NGU Report 97.002

Interpretation of two gravity profiles across the Engebøfjellet rutile-bearing eclogite deposit

NGU
Norges geologiske undersøkelse
Geological Survey of Norway

Geological Survey of Norway
P.O.Box 3006 - Lade
N-7002 Trondheim, Norway
Tel.: 47 73 90 40 11
Telefax 47 73 92 16 20

REPORT

Report no.: 97.002 | ISSN 0800-3416 | Grading: Åpen

Title:
Interpretation of two gravity profiles across the Engebøfjellet rutile-bearing eclogite deposit

Authors:
Eirik Mauring, Jomar Gellein & Are Korneliussen

Client:
DuPont

County:
Sogn & Fjordane

Municipality:
Naustdal

Map-sheet name (M=1:250.000)
Florø

Map-sheet no. and -name (M=1:50.000)
1117 I Dale

Deposit name and grid-reference:
Engebøfjellet 32V 3103 68229 (WGS84)

Number of pages: 21 Price (NOK): 80,-
Map enclosures: 2

Fieldwork carried out:	Date of report:	Project no.:	Person responsible:
August 1996	3/2-1997	1900.05	Jan S. Mauring

Summary:

Gravity measurements have been carried out along two profiles across the Engebøfjellet rutile-bearing eclogite deposit. The main objective of the investigations was to delineate the morphology and subsurface extension of the eclogite body, given results and constraints from surface mapping and drillholes. Two alternative models are proposed for both profiles. The volume and mass estimates for the models given must not be mistaken for the total volume and mass of the whole eclogite deposit, which is larger. This is because the eclogite deposit extends to the east at a longer distance thean would affect the calculated response.

For model 1 of the easternmost profile, a density of 3400 kg/m^3 was used in the modelling of the massive eclogite body. Length of the body along the dip is on the order of 250-275 m. The average width (horizontal cross section) and length of the body are 250 m and 900 m respectively. With these dimensions the total volume of the massive eclogite body is 52-62·10^6 m^3. This is equivalent to a mass of 190-210 Mt. For model 2 the density of the massive eclogite body was increased to 3500 kg/m^3. To get a match between the calculated model response and the observed values, the length of the body along the dip direction had to be reduced to 200-225 m, yielding a volume and a mass of 45-51·10^6 m^3 and 158-177 Mt respectively.

For the westernmost profile, density values were inconclusive in determining representative estimates for densities of the different bodies in the model. Model 1 was constructed using arithmetic mean density values for the modelled bodies. Length of the massive body is 900 m. The average width and length along the dip is 140 m and 375 m respectively, giving a volume of c. 47·10^6 m^3 and a mass of c. 160 Mt (with a density of 3400 kg/m^3 for the massive eclogite). In the second model, the highest probable density values were used in the modelling. The density of the massive eclogite body was set to 3500 kg/m^3, reducing the length along the dip to 250 m. This yields a volume and a mass of c. 32·10^6 m^3 and c. 110 Mt respectively.

Keywords: Geofysikk	Gravimetri	Eklogitt
Rutil	Modellforsøk	
		Fagrapport

CONTENTS

Appendices

1. Table of terrain function values
2. Table of co-ordinates, absolute gravity, corrections and Bouguer anomalies
3. Terrain corrected Bouguer anomaly values and regional gradient
4. Terrain correction and Bouguer anomaly values
5. Gravity profile 2, model 1
6. Gravity profile 2, model 2
7. Gravity profile 3, model 1
8. Gravity profile 3, model 2

Maps

97.002-01: Location of Engebøfjellet, scale 1:50 000
97.002-02: Gravity profiles and stations, scale 1:5000

1 INTRODUCTION

Gravity measurements have been made along two profiles across the Engebøfjellet rutile-bearing eclogite deposit in Naustdal municipality, Sogn & Fjordane county. The work is a part of a collaborative program between NGU and DuPont. Previous gravity measurements have been carried out across the eastern part of the deposit (Mauring & Gellein, 1996). Results from a drillhole program is presented in Korneliussen et al. (1996). The main objective of the investigations was to delineate the morphology and subsurface extension of the eclogite body, given results and constraints from surface mapping and drillholes.

Data acquisition was conducted by Jomar Gellein in august 1996. Data processing was carried out by Jomar Gellein and Eirik Mauring. Interpretation of the gravity profiles was done by Eirik Mauring and Are Korneliussen.

2 DATA ACQUISITION

Data acquisition was carried out using a LaCoste & Romberg gravity meter (model G No. 569). Measurements were made along two profiles (labelled P2 & P3 in map -02) with 41 stations along P2 and 39 stations along P3. The lengths of P2 and P3 were 882 m and 669 m respectively. The location of the profiles and stations is shown in maps -01 and -02. The stations are labelled on map -02. The station spacing is 12.5 m in the southern parts of the profiles which cross the outcrop of the eclogite body. In the northern parts of the profiles the station spacing is 25 m. Severe topography to the south limited the number of stations.

To correct for diurnal variations in the gravity field and instrument drift, base station readings were made before and after measurements along the gravity profile at a station located close to the profile (UTM 32V 3105 68224 WGS84). This base station was tied to a gravity base station at Mo School of Agriculture in Førde (UTM 32V 3390 68147 WGS84) where the value of absolute gravity was known. Absolute gravity values could thus be obtained for all stations. Station levelling was performed by Jomar Gellein and Jomar Staw (NGU).

3 PROCESSING

Bouguer anomaly values were calculated using software from the Norwegian Mapping Authority (Statens Kartverk, Mathisen 1976). Bouguer and terrain corrections were carried out using a standard density of 2670 kg/m^3. Within 1 km of each station, circle radii of 50, 100, 200, 400 and 800 m were used for terrain corrections. The relatively high number of circle radii was used due to severe topography in the area. For terrain corrections, 1:5000 scale maps were used as basis for manually elevations on the circle radii. In addition, elevations from the Norwegian Mapping Authority's database were used for terrain corrections. A table of terrain correction function values is shown in appendix 1. A table of co-ordinates (geodetic datum ED50), absolute gravity, corrections and Bouguer anomalies is shown in appendix 2. Prior to modelling the data, the regional gravity gradient was subtracted from the terrain corrected Bouguer anomaly values (see appendix 3).

