

NGU Rapport 94.061

**Tolkning av gravimetriske data over
Ofotsynklinalen**

Rapport nr. 94.061		ISSN 0800-3416	Gradering: Åpen	
Tittel: Tolkning av gravimetriske data over Ofotsynklinalen				
Forfatter: Atle Sindre		Oppdragsgiver: NGU		
Fylke: Nordland og Troms		Kommune:		
Kartbladnavn (M=1:250.000) Narvik		Kartbladnr. og -navn (M=1:50.000)		
Forekomstens navn og koordinater:		Sidetall: 30	Pris: kr 140	
		Kartbilag: 3		
Feltarbeid utført:	Rapportdato: 26.09.94	Prosjektnr.: 61.2543.08	Ansvarlig: <i>Terje S. Rønning</i>	
<p>Sammendrag:</p> <p>Ved hjelp av gravimetriske data er det gjort en beregning av tykkelsen på dekkebergartene i området Tysfjord - Ofoten - Harstad. Den gravimetrisk modelleringen er gjort langs 11 øst-vest gående profiler over Narvikdekkekomplekset og de utenforliggende grunnfjellsområdene. Beregningene viser at dekkebergartene danner et traue som er opp til 7 km dypt. Kanten faller brattest på vestsiden, mer slakt i øst. De største dyp er i Ballangenområdet. Resultatene av undersøkelsen er vist som profilsnitt og som dybdekontekart sammenstilt med geologisk kart. Datagrunnlaget for undersøkelsen er et gravimetrisk residualanomalikart som er basert på tyngdemålinger utført av NGU og andre i det aktuelle området over mange år, samlet i NGU's database for gravimetri, og petrofysiske data (bergartenes densitet) fra NGU's database for petrofysikk. Aeromagnetisk anomalikart er også framstilt over området til denne undersøkelsen.</p> <p>Resultatene av en gravimetrisk undersøkelse som ble gjort i 1970-årene i Ballangen i forbindelse med malmundersøkelser i Råna og som ikke tidligere er gjort offentlig tilgjengelig i rapportform, er her tatt med som bilag.</p>				
Emneord: Geofysikk		Berggrunnsgeologi	Gravimetri	
Magnetometri		Petrofysikk	Tolkning	
			Fagrapport	

INNHOOLD

1.	INNLEDNING	4
2.	DATAGRUNNLAG	4
2.1	Geologi	4
2.2.	Geofysikk	4
2.3	Petrofysikk	5
3.	MODELLBEREGNING	8
4.	RESULTATER OG KONKLUSJON	8
5.	REFERANSER	10

DATABILAG

Figur 1	Densitet marmor, Narvikdekkekompleks
Figur 2	Gravimetrisk modell, Profil 1 og 2
Figur 3	Gravimetrisk modell, Profil 3 og 4
Figur 4	Gravimetrisk modell, Profil 5 og 6
Figur 5	Gravimetrisk modell, Profil 7 og 8
Figur 6	Gravimetrisk modell, Profil 9 og 10
Figur 7	Gravimetrisk modell, Profil 11

KARTBILAG

Figur 8	Geologisk kart med tolket dyp til grunnfjell, M 1:500 000
Figur 9	Residual Bouguer anomalikart, M 1:500 000. Gravimetrisk modellering langs profilene 1-11
Figur 10	Aeromagnetisk anomalikart, M 1:500 000

TEKSTBILAG

A Gravity study of the Råna nickeliferous norite peridotite intrusion, Nordland, Norway. Sindre, Boyd & Mathiesen (1980).

1. INNLEDNING

I de siste årene har NGU utført flere tusen tyngdemålinger i Nordland, slik at størstedelen av fylket er dekket av et relativt tett nett av observasjoner. Ofoten er et av de områdene som er best dekket med gravimetri. Her ble det allerede i 1970-årene satset på gravimetri i forbindelse med malmundersøkelser i Ballangen. Et hittil ikke publisert manuskript fra disse undersøkelsene, presentert på NOFTIG-møtet i 1979 og Geologisk vintermøte i 1980, er vedlagt (Tekstbilag). Ny teknologi har nå gjort det lettere å framstille geofysiske kart, og bedre dataprogrammer for tolkning er tilgjengelige.

I denne undersøkelsen har en brukt gravimetriske data til å beregne tykkelsen av dekkebergartene i området Tysfjord - Ofoten - Harstad. Datagrunnlaget er det gravimetriske residualanomalikartet, Fig. 9. Her har en trukket regionalgradienter, som har med jordskorpe tykkelse å gjøre, fra Bougueranomali verdiene ved hjelp av en metode med bevegelig median med punkter innenfor en radius på 50 km. Kartframstillingsmetode er THEMAP, Kihle (1992). Modellberegningene er gjort langs 11 profiler, Fig. 9. For lettere å kunne vurdere om anomaliene skyldes dekkebergarter eller om de er forårsaket av tunge kropper i grunnfjell, er aeromagnetisk anomalikart for samme område framstilt, Fig. 10.

2. DATAGRUNNLAG

2.1 Geologi

I Fig. 8 vises et utsnitt av NGU's berggrunnsgeologiske kart Narvik i målestokk 1:250 000, her nedfotografert til 1:500 000. Geologien i området består av to hovedstrukturer som dominerer på kartet. Det er grunnfjell som er blottet i øst og i vest, og de overliggende kaledonske dekkebergartene som danner et belte i retning N-S i den sentrale delen av området. De vanligste bergartstypene i dekkene er glimmerskifer, glimmergneis, marmor, amfibolitt og gabbrointrusiver. Grunnfjellet består hovedsakelig av granitter og granittiske gneiser, syenitter, glimmerskifer og vulkanitter av basisk sammensetning.

2.2 Geofysikk

I den sentrale delen av det gravimetriske kartet, Fig. 9, har en kraftige positive anomalier over dekkebergartene. Det er ingen store magnetiske anomalier over dekkene her, Fig. 10, bare noen mindre anomalier ved Frostisen og ved Bogen, og disse skyldes

jernmalmlag i skifrene. Utstrekningen av den positive tyngdeanomalien faller sammen med dekkebergartene og det er sannsynlig at disse forårsaker anomalien. Det er grunn til å anta at de granittiske bergartene i Tysfjord, Lødingen og Rombaken er sammenhengende under dekkene. Langs svenskegrensa i øst, lager mafiske vulkanitter og gabbroer i grunnfjell kraftige magnetiske og gravimetriskke anomalier. Det anomalidraget fortsetter nordover gjennom dekkeområdet mot Bardu. Dekket er her tynt, grunnfjell er blottet mange steder i bunnen av dalene, så her kan en være sikker på at anomaliene skyldes grunnfjellsbergarter.

Ut fra dette kan en anta at de gravimetriskke anomalier i det sentrale området skyldes dekkebergartene som er tyngre enn grunnfjellet. De kraftige anomalier i øst, både gravimetriskke og magnetiske, skyldes tunge bergarter i grunnfjell.

2.3 Petrofysikk

Et stort antall prøver fra grunnfjellsområdene Rombakvinduet og Tysfjord- og Lødingen-granittkompleks fins i NGU's petrofysikkdatabase. Se Tabell 1, tatt fra Olesen og Torsvik (1993). Disse har en gjennomsnittlig densitet på 2670 kg/m^3 . Densiteten for dekkebergartene er tatt fra Narvikdekkekomplekset som ligger sentralt i det undersøkte området. Densiteten har et gjennomsnitt på 2811 kg/m^3 . (Tabell 1).

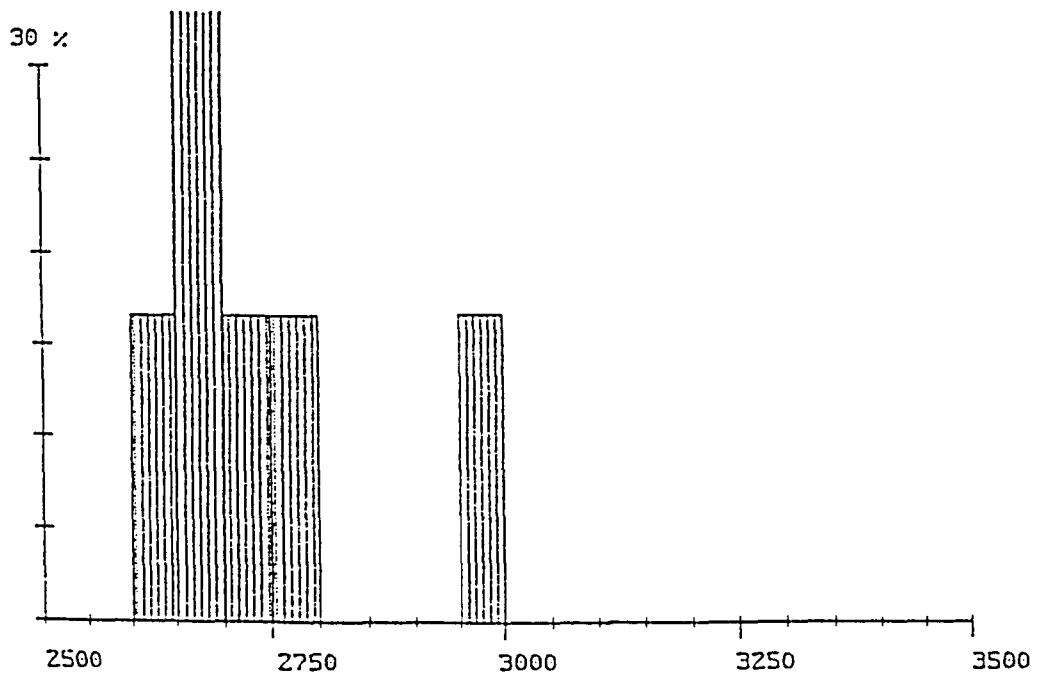
Sør for Ofotfjorden er det i dekkebergartene mange større og mindre gabbrokropper som forårsaker lokale topper i anomalikurvene. For å få en bedre tilpasning mellom målt og beregnet anomalikurve, har en lagt inn i modellene en del av disse kroppene, uten at en har lagt vekt på å beregne dem i detalj.

Gabbroen ved Råna, Profil 6 og 7, har i modellen densitet 2940 kg/m^3 , basert på 8 prøver fra Bruvatn, Arneshesten og Eiterdalen.

De små gabbrokroppene har i modellene i Profil 4, 5, og 6 densitet 2900 kg/m^3 , og i Profil 1 2910 kg/m^3 . Disse densitetene er tilpasset etter modellbredde og anomaliform.

Profil 11 krysser i den vestlige delen store områder med kalkbergarter. Det er her lagt inn i modellen en marmorstone med densitet 2740 kg/m^3 , som er tatt fra NGU's database for petrofysikk, Fig.1.

DEN (Kg/m³)
 ArMean : 2740.50000 ± 123.9286 N: 6
 LogMean: 2738.23633 Low: 2619.8342 High: 2861.99
 MIN : 2611.00000 MAX: 2974.0000 (A-Tick 50.00)



Figur 1. Densitet, marmor. Narvikdekkekompleks.
 Tatt fra NGU's database for petrofysikk.

