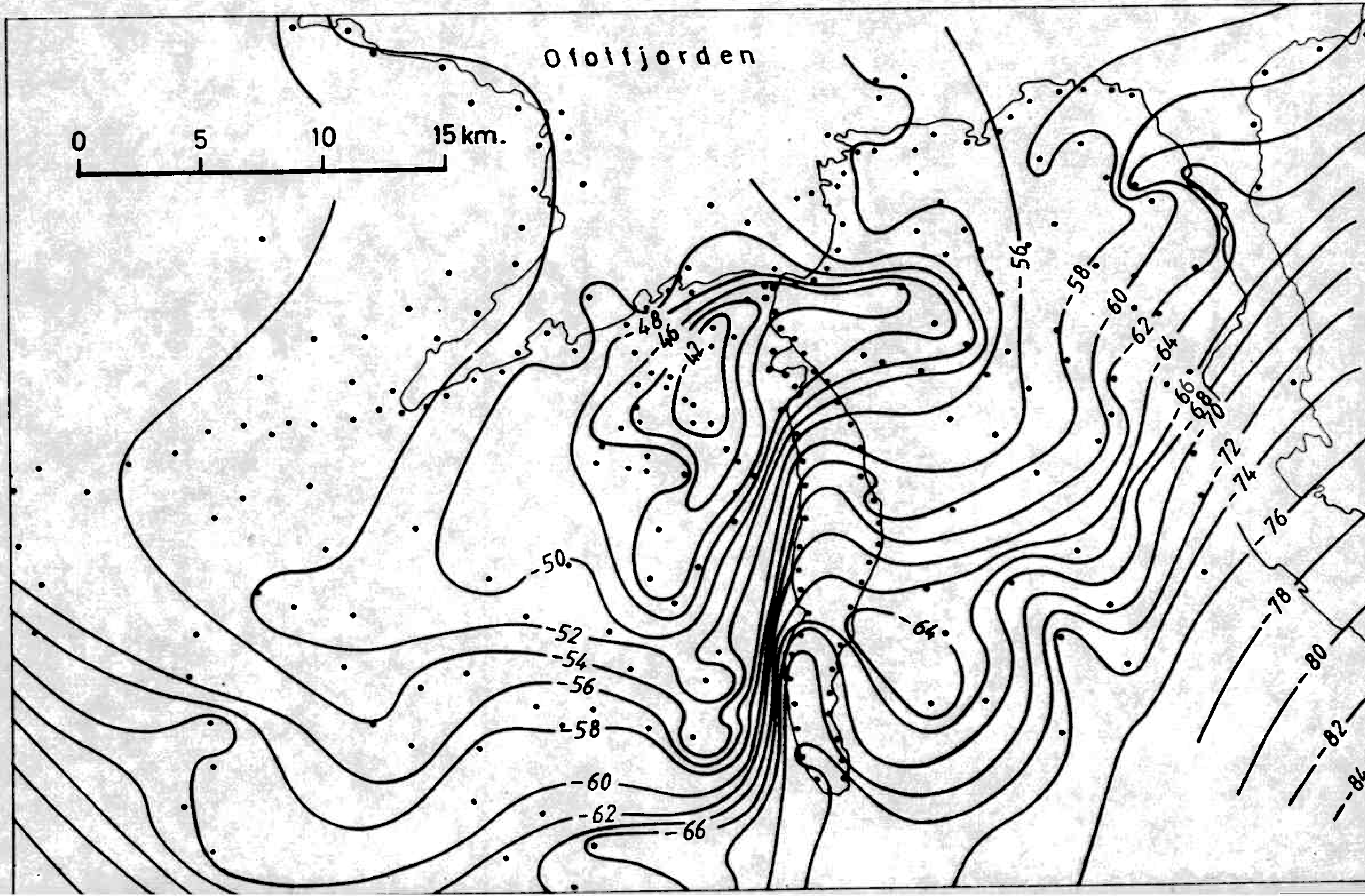

Ofotfjorden
0
5
10
15 km.
-42
-46
-48
-50
-52
-54
-56
-58
-60
-62
-64
-66
-68
-70
-72
-74
-76
-78
-80
-82
-84