The regional gravity gradient is very difficult to determine in this area, because just a few gravity stations could be measured to the sides of the eclogite deposit, not giving the complete shape of the gravity anomaly. The proximity to the sea also made this determination difficult. The gradient for profile 2 was partly based on prior measurements (P1, Mauring & Gellein 1996). This gradient could not be applied to profile 3. The residual anomaly would be too small compared to the calculated response from the smallest possible model given the constraints from surface mapping and drillholes (see chapter 4). The most reasonable (although somewhat debatable) gradient for P3 is shown in appendix 3 page 2. For both profiles, the gradient curve lies well above the value of station 1. This is because this value must be considered a part of a large negative anomaly due to the sea water. The gradient curve at the northern end of P3 lies lower than on P2. This is due to the presence of a bog at the end of P2 which 'pulls down' the Bouguer anomaly values in this area.

Modelling of the data was performed using the GMM (Gravity and Magnetic Modelling) program from Swedish Geological Co. (1991). For the presentation of the models and the model response curves, the GRAPHER program from Golden Software Inc. was employed.

4 INTERPRETATION

4.1 Densities and geological constraints

The background material for the interpretation of the gravity profiles is presented in a report in preparation (Korneliussen et al. 1997). The report will cover results from core-drillings, petrophysical measurements, surface mapping, chemical analysis and gravity modelling to yield an interpretation of the three-dimensional extension and chemical quality of the orebody. In the present report, density values measured on 70 samples from drillholes 10 and 12 (DH10 & DH12 in appendix 7 & 8) were applied in the modelling of gravity profile 3. The drillholes were placed in the close vicinity of this profile. Density values from 33 samples in drillhole 8 were used for the modelling of gravity profile 2 (drillhole 8 is placed c. 100 m offset to the east of the profile and is not shown in this report). The density values of massive eclogite body is in the area of 3400-3500 kg/m^3 in the surveyed area (orange colour in appendix 5-8). Close to the main orebody - or interfingered with it - are layers or lenses of leucogabbroic eclogite with average densities in the range of 3150-3200 kg/m^3 (yellow colour in appendix 5-8). To the north and south of the massive eclogite and leucogabbroic eclogite bodies the rocks comprise mostly banded amphibolitic eclogite with gneissic zones and gneiss with eclogite layers. The density of this rock unit is between 2850 kg/m^3 and 3000 kg/m^3 with the heaviest rocks north of the orebody (different green colours in appendix 5-8). Constraints from drillholes 10 & 12 are used to lock model parameters in the interpretation of gravity profile 3. Observations of geological structures at the surface indicate that the rocks are steeply dipping towards north-northwest. Because of the proximity to the fjord, a sea water body with a density of 1025 kg/m^3 had to be added to the models. Sea water depths were read from a sea map (scale 1:50 000). The sea water bodies in appendix 5-8 are not shown to their full extent as they actually appeared when performing the model calculation. The models were constructed using the information and constraints mentioned above. In the appendices (5-8), number tags on the observed values refer to stations on map -02. The volume and mass estimates for the models given later in this report must not be mistaken for the total volume and mass of the whole eclogite deposit, which is larger. This is because the eclogite deposit extends to the east at a longer distance than would affect the calculated response.

4.2 Profile 2

Two alternative models are proposed in the interpretation of the gravity data for this profile. These are shown in appendices 5 & 6 (scale 1:5000). The primary difference between the two models is the density of the massive eclogite body, which is set to 3400 kg/m^3 for model 1 and 3500 kg/m^3 for model 2.

Model 1

The model is shown together with the reduced Bouguer anomaly values and the calculated response curve in appendix 5. There are no severe mismatches between the observed values and the calculated response from the model. The small mismatches can probably be attributed to insufficient or erroneous terrain correction, especially for stations 29 to 38. This becomes more evident when comparing the terrain correction values with the Bouguer anomaly values. In appendix 4, page 1, these two sets of values are plotted. The plot shows that the shapes of the two curves yield good correlation between station 29 and 38, indicating that the Bouguer anomaly values could be affected by erroneous or insufficient terrain corrections. The model in appendix 5 is largely based on a preliminary interpretation based on cores from drillhole 8 and surface geological mapping. Only minor adjustments had to be made to the preliminary model to achieve optimum curve fit. The modelled massive eclogite body has an average width (horizontal cross section) of. c. 250 m and a length along its dip in the order of 250-275 m. Lenses of lighter bodies extending towards the surface (leucogabbroic eclogite with a density of 3150 kg/m^3) are placed within the massive eclogite body in accordance with surface mapping. The length of the model in the strike direction is set to 900 m, with 450 m to each side of the profile. The latter parameter is probably the most uncertain one, since the morphology of the orebody seems to change rather rapidly along the strike direction, which is evident from surface mapping and core drillings. The model could be made longer with little or no effect on the calculated response. Given the dimensions of the modelled eclogite body, the total volume is 52-62·10^6 m^3, equivalent to a mass of 190-210 Mt.

Model 2

The model is shown in appendix 6. For this model, the density of the massive eclogite body is increased to 3500 kg/m^3, which is considered to be the maximum probable density to be used in the modelling. Clearly, to get a good curve fit, the depth extent of the massive eclogite now has to be diminished compared to model 1. The length along its dip is now in the order of 200-225 m. However, with this reduction the calculated response curve falls off too rapidly towards north. To get optimum match between observed values and the calculated response, the modelled body to the north of the massive eclogite (i.e. banded amphibolitic eclogite with gneissic zones and gneiss with eclogite layers) had to be extended towards north in a distance of c. 30 m. This is justified because the position of the body's northern termination is not exactly determined from surface mapping. The volume of the eclogite body is now 45-51·10^6 m^3, equivalent to a mass of 158-177 Mt.

4.3 Profile 3

Two drillholes have been placed close to this profile and density values have been provided from measurements on cores. Despite this, representative densities for the different lithologic units (bodies) are not conclusive, so two alternative models are proposed for this profile as well. One model (model 1) uses arithmetic mean density values for the bodies, while the other model (model 2) uses the highest probable density values. In the latter case, a minimum size of the massive eclogite body is modelled.