Tabell 1. Petrofysikk på ulike bergartsenheter, fra Olesen & Torsvik (1993)

ROCK UNIT/TYPE	No.	DENSITY				No.	QVALUE				No.	SUSCEPTIBILITY				
		min	max	mean	std		min	max	logmean	std		min	max	logmean	std	
PRECAMB. OF LOFOTEN AND VESTERÅLEN	a	639	2579	3553	2776	137	582	.02	69.59	.38	.54	826	.00002	4.94550	.01136	.88
	b											213			.00061	.46
	c											613			.03135	.47
PRECAMB. OF SENJA, KVALØY AND RINGVASSØY, Gneiss etc.	a		3058	2685		75	285	.01	26.17	.59	.70	2296	.00001	.12344	.00361	.63
	b											947			.00108	.54
	c											1349			.00840	.38
PRECAMB. OF SENJA, KVALØY AND RINGVASSØY, Greenstone belts	a		3212	2957		129	58	.03	3.86	.36	.42	269	.00025	.19814	.00459	.70
	b											109			.00111	.28
	c											160			.01211	.57
LØDINGEN GRANITE COMPL.	a	20	2549	2778	2665	50	20	.02	3.90	.10	.62	69	.00003	.09350	.00831	.63
	b											13			.00106	.62
	c											56			.01338	.42
TYSFJORD GRANITE COMPL.	a	419	2566	2854	2670	44	404	.01	59.96	.55	.57	416	.00006	.30565	.00103	.76
	b											294			.00038	.34
	c											122			.01157	.38
ROMBAK WINDOW	a	51	2528	2875	2669	60	44	.03	10.13	.54	.61	51	.00001	.10298	.00045	.84
	b											42			.00021	.45
	c											9			.01655	.33
DIVIDAL GROUP	a	21	2543	2765	2669	56	9	.61	9.86	1.69	.37	21	.00001	.00101	.00011	.47
ABISKO NAPPE	a	68	2521	3182	2710	120	55	.04	15.70	1.16	.58	67	.00001	.03264	.00027	.71
	b											63			.00021	.57
	c											4			.01446	.33
KALAK NAPPE COMPL.	a	249	2585	3224	2776	156	54	.08	16.49	1.14	.49	249	.00001	.35022	.00038	.63
	b											234			.00029	.41
	c											15			.02298	.68
SEILAND IGNEOUS COMPL.	a	172	2593	3438	3048	182	165	.07	138.47	1.01	.51	172	.00021	.24627	.00642	.71
	b											65			.00116	.28
	c											107			.01811	.48
REISA NAPPE COMPL.	a	175	2578	3182	2805	129	86	.07	112.28	1.29	.57	171	.00002	.02226	.00041	.54
	b											160			.00033	.39
	c											11			.01099	.27
NARVIK NAPPE COMPL.	a	164	2547	3183	2811	130	143	.04	46.22	.78	.50	161	.00001	.16264	.00046	.57
	b											149			.00035	.35
	c											12			.01467	.61
OFOTEN NAPPE COMPL.	a	93	2524	3178	2830	167	69	.04	15.64	.73	.61	92	.00001	1.68400	.00042	.93
	b											82			.00024	.59
	c											10			.03712	.88
LYNGEN NAPPE	a	31	2665	3074	2849	128	10	.25	23.46	3.74	.57	31	.00001	.40981	.00057	1.02
	b											25			.00022	.55
	c											6			.02859	.71
NIINGEN AND TROMSØ NAPPES	a	33	2611	3137	2792	111	6	.26	19.29	1.27	.81	32	.00001	.01438	.00042	.53
	b											30			.00034	.41
	c											2			.00883	.21

Tabell 2. Densiteter og kontraster benyttet i modellberegningene.

Bergart	Densitet	Kontrast til grunnfjell
Grunnfjell	2670 kg/m ³	--- kg/m ³
Dekkebergarter	2811 -	140 -
Gabbro, Råna	2940 -	270 -
Gabbro, små kropper	2900 -	230 -
Gabbro, i profil 1	2910 -	240 -
Marmor	2740 -	070 -

3. MODELLBEREGNINGER

De gravimetriske anomalikurvene som brukes i modellberegningene er plukket ut av et gridd for residualfeltverdier, det samme som også er grunnlaget for residualanomali kartet Figur 9. Det har likevel vært nødvendig å korrigere profilkurvene for mindre gradienter. Utplukksprogrammet GDB2 av Smethurst (1992) er benyttet. Det er plukket ut langs 11 profiler hovedsakelig i øst-vest retning, Fig. 9. Dataprogrammet IMP 5, (Torsvik 1993), er brukt til beregningene. Beregningene av dekketykkelsen er i høy grad regional. En har ikke gjort forsøk på å kartlegge mindre kropper mot dypet, bare noen kjente gabbrokropper er tatt med for å "pynte" på kurvene. I det nordligste profilet er det også tatt med en større marmorsone.

4. RESULTATER OG KONKLUSJON

Resultatet av beregningene er vist som profilsnitt i Fig. 2, 3, 4, 5, 6 og 7, og som dybdekontekart for grunnfjelloverflaten i Fig. 8, sammenstilt med geologien. Kotetrekkingen er gjort for hånd, og en har tatt hensyn til anomalibildet i områdene mellom profilene.

Dekkebergartene danner et traue som er opp til 7 km dypt. Kanten faller brattest på vestsiden, mer slakt i øst. De største dypene er i Ballangenområdet, Profil 5, 6 og 7. Lengst i sør, Profil 1 og 2, har en to mindre traue. Ved Harstad, Profil 11, er de geologiske forhold mer komplisert enn modellen viser, og resultatene kan her ha større usikkerhet enn ellers.

Hvor stor usikkerheten er i de beregnede dekketykkelser er det vanskelig å si. En har regnet med at dekkene har den samme sammensetning av bergarter helt til bunns som en har i overflaten. Dette er sannsynlig, etter som de undre lagene er blottet langs kantene av dekkene, men ikke sikkert, for det er flere overskyvninger i området. En har også regnet med at det ikke er tunge kropper i grunnfjellet under dekkene. Det magnetiske anomalikartet, Fig. 10, indikerer at grunnfjellsbergarter er sammenhengende under dekkene. Konklusjonen er at profilsnittene i Fig. 2 - 7 og kotekartet i Figur 8 gir et pålitelig bilde i grove trekk av tykkelsen på dekkebergartene i det undersøkte området.

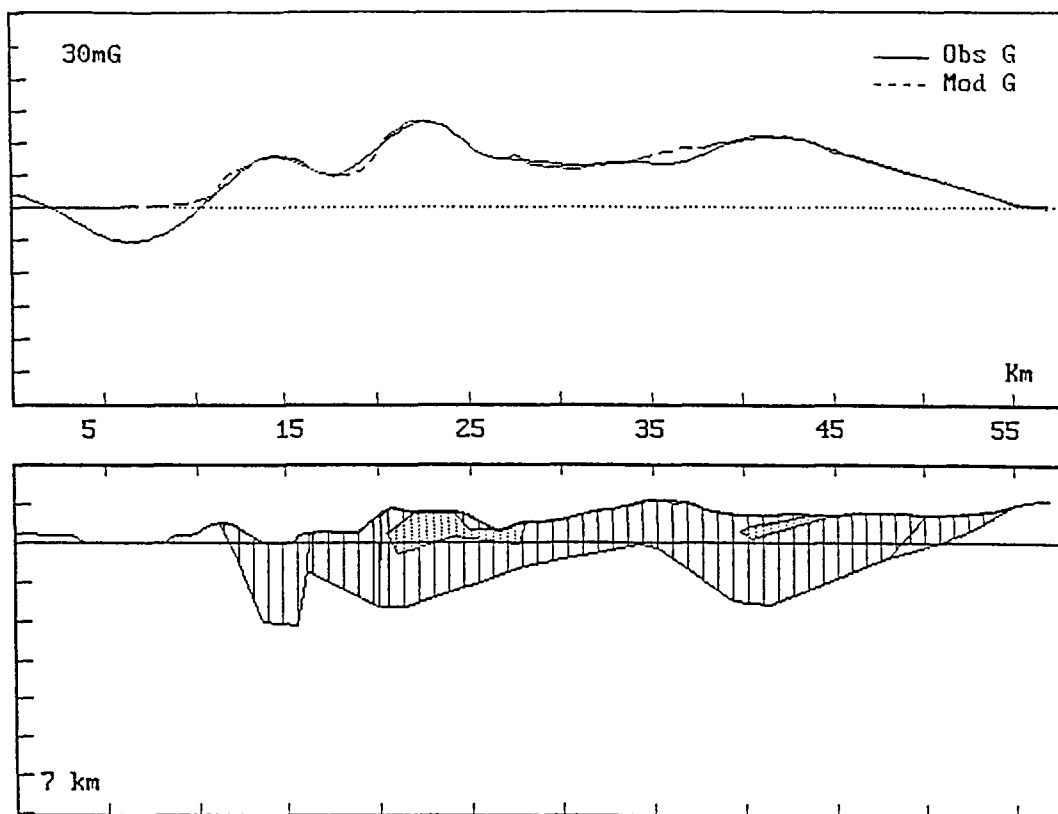
Datagrunnlaget for denne undersøkelsen er delvis de målinger som ble gjort i 1970 årene i forbindelse med malmundersøkelser i Råna, Ballangen. Resultatene av de gravimetriske undersøkelsene ble lagt fram som foredrag på Nordisk geofysikermøte i Oslo i 1979 og på Geologisk vintermøte i Bergen i 1980, men de er ikke gjort offentlig tilgjengelige i rapportform. Vi har derfor tatt dette med her som tekstbilag: (Sindre, Boyd & Mathisen 1980): A gravity study of the Råna nickeliferous norite-peridotite intrusion, Nordland, Norway.

Vi har idag flere gravimetriske data og bedre dataprogrammer for prosessering og modellering, og det er mulig at en ville komme til litt andre resultater om en gjorde en ny tolkning av gravimetrien i Rånafeltet. Det anbefales derfor å gjøre en mer detaljert tolkning av Råna intrusjonen. Før dette eventuelt gjøres, må det petrofysiske data-grunnlaget for denne intrusjonen bedres, dvs. flere bergartsprøver må måles.