FIG 5

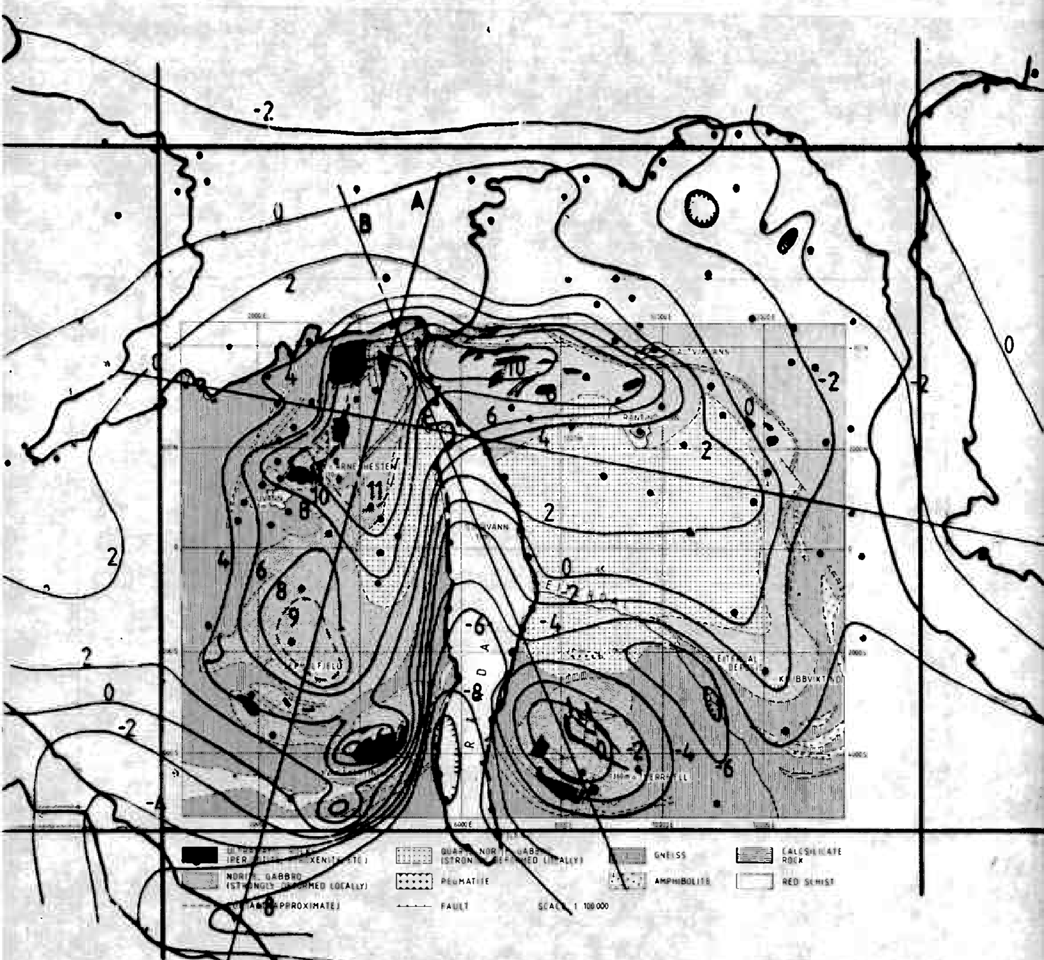
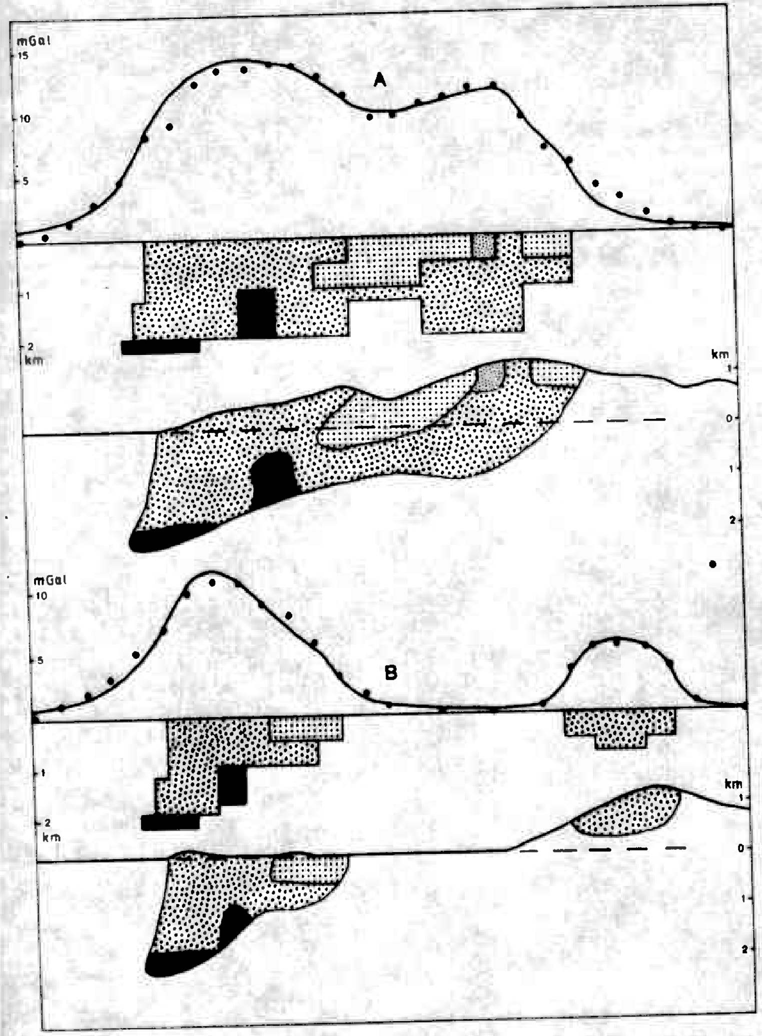