Model 1

Model with calculated response curve and reduced Bouguer anomaly values (observed values) are shown in appendix 7. The worst mismatch between observed values and calculated response is seen between station 21 and station 30. In this area there is a depression in the observed values, with the lowest value at station 26. In order to get the calculated response curve to match these values, a shallow, low density body has to be inserted. An outcropping body with a density of 2000 kg/m^3 and a depth of 20-30 m between position 390 and 450 will accomplish this (not shown in this report). This body would represent Quaternary deposits. However, such a thick sediment cover is not present in the area. A preliminary Quaternary map indicates just a thin (less than 2 m thick) till cover in the same area (Arne Reite, pers. comm.). A more likely explanation for the low Bouguer anomaly values between station 21 and station 30 is poor or insufficient terrain corrections. This is evident when comparing terrain correction values with the Bouguer anomaly values plotted in appendix 4 page 2. A depression can be seen in the terrain correction values between station 21 and 30 which correlates very well with the depression in the Bouguer anomaly values. Thus, the mismatch between calculated response from the model and the observed values can mostly be attributed to poor or insufficient terrain corrections. This suggests that stations 21 to 30 should carry little weight during modelling. From appendix 4 page 2, it is also evident that Bouguer anomaly values at station 15, 25 and 35 suffer from terrain correction effects and are considered noisy.

Two massive eclogite bodies have been modelled. The smaller, subcropping body to the southwest is added because surface mapping indicates a massive eclogite body c. 50 m offset to the west of the profile. A possible interpretation could be that this body continues towards the profile at depth. The larger eclogite body is constructed with the constraints from surface mapping and cores from drillhole 10 and 12 (DH10 & DH12 in appendix 7). The model shows that the massive eclogite body is thinner than in profile 2, but more extensive towards depth. The leucogabbroic unit (with a density of 3150 kg/m^3) is however much more extensive than in profile 2. The average width of the massive eclogite body is c. 140 m and the length along its dip is c. 375 m. The length of the body in the strike direction is 900 m, with 450 m to each side of the profile. The body could be made longer with little or no effect on the calculated response. To the west of the profile, the massive eclogite body can not be followed

further than c. 50 m at the surface, but it is suggested that it continues at depth towards west. With the dimension parameters listed above (not considering the smaller body to the southwest), the massive eclogite body amounts to a total of c. $47 \cdot 10^6$ m^3, equivalent to a mass of c. 160 Mt.

Model 2

For this model, the highest probable density values have been used for all bodies to yield a minimum size of the massive eclogite body. The massive eclogite body is now given a density of 3500 kg/m^3, while the density of the leucogabbroic eclogite is set to 3200 kg/m^3. The densities of the complex units to the southwest and northeast of the eclogite units are given densities of 2900 kg/m^3 and 3000 kg/m^3 respectively. The extension of the bodies towards depth had to be decreased to get a good fit between the observed values and the calculated model response. The length along the dip of the massive eclogite had to be reduced to c. 250 m, giving a volume of the eclogite body of c. $32 \cdot 10^6$ m^3, equivalent to a mass of c. 110 Mt.

5 CONCLUSIONS

Gravity measurements have been carried out along two profiles across the Engebøfjellet rutile-bearing eclogite deposit. Two alternative models are proposed for both profiles. The volume and mass estimates for the models given must not be mistaken for the total volume and mass of the whole eclogite deposit, which is larger. This is because the eclogite deposit extends to the east at a longer distance thean would affect the calculated response.

For model 1 of the easternmost profile (labelled P2), a density of 3400 kg/m^3 was used in the modelling of the massive eclogite body. Length of the body along the dip is on the order of 250-275 m. The average width (horizontal cross section) and length of the body are 250 m and 900 m respectively. With these dimensions the total volume of the massive eclogite body is 52-62·10^6 m^3. This is equivalent to a mass of 190-210 Mt. For model 2 the density of the massive eclogite body was increased to 3500 kg/m^3. To get a match between the calculated model response and the observed values, the length of the body along the dip direction had to be reduced to 200-225 m, yielding a volume and a mass of 45-51·10^6 m^3 and 158-177 Mt respectively.

Profile 3 (P3) was measured across the western part of the eclogite deposit. Density values from drillholes were inconclusive in determining representative estimates for densities of the different bodies in the model. Two alternative models are proposed. Model 1 was constructed using arithmetic mean density values for the modelled bodies. Length of the massive body is 900 m. The average width and length along the dip is 140 m and 375 m respectively, giving a volume of c. 47·10^6 m^3 and a mass of c. 160 Mt (with a density of 3400 kg/m^3 for the massive eclogite). In the second model, the highest probable density values were used in the modelling. The density of the massive eclogite body was set to 3500 kg/m^3, reducing the length along the dip to 250 m. This yields a volume and a mass of c. 32·10^6 m^3 and c. 110 Mt respectively.

6 REFERENCES

Korneliussen, A., Furuhaug, L., Staw, J. & Fossflaten, G. 1996: Core-drilling at Engebøfjellet 1995/96; Dh1 to Dh5. *NGU Report 96.062.*

Korneliussen, A. & Erambert, M. 1997: Core-drilling at the Engebøfjellet rutile-bearing eclogite 1995/96; Dh1 to Dh10. *NGU Report in prep.*

Mathisen 1976: Method for Bouguer reduction with rapid calculation of terrain corrections. *NGO. Geodetic publications no. 18.*

Mauring, E. & Gellein, J. 1996: Interpretation of a gravity profile across the Engebøfjellet rutile-bearing eclogite deposit. *NGU Report 96.061.*

Swedish Geological Co. 1991: GMM. Interactive Gravity and magnetic modelling program. *User's manual.*

Location: Engebøfjellet r=50,100,200,400,800m Project no: 1900.05 Fieldwork carried out in 1996 Processing performed in Aug 1996