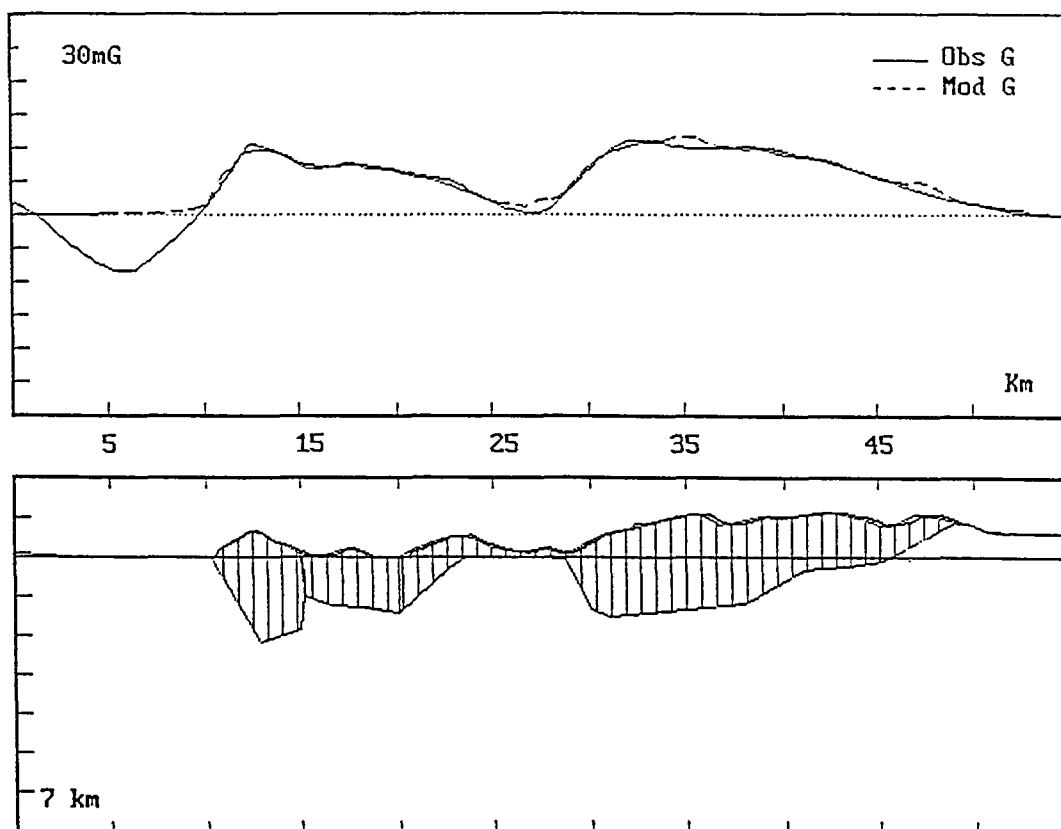
5. REFERANSER

- Kihle, O. 1992: THEMAB - et Uniras-basert produksjonssystem for fargerasterkart. *NGU internrapport 92.068*.
- Olesen, O. & Torsvik, T. 1993: Interpretation of aeromagnetic and gravimetric data from the Lofoten-Lopphavet area. *NGU Rapport 93.032*.
- Sindre, A., Boyd, R. & Mathisen, C.O. 1980: A gravity study of the Råna nickeliferous norite-peridotite intrusion, Nordland, Norway. Foredrag på *Nordisk geofysikermøte i Oslo (NOFTIG 1979)*, og *Geologisk vintermøte i Bergen 1980*.
- Smethurst, M.A. 1992: GDB2: A PC database program for data ordered in a grid pattern and for profiles through such grids. *NGU Rapport 92.328*.
- Torsvik, T. 1992: IMP - Interactive modelling of potential field data (Release 5). *NGU Rapport 92.305*.

PROFIL 1



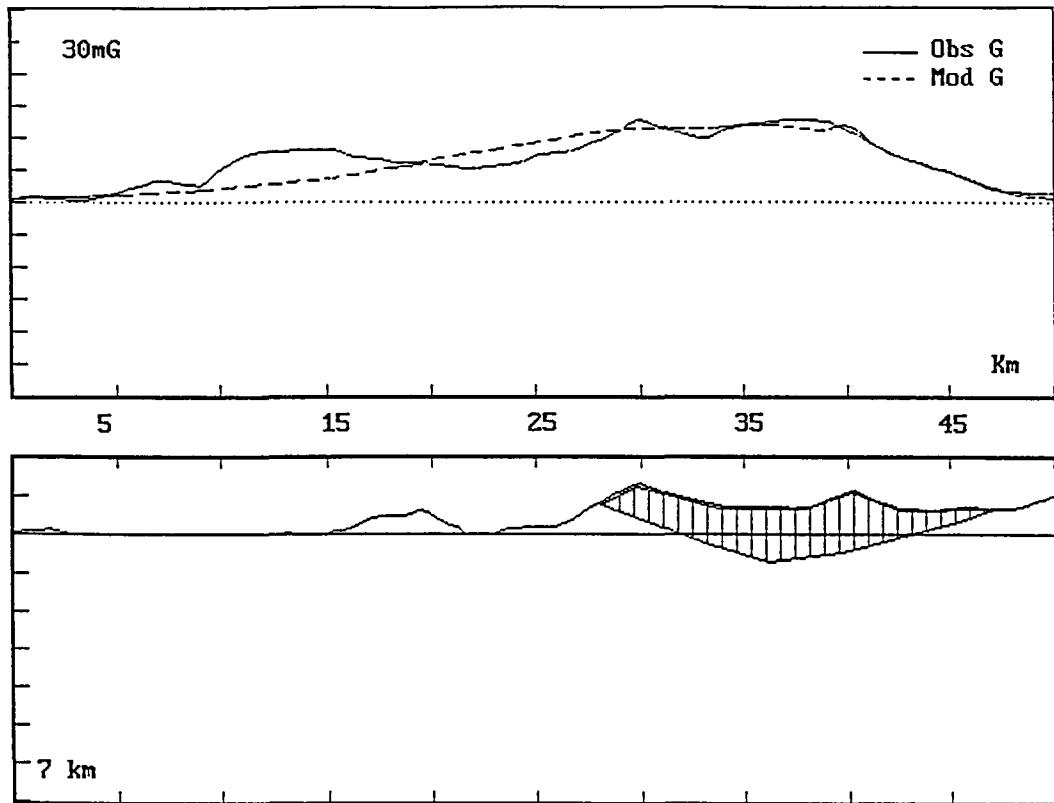
PROFIL 2



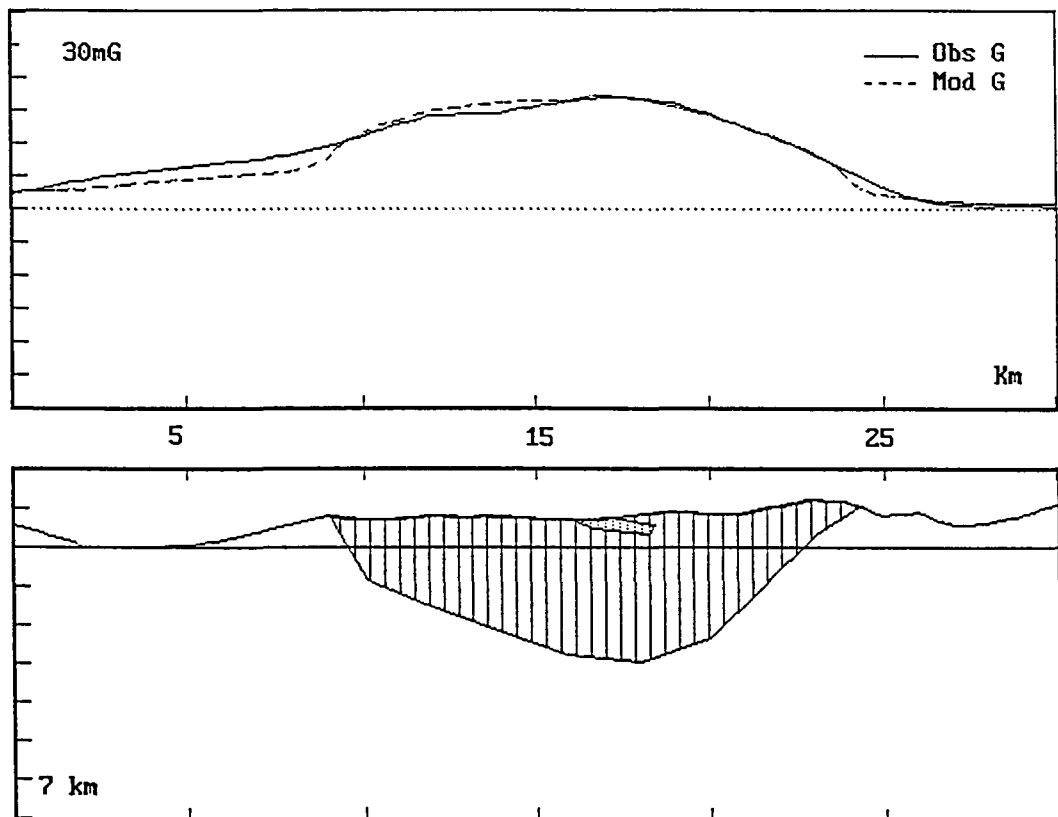
□ Grunnfjell ▨ Dekkebergarter ▤ Gabbro

Figur 2. Gravimetrisk modellering, profil 1 og 2.

PROFIL 3



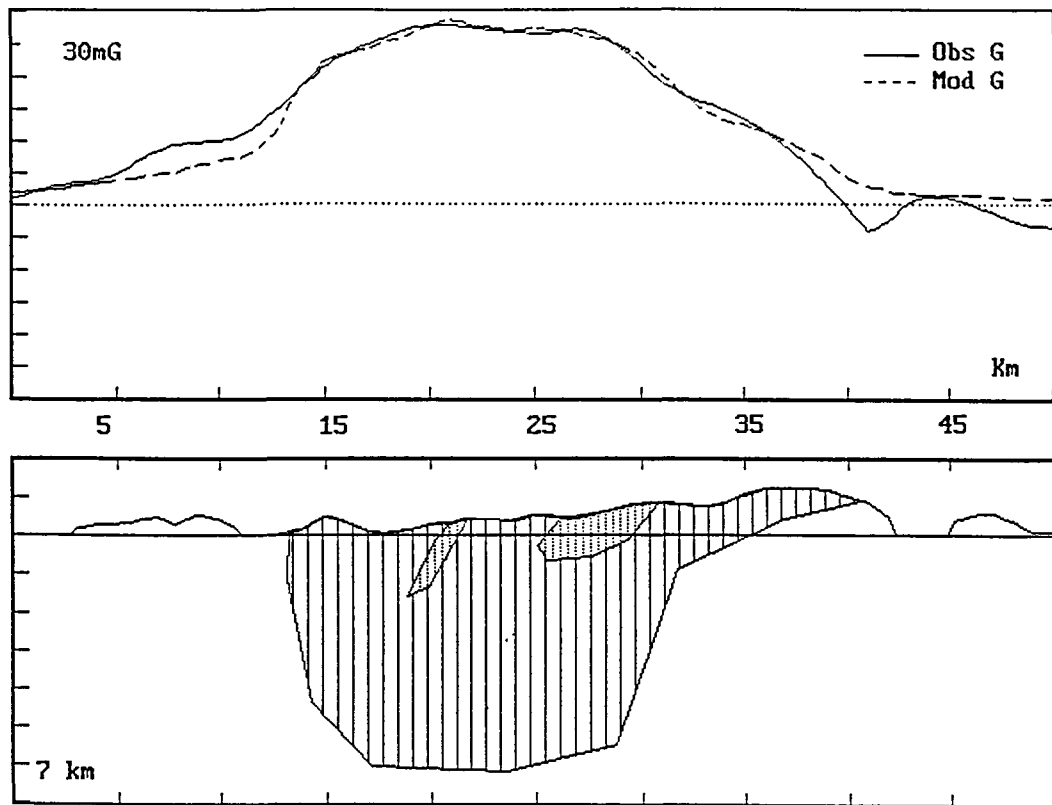
PROFIL 4



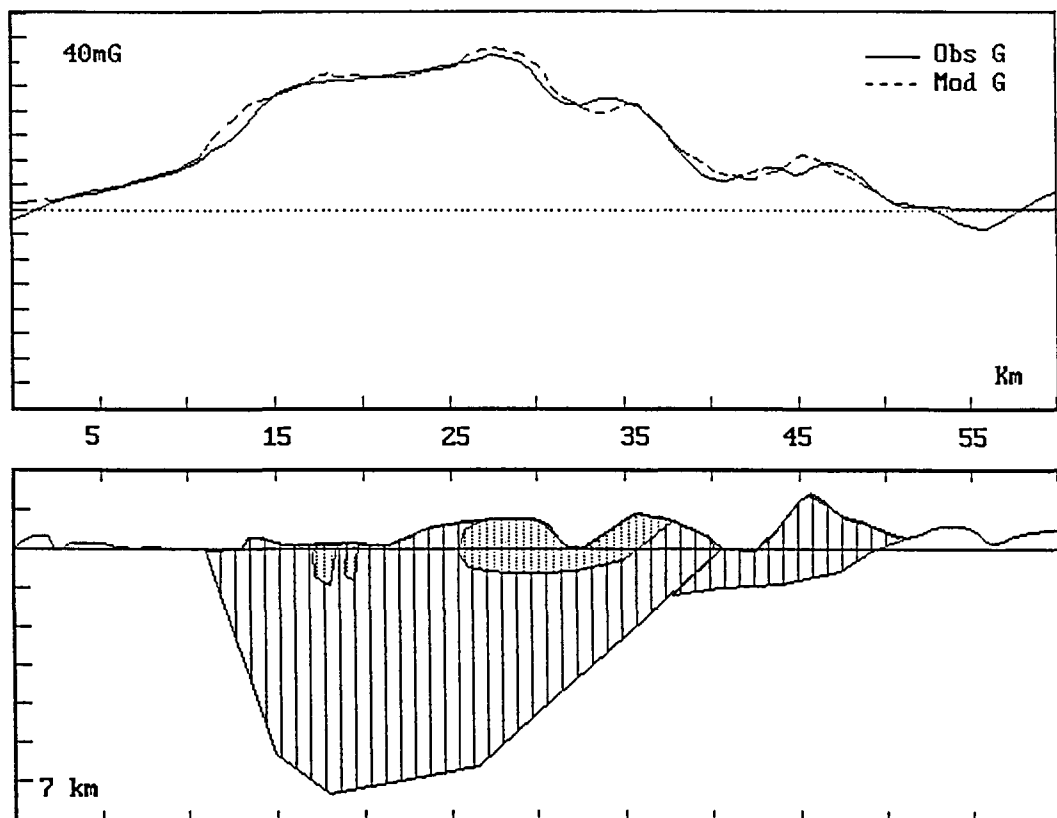
□ Grunnfjell ▨ Dekkebergarter ▩ Gabbro

Figur 3. Gravimetrisk modellering, profil 3 og 4.