PEGMATITE
FAULT
SCALE 1 100 000
GNEISS
AMPHIBOLITE
CALCSILICATE ROCK
RED SCHIST

FIG. 6

RÅNA: GRAVIMETRISK RESIDUALKART, KONTURINTERVALL 2 MGAL
• MÅLEPUNKT

(dette + Fig 5's kotedel)

FIG 7 A,B



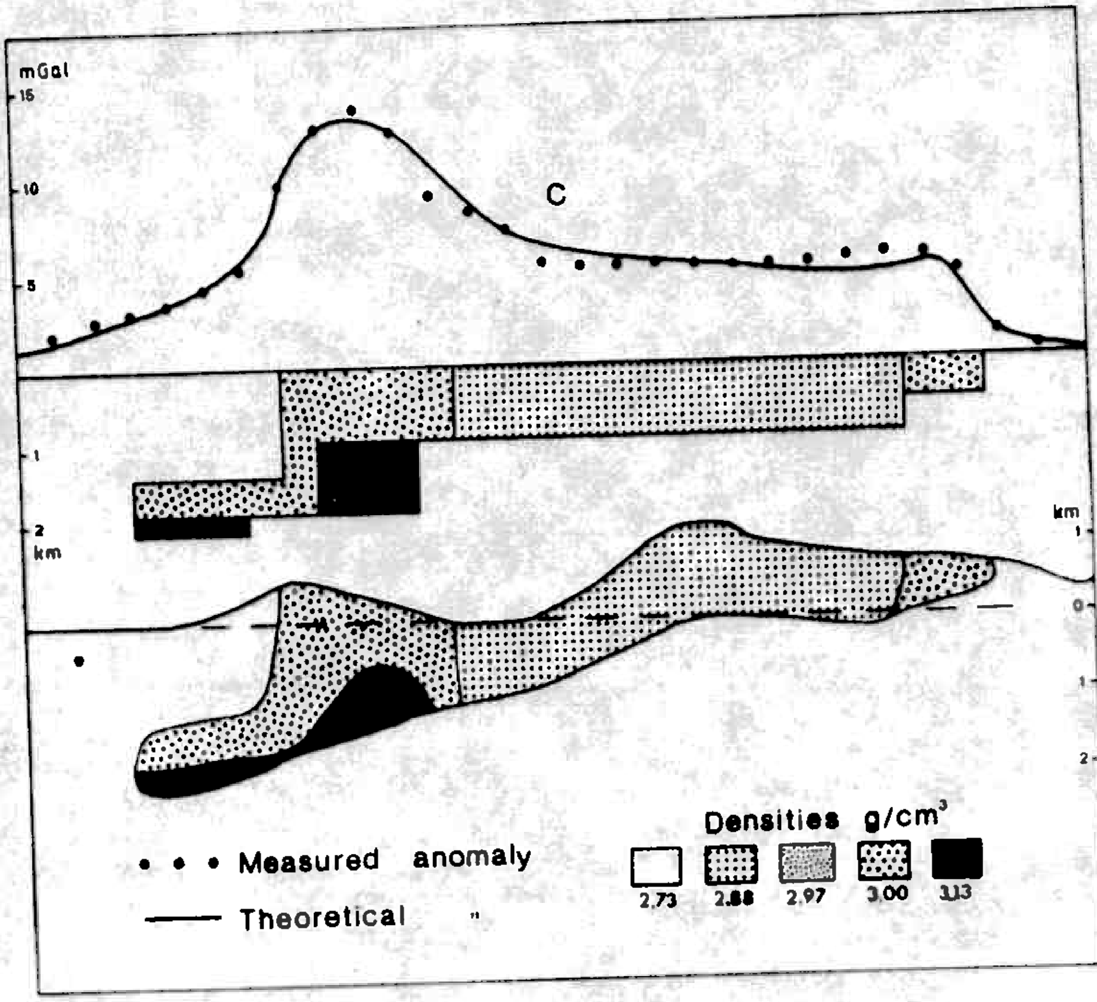

mGal
15
10
5
C
1
2
km
km
1
0
1
2
Densities g/cm³
2.73
2.88
2.97
3.00
3.13
Measured anomaly
Theoretical "

Fig 7, e