TERRAIN CORRECTION INCREMENTS PR. KM RADIUS. CHECK AGAINST UNNORMAL VALUES

DISTANCE KM 0 0.002 0.068 0.23 0.59 0.90 1.28 1.75 2.29 2.87 3.52 5.24 8.44 12.4 18.8 28.8 58.8 99.0 166.7

																				CIRCLE
2	1	0.00	7.73	9.14	6.08	1.57	1.96	0.08	1.03	0.42	0.58	0.356	0.176	0.074	0.027	0.010	0.000	0.000	0.000	10.47
2	2	0.00	18.55	14.14	7.90	2.48	1.73	1.16	0.63	0.39	0.16	0.139	0.066	0.035	0.013	0.007	0.003	0.002	0.002	17.21
2	3	0.00	15.68	13.55	7.78	2.65	1.82	1.21	0.65	0.40	0.16	0.136	0.066	0.035	0.013	0.007	0.003	0.002	0.002	15.47
2	4	0.00	12.50	13.13	8.03	2.82	1.92	1.26	0.66	0.40	0.18	0.135	0.064	0.035	0.013	0.008	0.004	0.002	0.002	14.08
2	5	0.00	10.19	12.02	8.36	2.95	2.05	1.33	0.68	0.40	0.19	0.135	0.063	0.035	0.013	0.008	0.004	0.003	0.002	12.47
2	6	0.00	7.61	10.31	8.39	3.59	2.14	1.37	0.70	0.37	0.21	0.135	0.063	0.035	0.013	0.008	0.004	0.003	0.002	11.72
2	7	0.00	5.20	8.47	8.51	3.63	2.19	1.40	0.61	0.40	0.21	0.136	0.062	0.036	0.013	0.008	0.004	0.003	0.002	10.71
2	8	0.00	4.44	6.55	8.57	3.73	2.31	1.46	0.63	0.41	0.22	0.136	0.062	0.036	0.013	0.009	0.004	0.003	0.002	9.94
2	9	0.00	3.95	5.41	8.79	3.77	2.36	1.49	0.64	0.41	0.22	0.139	0.060	0.036	0.013	0.008	0.004	0.003	0.002	9.16
2	10	0.00	2.88	6.15	0.00	3.83	2.41	1.52	0.65	0.41	0.25	0.137	0.060	0.036	0.013	0.009	0.005	0.003	0.003	8.78
2	11	0.00	2.00	5.03	0.00	3.81	2.40	1.51	0.65	0.41	0.25	0.137	0.060	0.036	0.013	0.009	0.005	0.003	0.003	8.65
2	12	0.00	1.81	4.64	0.00	3.93	2.49	1.56	0.67	0.41	0.26	0.138	0.060	0.036	0.014	0.009	0.005	0.003	0.003	8.70
2	13	0.00	1.44	3.97	0.00	3.95	2.48	1.30	0.85	0.41	0.24	0.143	0.060	0.036	0.014	0.009	0.005	0.003	0.003	8.69
2	14	0.00	0.52	3.24	0.00	3.90	2.45	1.29	0.85	0.41	0.24	0.143	0.060	0.036	0.014	0.009	0.005	0.003	0.003	8.44
2	15	0.00	0.37	2.67	0.00	3.89	2.44	1.29	0.85	0.41	0.23	0.145	0.060	0.036	0.014	0.009	0.005	0.003	0.003	8.19
2	16	0.00	0.31	2.84	0.00	3.88	2.42	1.29	0.84	0.41	0.22	0.146	0.060	0.036	0.014	0.009	0.005	0.003	0.003	7.85
2	17	0.00	0.22	1.82	0.00	3.88	2.41	1.28	0.84	0.41	0.22	0.149	0.060	0.036	0.014	0.009	0.005	0.003	0.003	7.52
2	18	0.00	0.30	1.62	0.00	3.88	2.42	1.29	0.84	0.41	0.22	0.149	0.060	0.036	0.014	0.009	0.005	0.003	0.003	7.30
2	19	0.00	0.35	1.44	0.00	3.84	2.37	1.28	0.83	0.41	0.22	0.149	0.059	0.036	0.014	0.009	0.005	0.003	0.003	6.77
2	20	0.00	0.52	1.33	0.20	4.17	2.32	1.26	0.82	0.41	0.23	0.149	0.059	0.036	0.014	0.009	0.005	0.003	0.003	6.10
2	21	0.00	0.75	1.23	0.20	4.14	2.31	1.26	0.82	0.41	0.23	0.149	0.059	0.036	0.014	0.009	0.005	0.003	0.003	5.71
2	22	0.00	0.85	1.35	0.19	4.05	2.25	1.25	0.81	0.40	0.24	0.145	0.057	0.036	0.014	0.009	0.005	0.003	0.003	5.02
2	23	0.00	1.33	1.49	0.18	3.91	2.19	1.23	0.77	0.46	0.24	0.145	0.057	0.036	0.014	0.009	0.005	0.003	0.003	4.30
2	24	0.00	2.06	1.55	0.16	3.81	2.15	1.22	0.76	0.46	0.24	0.144	0.057	0.036	0.014	0.008	0.005	0.003	0.003	3.80
2	25	0.00	3.15	1.49	0.15	3.71	1.75	1.24	0.74	0.45	0.24	0.144	0.057	0.035	0.013	0.008	0.005	0.003	0.003	3.46
2	26	0.00	3.01	1.47	2.92	6.01	1.77	1.24	0.75	0.46	0.24	0.145	0.057	0.035	0.014	0.008	0.005	0.003	0.003	3.44
2	27	0.00	3.88	1.68	2.92	6.29	1.94	1.27	0.74	0.47	0.25	0.148	0.058	0.035	0.014	0.009	0.005	0.003	0.003	3.63
2	28	0.00	3.69	2.20	2.47	6.28	2.01	1.11	0.88	0.47	0.24	0.152	0.058	0.035	0.014	0.009	0.005	0.003	0.003	3.57
2	29	0.00	2.29	2.21	2.20	5.87	1.98	1.10	0.86	0.46	0.26	0.152	0.058	0.035	0.014	0.009	0.005	0.003	0.003	3.43
2	30	0.00	2.24	1.93	1.62	5.59	1.92	0.92	0.81	0.50	0.26	0.151	0.059	0.035	0.014	0.009	0.005	0.003	0.003	3.29
2	31	0.00	1.60	1.71	1.31	5.33	1.87	0.92	0.79	0.50	0.26	0.149	0.058	0.035	0.014	0.008	0.005	0.003	0.003	3.18
2	32	0.00	2.65	1.44	0.93	0.00	2.05	1.03	0.73	0.48	0.25	0.148	0.056	0.036	0.014	0.008	0.005	0.003	0.003	2.94
2	33	0.00	1.89	2.37	1.16	0.00	2.13	1.03	0.76	0.50	0.25	0.144	0.057	0.036	0.014	0.008	0.005	0.003	0.003	3.10
2	34	0.00	3.72	1.54	1.07	2.95	2.02	1.03	0.73	0.54	0.25	0.141	0.056	0.036	0.014	0.008	0.005	0.003	0.003	3.54
2	35	0.00	6.57	1.59	0.88	0.00	1.54	1.46	0.66	0.56	0.23	0.142	0.056	0.035	0.014	0.007	0.004	0.003	0.002	2.67
2	36	0.00	6.57	1.10	0.86	2.34	1.37	1.38	0.64	0.51	0.21	0.138	0.057	0.035	0.013	0.007	0.004	0.003	0.002	2.70
2	37	0.00	3.69	1.49	0.97	2.13	1.30	1.35	0.62	0.51	0.20	0.138	0.058	0.035	0.013	0.007	0.004	0.003	0.002	3.11
2	38	0.00	0.88	1.98	1.04	2.00	1.26	1.33	0.60	0.55	0.23	0.129	0.058	0.035	0.013	0.007	0.004	0.003	0.002	2.60
2	39	0.00	0.44	1.75	1.12	1.93	1.25	1.32	0.60	0.55	0.23	0.129	0.058	0.035	0.013	0.007	0.004	0.003	0.002	2.42
2	40	0.00	0.96	1.76	1.20	1.60	1.24	1.31	0.60	0.55	0.23	0.129	0.058	0.035	0.013	0.007	0.004	0.003	0.002	2.27
2	41	0.00	2.49	1.98	2.04	1.38	1.25	1.30	0.60	0.55	0.28	0.115	0.058	0.035	0.013	0.007	0.004	0.003	0.002	2.59