PROFIL 5



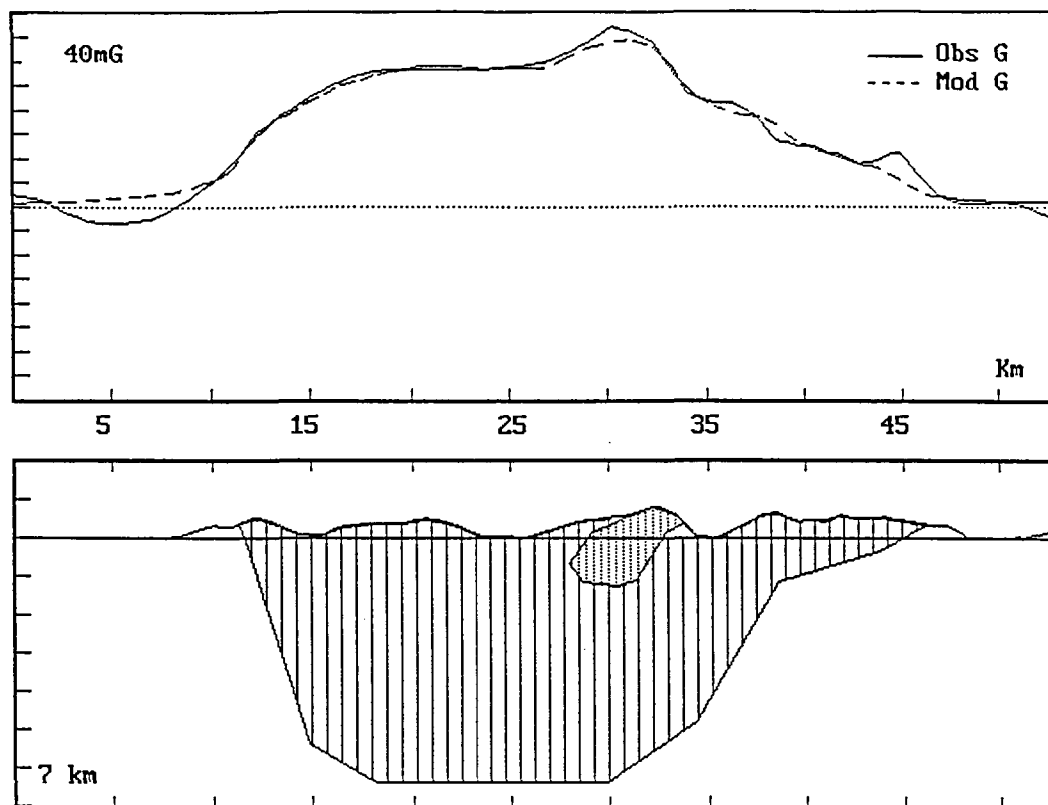
PROFIL 6



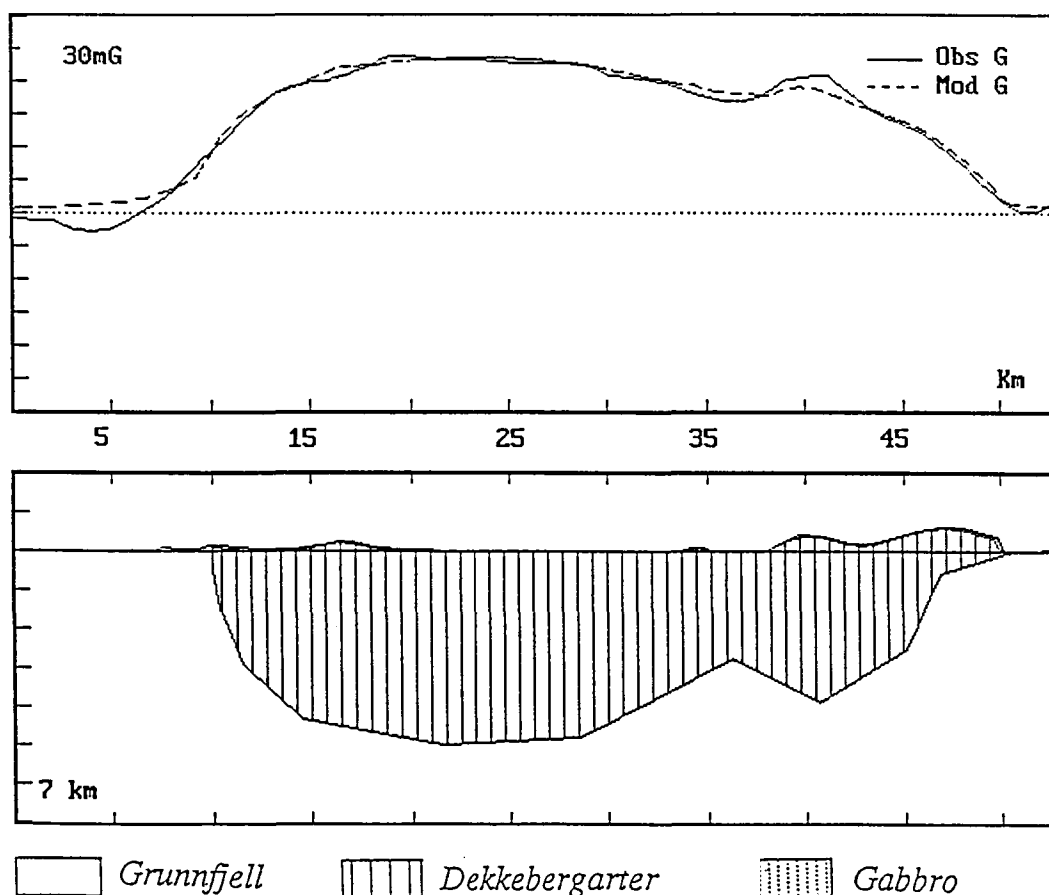
□ Grunnfelt ▨ Dekkebergarter ▩ Gabbro

Figur 4. Gravimetrisk modellering, profil 5 og 6.

PROFIL 7

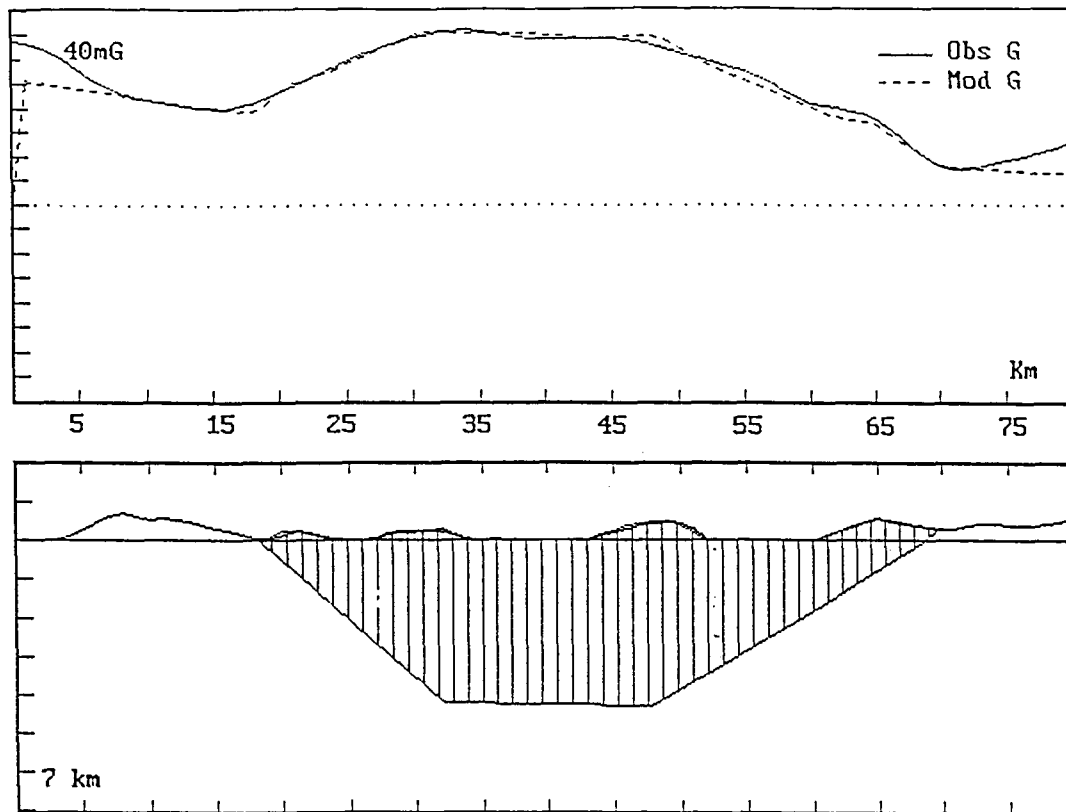


PROFIL 8

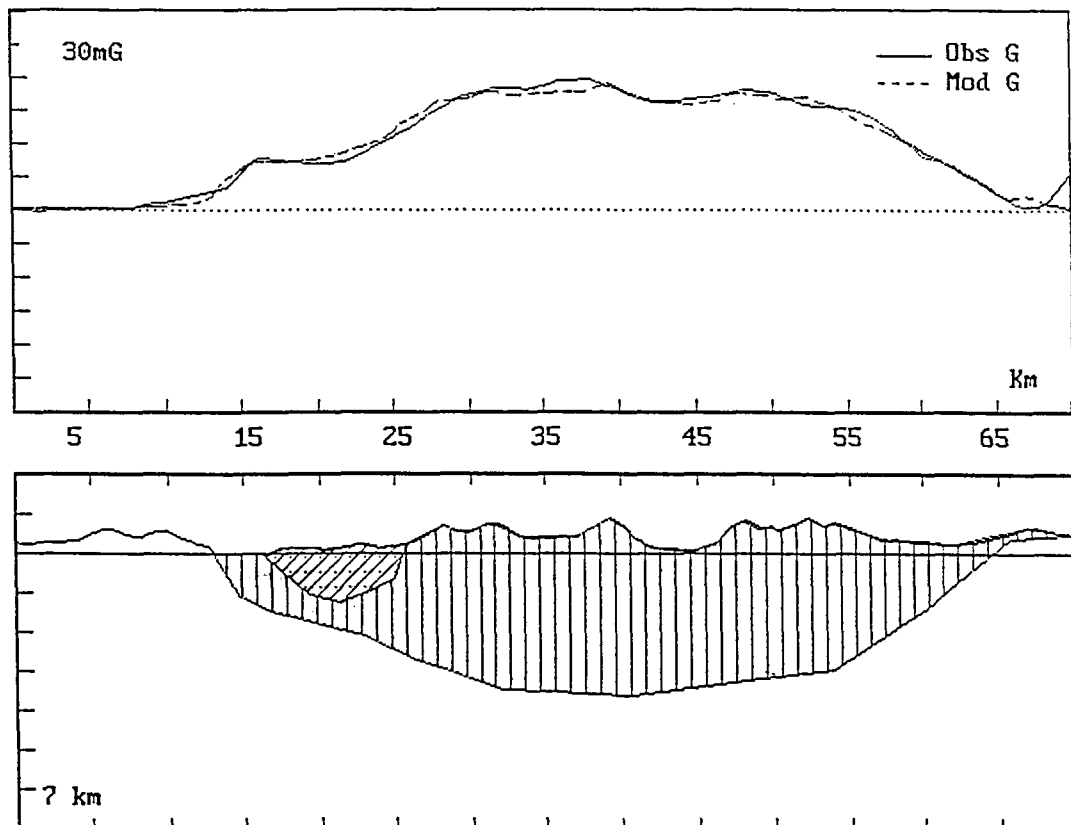


Figur 5. Gravimetrisk modellering, profil 7 og 8.