Terrain correction function values for various distance intervals at each gravity station. The total terrain correction is the sum of each function value multiplied by the corresponding distance interval (e.g. for station 1, the terrain correction is; 0*(0.002-0)+ 7.73*(0.068-0.002)+9.14*(0.23-0.068)+.......). The total terrain correction values are listed in appendix 2 page 1.

TABLE OF TERRAIN FUNCTION VALUES

PROFILE 2

TABLE OF TERRAIN FUNCTION VALUES PROFILE 3

Location: Engebøfjellet r=50,100,200,400,800m Project no: 1900.05 Fieldwork carried out in 1996 Processing performed in Aug 1996

TERRAIN CORRECTION INCREMENTS PR. KM RADIUS. CHECK AGAINST UNNORMAL VALUES

DISTANCE KM		0	0.002	0.068	0.23	0.59	0.90	1.28	1.75	2.29	2.87	3.52	5.24	8.44	12.4	18.8	28.8	58.8	99.0 166.7	CIRCLE
3	1	0.00	7.82	1.73	0.88	2.07	0.50	1.41	0.95	0.94	0.35	0.368	0.152	0.072	0.026	0.011	0.000	0.000	0.000	4.50
3	2	0.00	9.02	1.76	1.08	1.86	0.34	1.22	0.83	0.84	0.30	0.300	0.122	0.067	0.023	0.009	0.000	0.000	0.000	4.11
3	3	0.00	8.01	1.73	1.53	1.84	0.32	1.19	0.81	0.82	0.29	0.293	0.119	0.067	0.022	0.009	0.000	0.000	0.000	4.00
3	4	0.00	5.22	2.06	1.55	1.85	0.31	1.19	0.81	0.81	0.29	0.289	0.116	0.065	0.022	0.009	0.000	0.000	0.000	3.32
3	5	0.00	4.83	2.39	1.66	1.87	0.63	1.04	0.81	0.80	0.28	0.285	0.115	0.063	0.021	0.009	0.000	0.000	0.000	4.61
3	6	0.00	3.49	2.59	1.67	1.90	0.61	1.03	0.79	0.79	0.28	0.280	0.113	0.062	0.021	0.009	0.000	0.000	0.000	4.92
3	7	0.00	1.81	2.55	1.99	2.02	0.63	1.58	0.71	0.80	0.28	0.288	0.112	0.063	0.021	0.009	0.000	0.000	0.000	4.99
3	8	0.00	1.28	2.54	1.95	2.08	0.63	1.59	0.71	0.81	0.28	0.289	0.113	0.063	0.021	0.009	0.000	0.000	0.000	3.33
3	9	0.00	1.36	2.60	2.82	1.96	0.64	1.62	0.72	0.81	0.28	0.290	0.113	0.063	0.021	0.009	0.000	0.000	0.000	3.48
3	10	0.00	1.68	2.47	2.83	2.02	0.66	1.65	0.73	0.83	0.28	0.292	0.114	0.063	0.021	0.009	0.000	0.000	0.000	2.94
3	11	0.00	1.88	2.65	0.00	2.05	0.65	1.65	0.73	0.82	0.28	0.291	0.113	0.062	0.021	0.009	0.000	0.000	0.000	3.02
3	12	0.00	2.46	2.73	0.00	2.07	0.65	1.67	0.73	0.82	0.30	0.284	0.112	0.061	0.022	0.009	0.000	0.000	0.000	3.05
3	13	0.00	3.11	2.26	3.09	2.10	0.65	1.66	0.73	0.82	0.28	0.289	0.112	0.062	0.021	0.009	0.000	0.000	0.000	3.28
3	14	0.00	4.18	2.43	2.94	2.09	0.65	1.69	0.73	0.83	0.38	0.260	0.111	0.060	0.022	0.009	0.000	0.000	0.000	4.14
3	15	0.00	2.46	2.44	3.14	2.10	0.65	1.71	0.74	0.83	0.38	0.265	0.108	0.059	0.022	0.009	0.000	0.000	0.000	3.93
3	16	0.00	4.01	2.59	2.92	2.09	0.64	1.69	0.73	0.81	0.38	0.263	0.104	0.059	0.021	0.009	0.000	0.000	0.000	3.76
3	17	0.00	4.59	2.67	2.93	2.00	0.63	1.70	0.73	0.81	0.37	0.259	0.105	0.057	0.021	0.008	0.000	0.000	0.000	3.77
3	18	0.00	4.61	2.69	2.95	2.02	0.62	1.68	0.72	0.80	0.37	0.258	0.101	0.057	0.021	0.009	0.000	0.000	0.000	3.78
3	19	0.00	6.05	2.81	2.87	2.03	0.62	1.70	0.72	0.80	0.37	0.261	0.099	0.057	0.021	0.008	0.000	0.000	0.000	3.64
3	20	0.00	5.79	2.94	2.93	2.10	0.64	1.74	0.74	0.82	0.38	0.267	0.102	0.058	0.021	0.008	0.000	0.000	0.000	3.49
3	21	0.00	6.04	2.83	2.62	2.22	0.67	2.06	0.52	0.85	0.39	0.268	0.103	0.058	0.021	0.008	0.000	0.000	0.000	3.48
3	22	0.00	5.48	2.34	2.52	2.27	0.70	2.10	0.52	0.86	0.39	0.272	0.106	0.059	0.022	0.008	0.000	0.000	0.000	3.35
3	23	0.00	4.37	3.66	2.64	2.32	0.92	1.66	0.53	0.88	0.40	0.276	0.107	0.059	0.022	0.009	0.000	0.000	0.000	3.78
3	24	0.00	4.21	4.60	2.11	2.39	0.97	1.69	0.54	0.90	0.41	0.282	0.110	0.060	0.022	0.009	0.000	0.000	0.000	4.64
3	25	0.00	3.45	5.16	3.01	2.42	1.00	1.73	0.55	1.00	0.40	0.279	0.109	0.060	0.022	0.009	0.000	0.000	0.000	5.20
3	26	0.00	3.12	5.41	2.36	2.47	1.02	1.77	0.55	1.01	0.41	0.281	0.109	0.060	0.022	0.009	0.000	0.000	0.000	5.61
3	27	0.00	2.56	5.20	3.18	2.51	1.01	1.77	0.55	1.01	0.41	0.280	0.109	0.060	0.022	0.008	0.000	0.000	0.000	5.70
3	28	0.00	2.17	4.76	3.61	2.55	1.02	1.80	0.55	1.02	0.53	0.235	0.109	0.060	0.022	0.009	0.000	0.000	0.000	5.52
3	29	0.00	2.83	4.52	3.92	2.59	1.03	2.19	0.05	1.03	0.53	0.235	0.109	0.060	0.022	0.009	0.000	0.000	0.000	5.30
3	30	0.00	4.10	4.86	4.37	2.64	1.04	2.76	0.05	1.16	0.50	0.235	0.109	0.059	0.022	0.009	0.000	0.000	0.000	5.51
3	31	0.00	4.36	4.42	4.63	2.57	1.01	2.75	0.05	1.15	0.49	0.230	0.106	0.058	0.022	0.009	0.000	0.000	0.000	5.12
3	32	0.00	3.89	3.98	4.54	2.54	0.95	2.70	0.51	0.80	0.48	0.223	0.103	0.056	0.021	0.008	0.000	0.000	0.000	4.71
3	33	0.00	3.98	3.86	4.34	2.51	0.92	2.67	0.56	0.68	0.49	0.209	0.103	0.055	0.021	0.008	0.000	0.000	0.000	4.45
3	34	0.00	4.39	4.01	4.27	2.51	0.91	2.68	0.56	0.68	0.49	0.204	0.102	0.054	0.020	0.008	0.001	0.000	0.000	4.57
3	35	0.00	4.50	3.92	4.77	2.72	1.50	2.21	0.57	0.61	0.52	0.206	0.100	0.053	0.020	0.008	0.001	0.000	0.000	4.85
3	36	0.00	4.01	4.36	3.93	2.67	1.48	2.19	0.57	0.75	0.45	0.201	0.097	0.052	0.020	0.008	0.001	0.001	0.000	4.88
3	37	0.00	4.21	3.95	3.48	2.64	1.45	2.15	0.56	0.73	0.44	0.195	0.094	0.050	0.019	0.007	0.001	0.001	0.001	4.72
3	38	0.00	4.33	3.72	3.12	2.56	1.31	2.12	0.56	0.71	0.43	0.191	0.089	0.049	0.019	0.007	0.001	0.001	0.001	4.53
3	39	0.00	3.54	3.60	2.59	2.51	1.29	2.06	0.61	0.64	0.41	0.183	0.085	0.048	0.018	0.007	0.001	0.001	0.001	4.33

Terrain correction function values for various distance intervals at each gravity station. The total terrain correction is the sum of each function value multiplied by the corresponding distance interval (e.g. for station 1, the terrain correction is; 0*(0.002-0)+ 7.82*(0.068-0.002)+1.73*(0.23-0.068)+.......). The total terrain correction values are listed in appendix 2 page 2.

TABLE OF CO-ORDINATES, ABSOLUTE GRAVITY, CORRECTIONS AND BOUGUER ANOMALIES, PROFILE 2

Location: Engebøfjellet r=50,100,200,400,800m Project no: 1900.05 Fieldwork carried out in 1996 Processing performed in Aug 1996

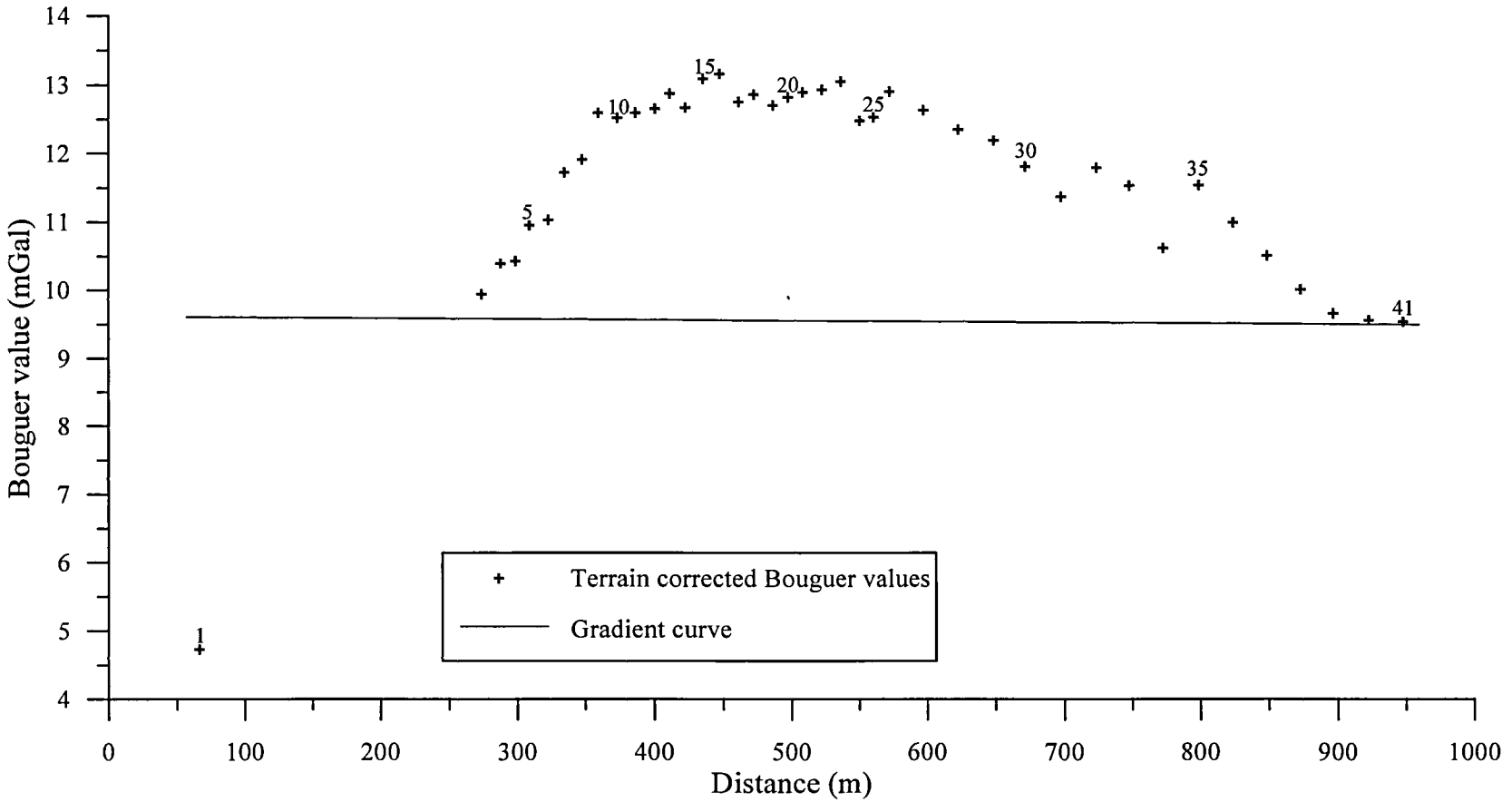
Station Profile	Point	Lati- tude	Longi- tude	UTM zone	UTM east	UTM north	Elevation: (in m)	Absolute gravity	Bouguer: corr.	Terrain corr.	Free air corr.	Bouguer anomaly
2	1	61 29.37	5 26.14	32V	310248	6822669	0.40	982028.746	0.05	8.99	0.12	4.73
2	2	61 29.48	5 26.20	32V	310318	6822873	244.39	981984.692	27.67	10.77	75.37	9.94
2	3	61 29.49	5 26.20	32V	310319	6822887	251.96	981984.005	28.53	10.43	77.71	10.39
2	4	61 29.50	5 26.20	32V	310321	6822898	260.20	981982.577	29.46	10.34	80.25	10.43
2	5	61 29.50	5 26.20	32V	310321	6822908	268.29	981981.501	30.38	10.37	82.74	10.95
2	6	61 29.51	5 26.20	32V	310322	6822922	275.19	981980.767	31.16	9.83	84.87	11.03
2	7	61 29.52	5 26.20	32V	310322	6822934	280.33	981980.860	31.74	9.43	86.45	11.72
2	8	61 29.52	5 26.20	32V	310323	6822947	286.95	981979.798	32.49	9.38	88.50	11.91
2	9	61 29.53	5 26.20	32V	310323	6822959	291.80	981979.473	33.04	9.44	89.99	12.59
2	10	61 29.54	5 26.20	32V	310324	6822973	296.55	981978.896	33.57	9.02	91.46	12.52
2	11	61 29.55	5 26.20	32V	310324	6822986	297.71	981979.277	33.71	8.55	91.81	12.59
2	12	61 29.55	5 26.20	32V	310325	6823000	302.47	981978.380	34.24	8.57	93.28	12.65
2	13	61 29.56	5 26.20	32V	310325	6823011	304.00	981978.493	34.42	8.38	93.75	12.87
2	14	61 29.56	5 26.20	32V	310326	6823022	302.32	981979.057	34.23	7.95	93.24	12.67
2	15	61 29.57	5 26.20	32V	310326	6823035	303.83	981979.425	34.40	7.70	93.70	13.09
2	16	61 29.58	5 26.20	32V	310327	6823047	304.60	981979.424	34.49	7.62	93.94	13.16