PROFIL 9



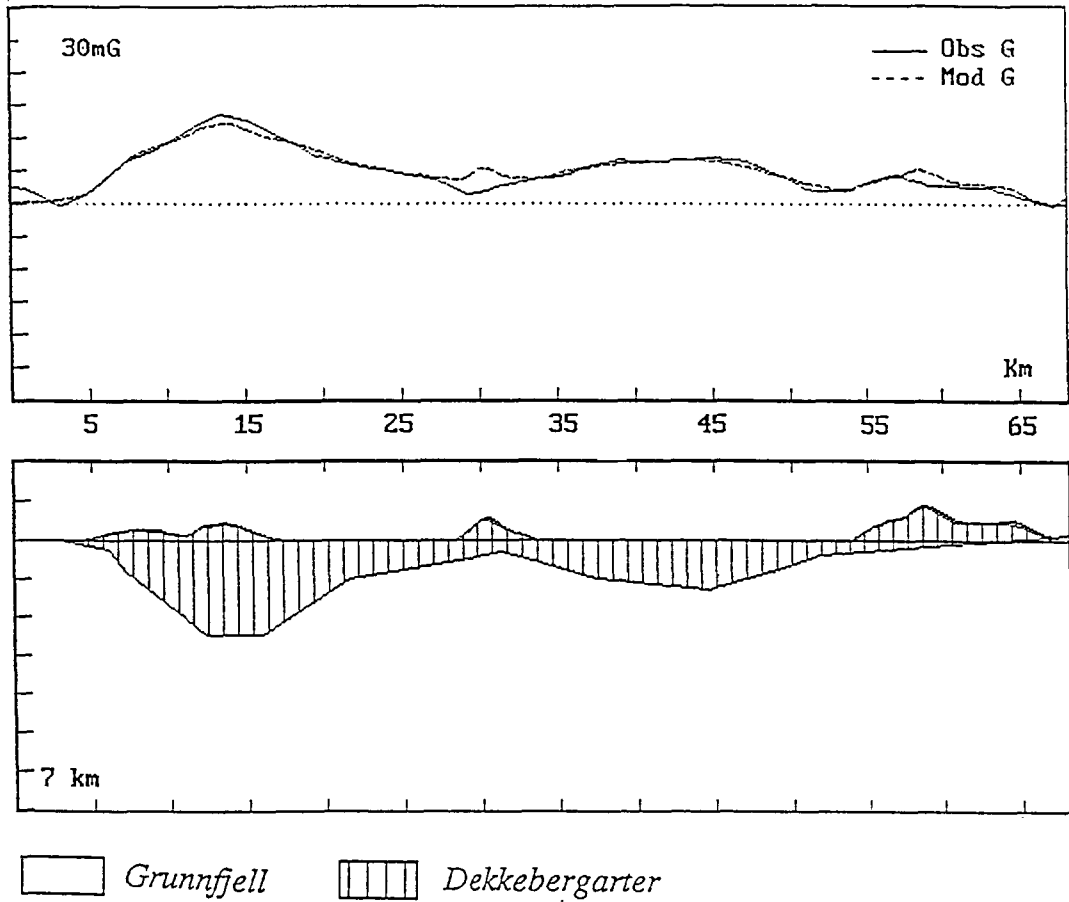
PROFIL 10



□ Grunnfjell ▨ Dekkebergarter ▩ Marmor

Figur 6. Gravimetrisk modellering, profil 9 og 10.

PROFIL 11



Figur 7. Gravimetrisk modellering, profil 11.

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

Atle Sindre, Rognvald Boyd and Carl O. Mathiesen.

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 northernmost 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 station per 100 km² 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 the intrusion and in a wide area around it: the average density of points is ca. 1/km².

GEOLOGY

The country 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 the 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 peripheral 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 to the outer margins of the intrusion. Two roughly synformal outliers are present at the southern margin, one of them, on the 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 Arneshøsten 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 program geophysical methods offered the only possibility for confirming or supporting this hypothesis.

METHODS, CORRECTION PROCEDURES, ETC.

The density 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/cm³. For the surrounding gneisses the figure of 2.73 g/cm³ (Brooks, 1970) was used to calculate density contrasts. The rocks within the intrusion thus have densities 0.15-0.50 g/cm³ 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/cm³ 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 program written by Mathiesen (1976) while corrections for the depth 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. 5) on which a zero anomaly 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 ca. 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 program.

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 at most of the stations have been determined photogrammetrically with an accuracy of $\pm 2 \text{ m}$: this results in an error of $\pm 0.4 \text{ mGal}$ in the residual anomaly.

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 program written by Ola Kihle, NGU. 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 gneiss 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 Arneshøsten 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 southernmost 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 the most probable form of the bodies. 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 margin 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 and much of the easternmost part of the intrusion also appears to be quite shallow.

As to the distribution of rock types within the intrusion the interpretation indicates 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 Arneshøsten 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.

REFERENCES

- Boyd, R. & Mathiesen, C.O. 1979: The nickel mineralization of the Råna mafic intrusion, Nordland, Norway. *Can. Mineral.* 17, 287-289.
- Brooks, M. 1970: A gravity survey of coastal areas of West Finnmark, northern Norway, *Q.J. Geol. Soc. London* 125, 171-192.
- Foslie, S. 1921: Field observations in northern Norway bearing on magmatic differentiation, *J. Geol.* 29, 701-719.
- Gustavson, M. 1972: The Caledonian mountain chain of the southern Troms and Ofoten areas. III Structures and structural history. *Norges geol. unders.* 283.
- Hammer, S. 1939: Terrain Correction to gravimeter stations, *Geophysics* 4, 184-194.
- Mathisen, O. 1976: A Method for Bouguer Reduction with Rapid Calculation of Terrain Corrections. *Norges geogr. oppmåling, Geodetic publications, nr. 18.*
- Norges geografiske oppmåling 1979: Gravity Anomaly Map, Sheet 24, Narvik. *Norges geogr. oppmåling.*
- Ramberg, I.B. 1976: Gravity Interpretation of the Oslo Graben and Associated Igneous Rocks. *Norges geol. unders.* 325.
- Roddick, J.C. 1977: Age of the Råna massif, north Norway. *Fifth Eur. Colloq. Cosmochron. & Isotope Geol. Pisa (Abstr.).*

GEOLOGISK OVERSIKTSKART OVER NORGE

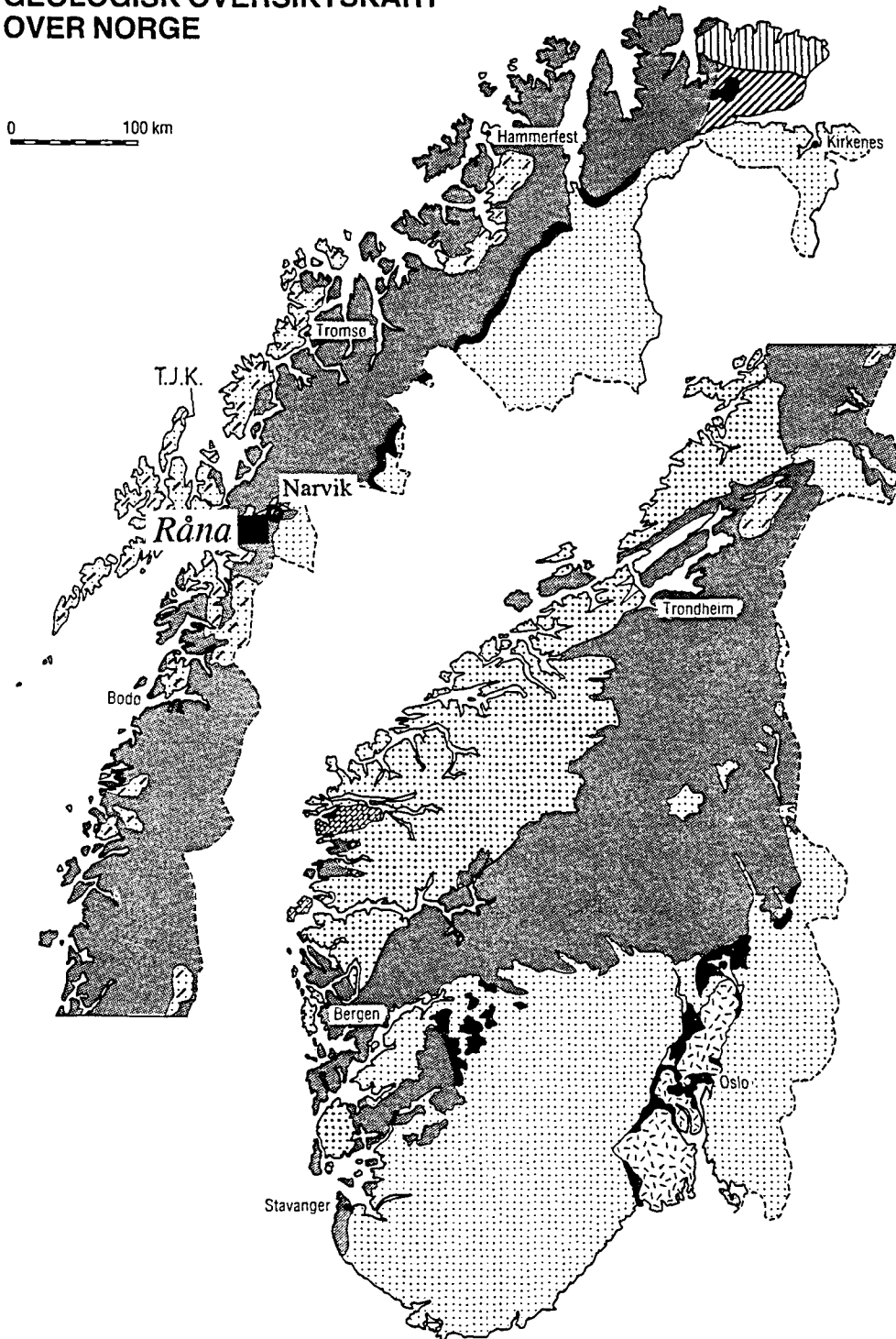


Figure 1 Map of Norway showing the location of the Råna intrusion.