2	17	61 29.59	5 26.20	32V	310327	6823061	305.86	981979.120	34.63	7.27	94.33	12.75
2	18	61 29.59	5 26.20	32V	310328	6823072	306.22	981979.253	34.67	7.18	94.44	12.86
2	19	61 29.60	5 26.20	32V	310328	6823086	305.86	981979.443	34.63	6.96	94.33	12.70
2	20	61 29.61	5 26.20	32V	310329	6823097	304.95	981979.816	34.53	6.89	94.05	12.82
2	21	61 29.61	5 26.20	32V	310329	6823108	304.70	981979.989	34.50	6.83	93.97	12.89
2	22	61 29.62	5 26.20	32V	310330	6823122	303.22	981980.397	34.33	6.75	93.51	12.93
2	23	61 29.63	5 26.20	32V	310331	6823136	301.74	981980.867	34.16	6.69	93.06	13.05
2	24	61 29.63	5 26.20	32V	310331	6823150	299.12	981981.387	33.87	6.12	92.25	12.48
2	25	61 29.64	5 26.20	32V	310333	6823160	297.73	981981.667	33.71	6.16	91.82	12.53
2	26	61 29.65	5 26.20	32V	310333	6823172	300.48	981980.995	34.02	6.72	92.67	12.90
2	27	61 29.66	5 26.20	32V	310334	6823197	312.71	981977.889	35.40	7.17	96.44	12.63
2	28	61 29.67	5 26.20	32V	310334	6823222	318.04	981976.835	36.01	6.90	98.08	12.35
2	29	61 29.69	5 26.20	32V	310336	6823248	318.51	981976.993	36.06	6.49	98.23	12.19
2	30	61 29.70	5 26.20	32V	310337	6823271	316.14	981977.637	35.79	5.99	97.50	11.81
2	31	61 29.71	5 26.20	32V	310337	6823297	314.17	981978.039	35.57	5.54	96.89	11.37
2	32	61 29.73	5 26.20	32V	310339	6823323	302.67	981980.752	34.27	5.49	93.34	11.79
2	33	61 29.74	5 26.20	32V	310341	6823347	311.41	981978.377	35.26	5.90	96.04	11.53
2	34	61 29.75	5 26.20	32V	310342	6823372	306.11	981979.258	34.66	5.20	94.40	10.62
2	35	61 29.77	5 26.20	32V	310343	6823398	292.13	981982.325	33.08	5.79	90.09	11.54
2	36	61 29.78	5 26.20	32V	310344	6823423	275.29	981985.799	31.17	5.06	84.90	10.99
2	37	61 29.79	5 26.20	32V	310346	6823448	267.16	981987.513	30.25	4.45	82.39	10.51
2	38	61 29.81	5 26.20	32V	310347	6823472	265.12	981987.945	30.02	3.98	81.76	10.01
2	39	61 29.82	5 26.20	32V	310347	6823496	265.14	981987.463	30.02	4.10	81.77	9.66
2	40	61 29.83	5 26.20	32V	310348	6823522	265.34	981987.396	30.04	4.03	81.83	9.56
2	41	61 29.85	5 26.20	32V	310350	6823547	268.87	981986.323	30.44	4.46	82.92	9.54