NICKEL IN THE RÅNA MAFIC INTRUSION

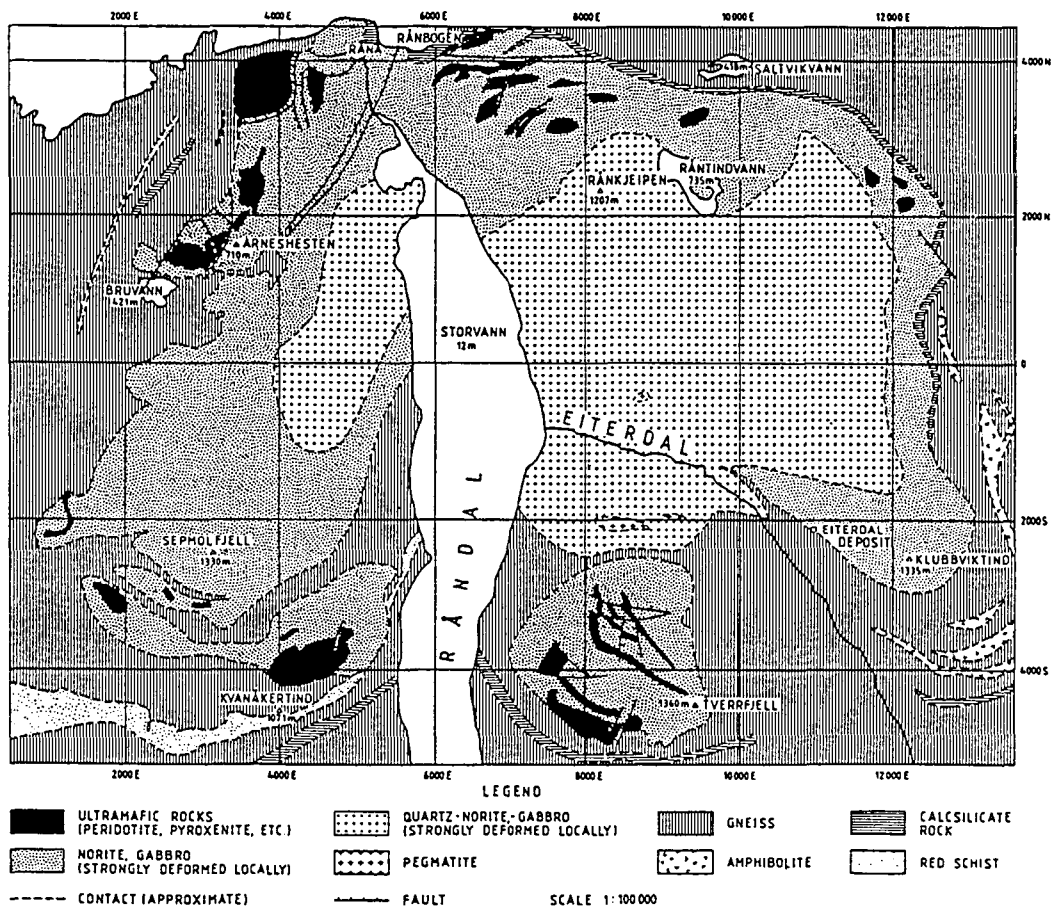


Figure 2 Geological map of the Råna intrusion.

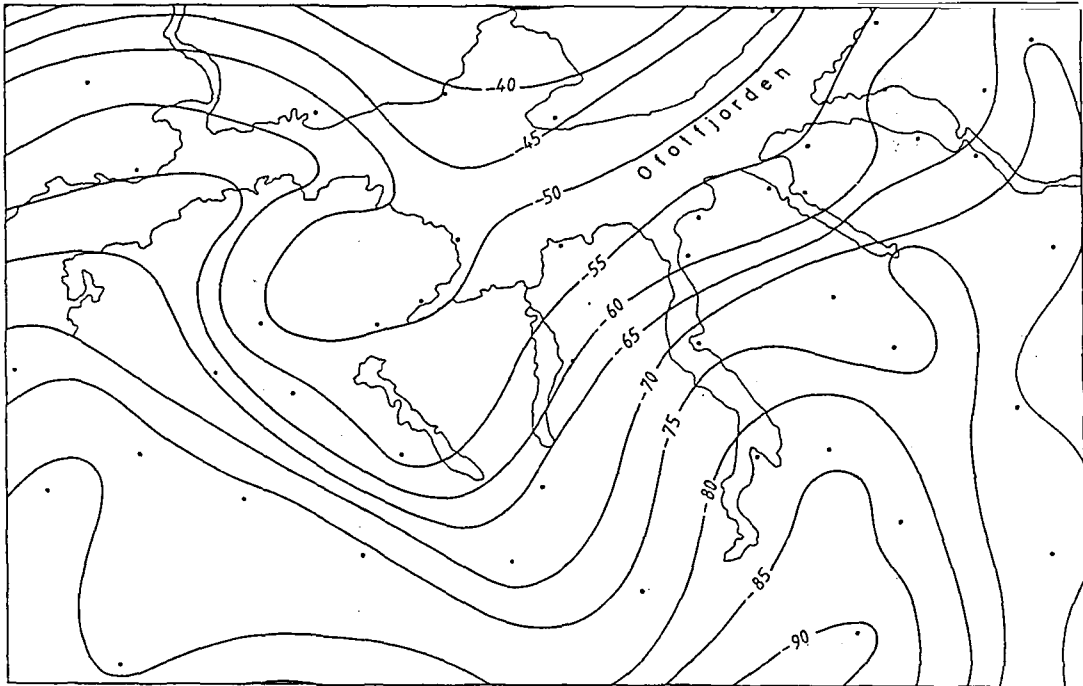


Figure 3 Regional Bouguer anomaly map (scale 1:500 000) based on data from the Geographical Survey of Norway (1979).

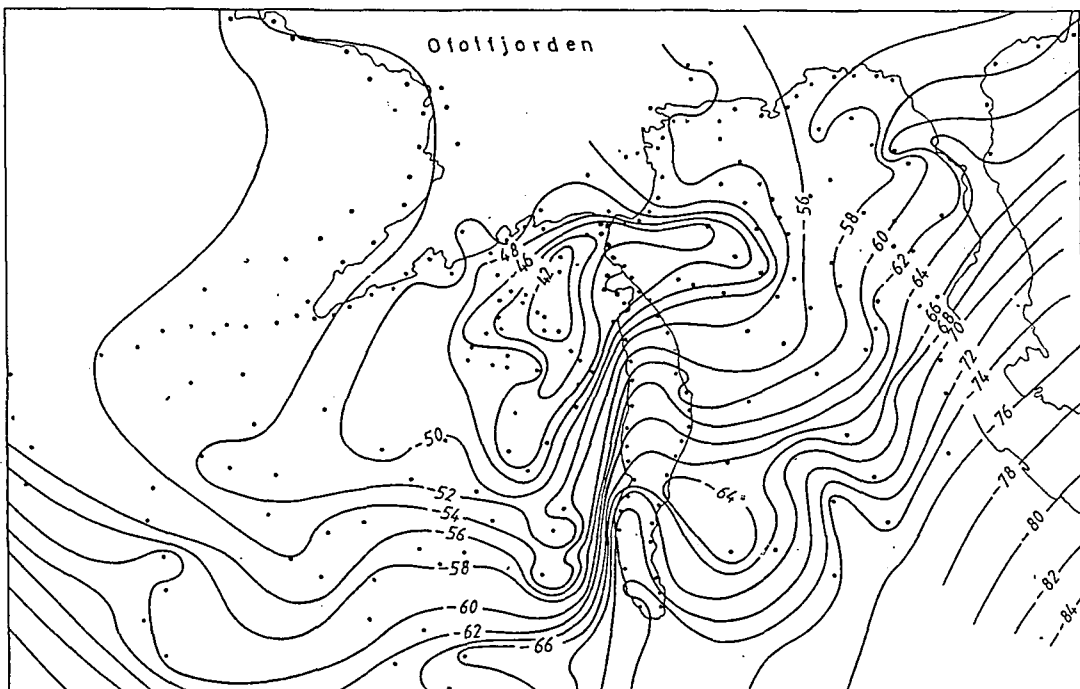


Figure 4 Bouguer anomaly map of the Rana area (scale 1:200 000).

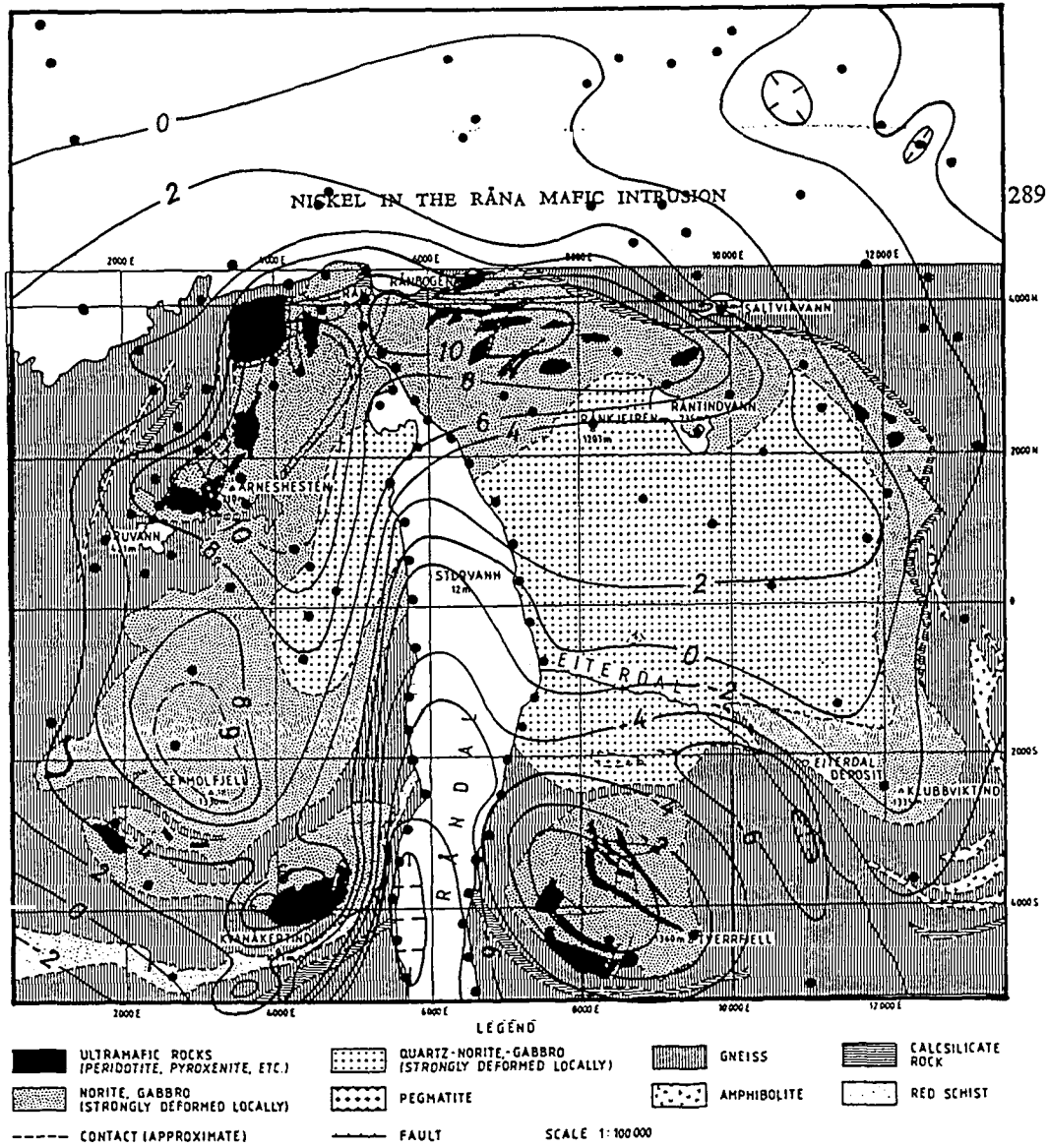


Figure 5 Map showing residual gravity anomaly and geology of the Råna area.

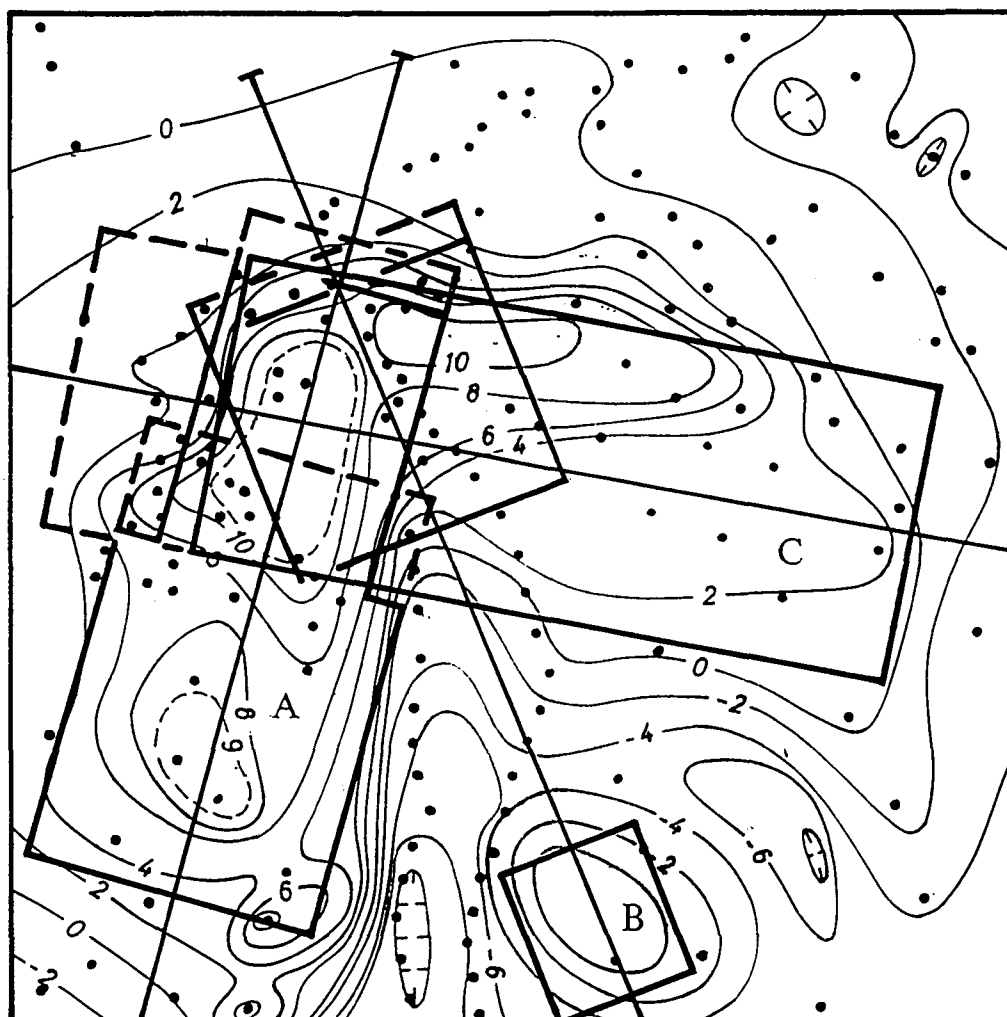


Figure 6 Map showing residual gravity anomaly and the horizontal projections of the prisms involved in the model interpretations (scale 1:100 000).

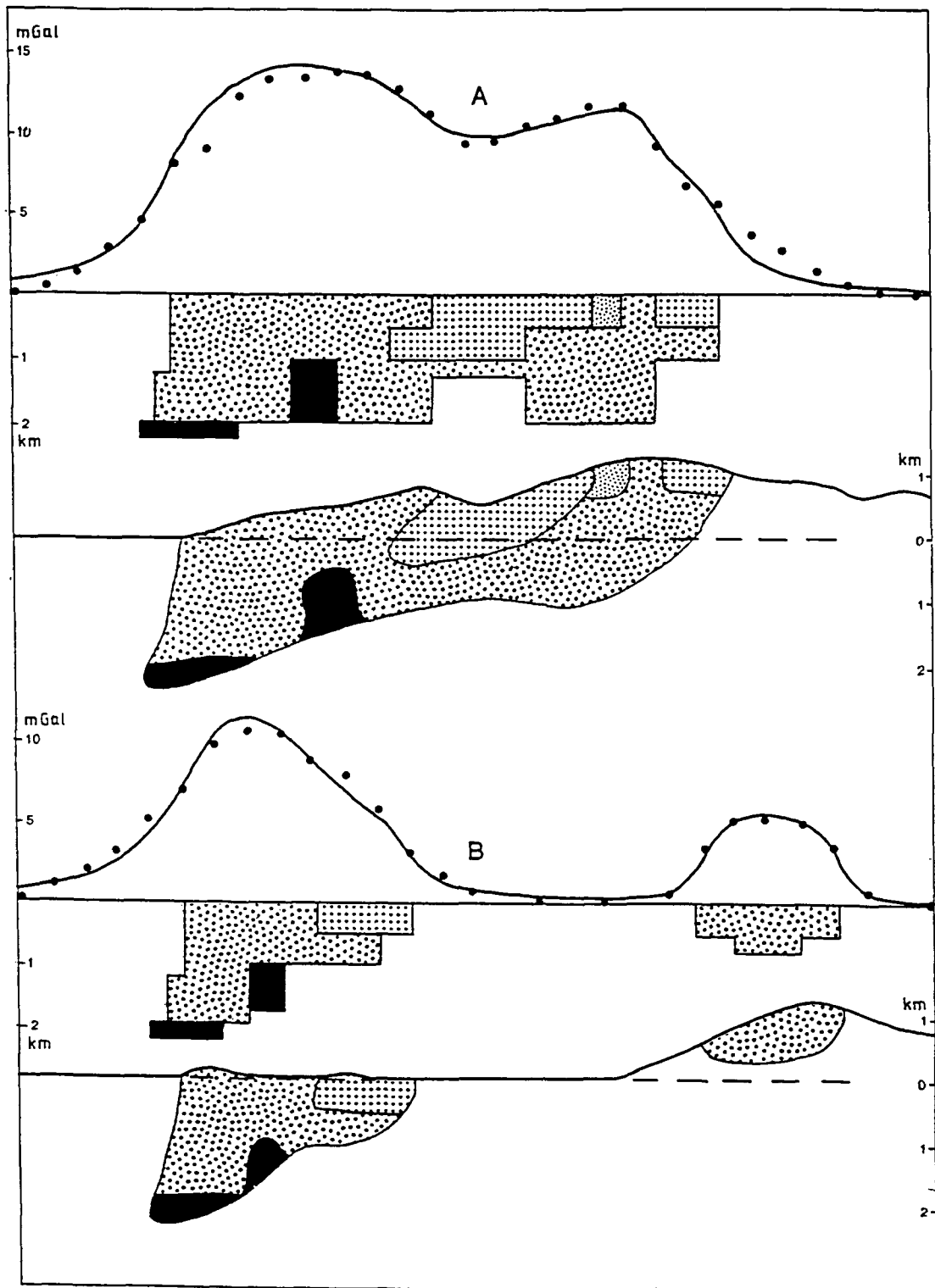


Figure 7 A and B

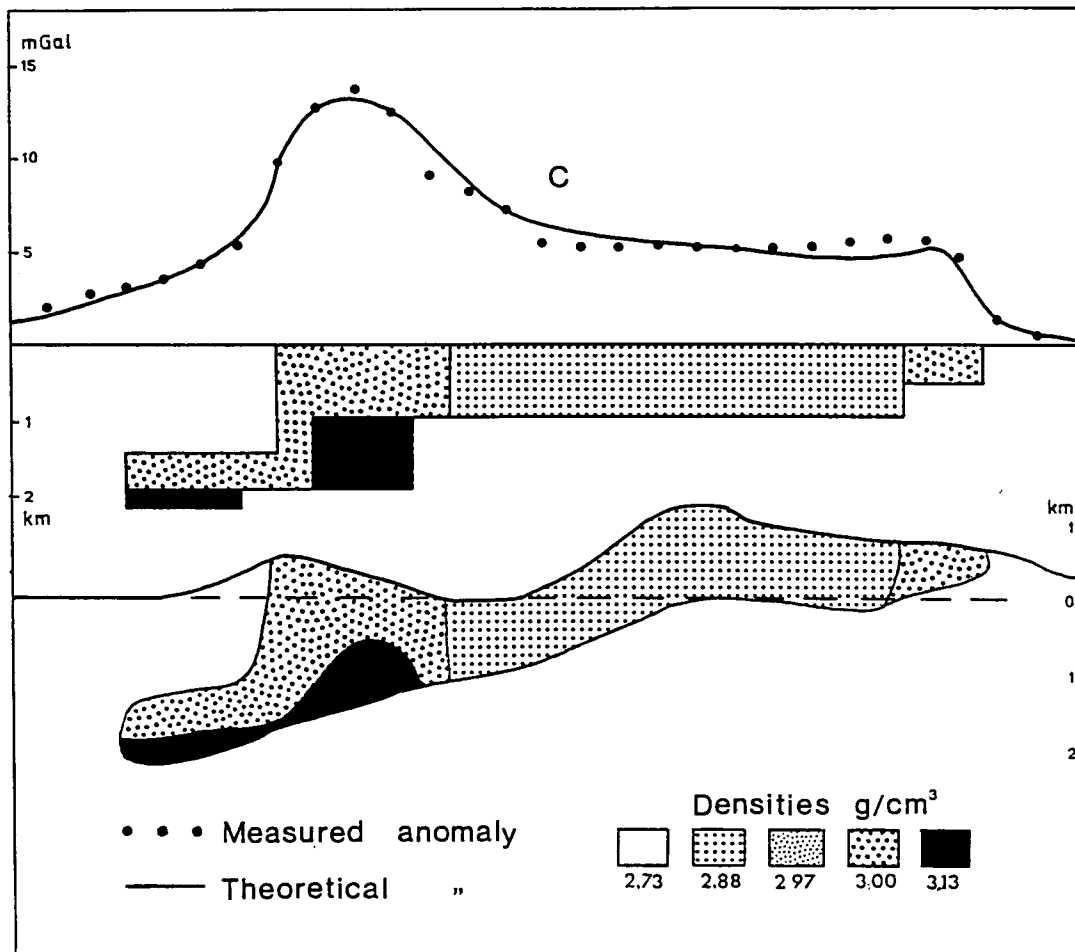
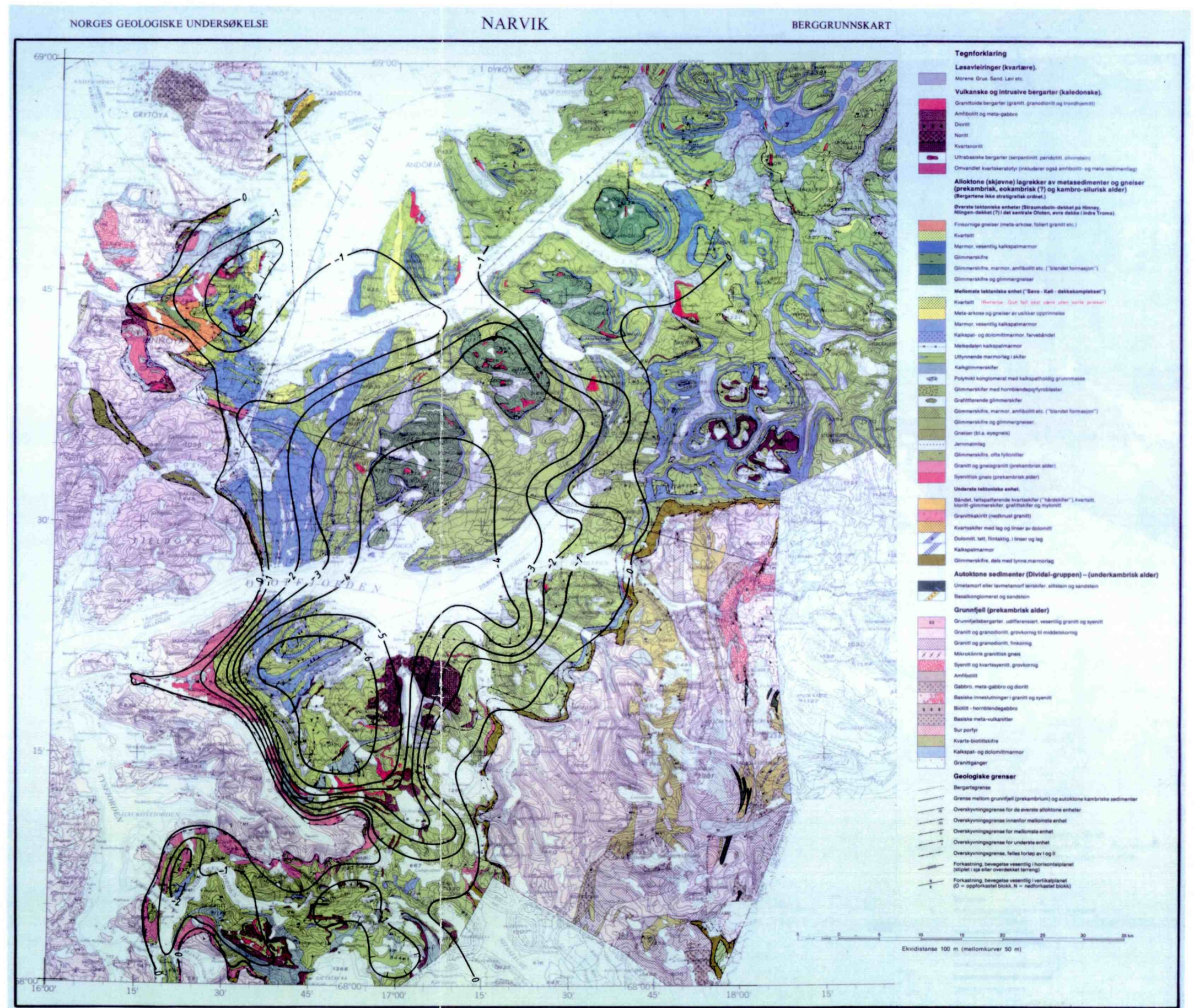
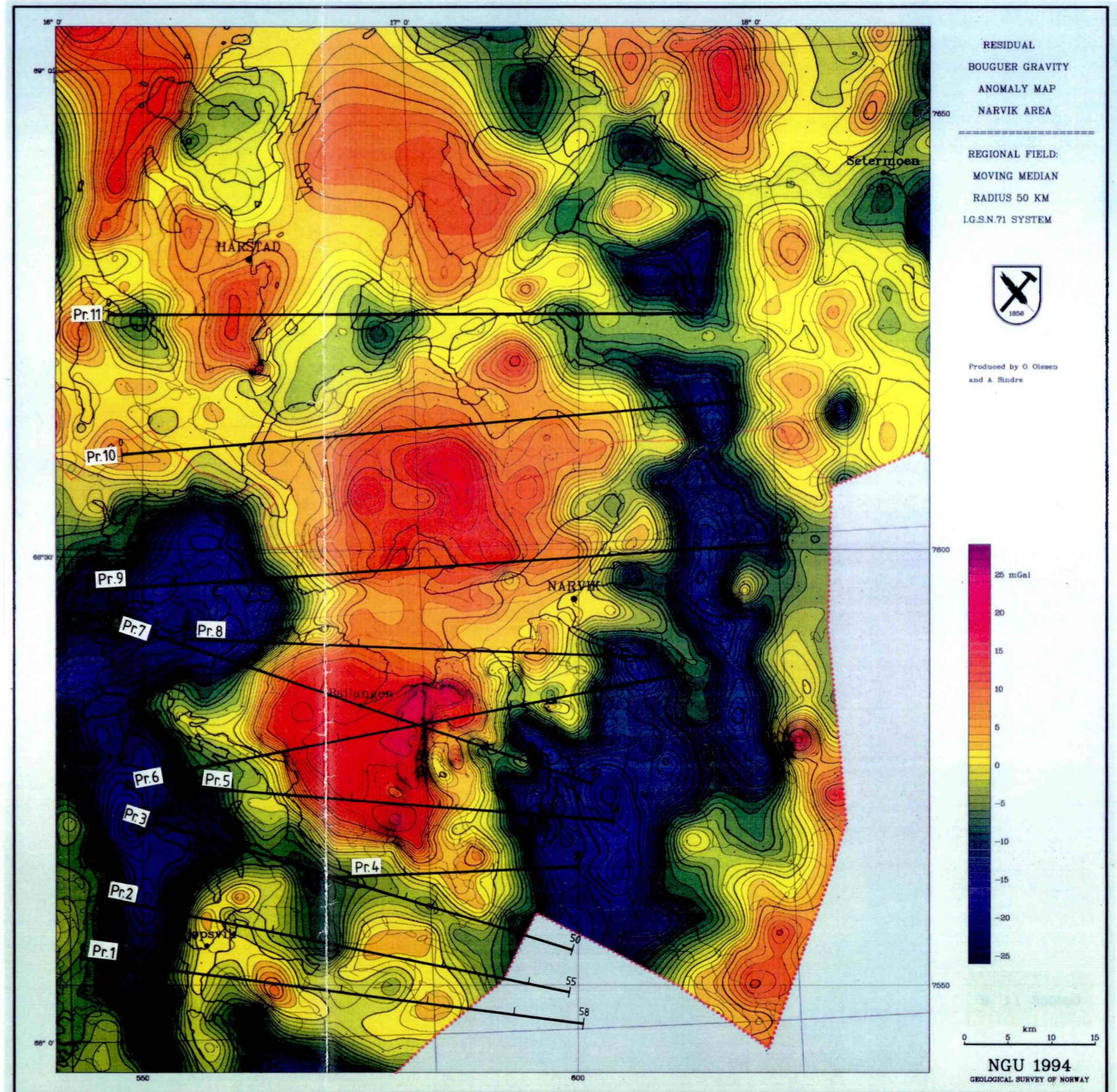


Figure 7 A, B and C

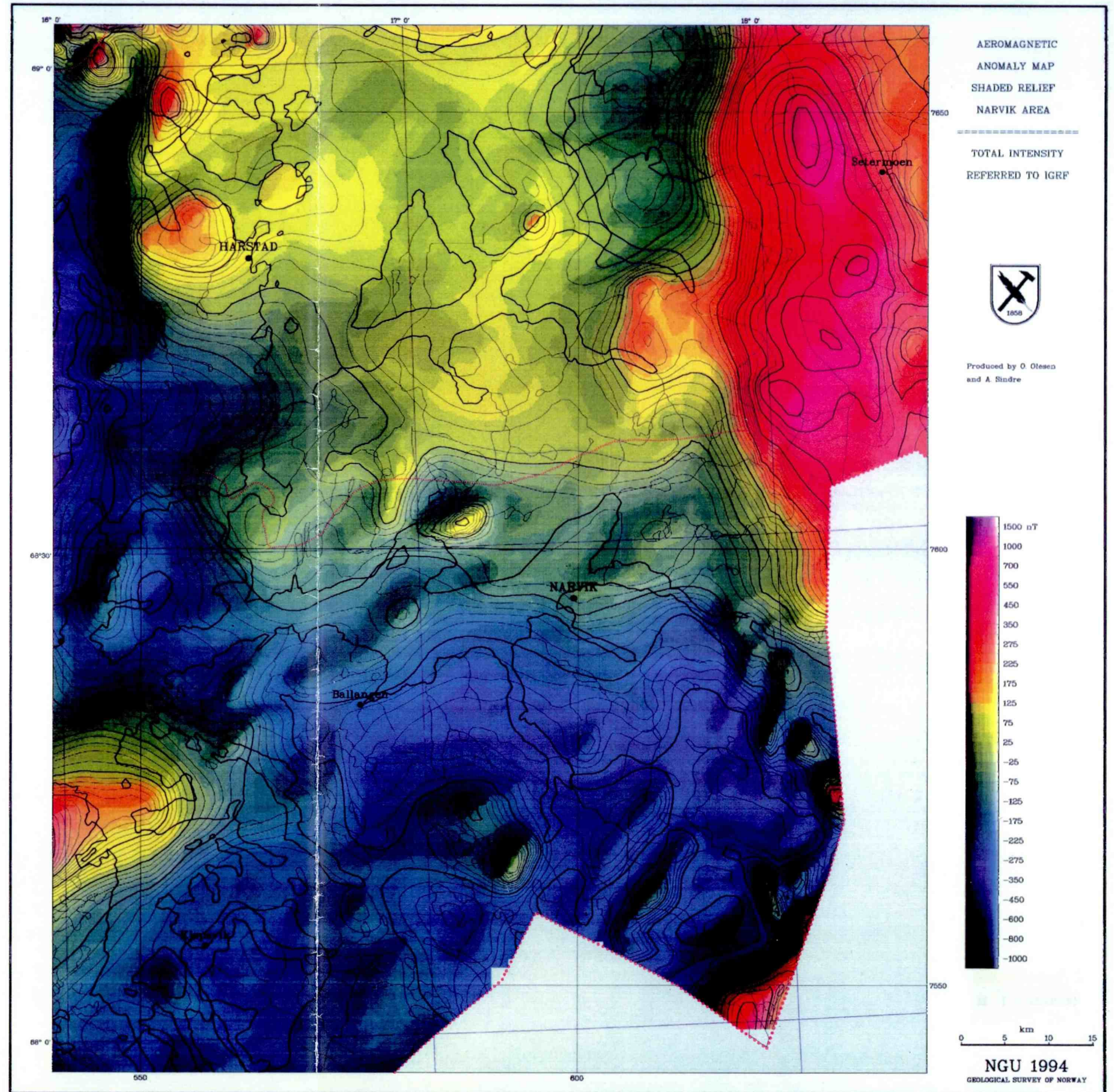
Each figure shows a gravity profile as measured across the intrusion, a geological model built up of prisms with densities approximating those of the rocks in the intrusion, a theoretical gravity profile which the model would generate and a schematic geological profile based on the model (scale 1:100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



Figur 8. Geologisk kart med tolket dyp til grunnfjell, M 1:500 000.



Figur 9. Residual Bouguer anomalikart, M 1:500 000.
Gravimetrisk modellering gjort langs profilene 1 - 11.



Figur 10. Aeromagnetisk anomalikart, M 1:500 000.