TABLE OF CO-ORDINATES, ABSOLUTE GRAVITY, CORRECTIONS AND BOUGUER ANOMALIES, PROFILE 3

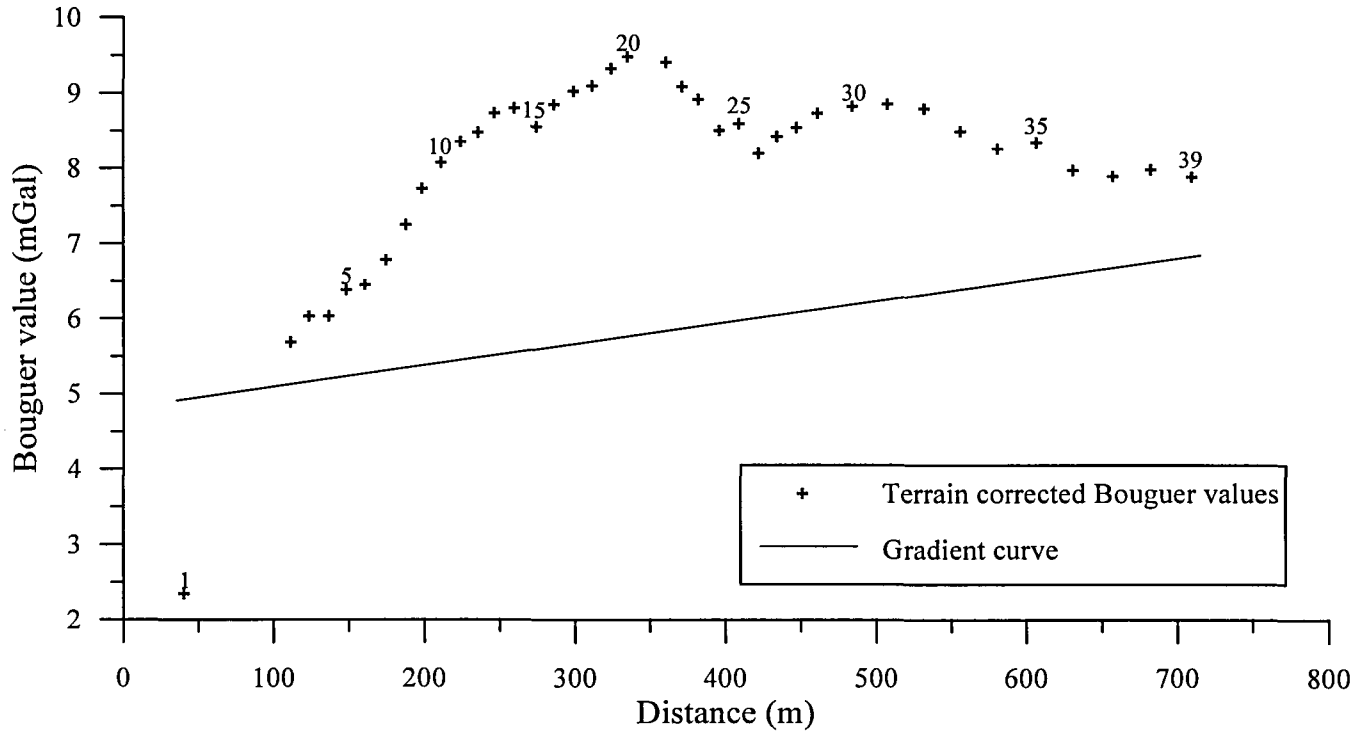
Location: Engebøfjellet r=50,100,200,400,800m Project no: 1900.05 Fieldwork carried out in 1996 Processing performed in Aug 1996

Station Profile	Point	Latitude	Longitude	UTM zone	UTM east	UTM north	Elevation (in m)	Absolute gravity	Bouguer corr.	Terrain corr.	Free air corr.	Bouguer anomaly
3	1	61 29.44	5 25.13	32V	309365	6822838	1.00	982028.953	0.11	6.34	0.31	2.34
3	2	61 29.47	5 25.18	32V	309413	6822892	38.64	982025.213	4.38	6.15	11.92	5.69
3	3	61 29.47	5 25.19	32V	309420	6822902	44.22	982025.029	5.01	5.59	13.64	6.03
3	4	61 29.48	5 25.20	32V	309427	6822913	48.39	982024.488	5.48	5.31	14.92	6.03
3	5	61 29.49	5 25.20	32V	309433	6822923	52.90	982024.202	5.99	5.08	16.32	6.38
3	6	61 29.49	5 25.21	32V	309439	6822934	56.71	982023.812	6.43	4.79	17.49	6.45
3	7	61 29.50	5 25.22	32V	309446	6822946	54.93	982024.605	6.22	4.73	16.94	6.78
3	8	61 29.50	5 25.22	32V	309453	6822957	54.30	982024.996	6.15	4.94	16.75	7.25
3	9	61 29.51	5 25.23	32V	309459	6822966	54.67	982025.096	6.19	5.25	16.86	7.73
3	10	61 29.52	5 25.24	32V	309465	6822977	54.06	982025.368	6.13	5.44	16.67	8.08
3	11	61 29.52	5 25.24	32V	309472	6822988	55.15	982025.268	6.25	5.60	17.01	8.35
3	12	61 29.53	5 25.25	32V	309478	6822998	56.85	982025.021	6.44	5.65	17.53	8.48
3	13	61 29.53	5 25.26	32V	309483	6823008	57.71	982024.990	6.54	5.77	17.80	8.74
3	14	61 29.54	5 25.26	32V	309490	6823019	59.09	982024.719	6.70	5.83	18.22	8.80
3	15	61 29.55	5 25.27	32V	309497	6823032	61.56	982024.268	6.97	5.62	18.99	8.56
3	16	61 29.55	5 25.28	32V	309503	6823042	64.63	982023.733	7.32	5.85	19.93	8.85
3	17	61 29.56	5 25.28	32V	309510	6823053	67.64	982023.239	7.66	5.94	20.86	9.03
3	18	61 29.56	5 25.29	32V	309516	6823064	70.25	982022.790	7.96	5.95	21.67	9.10
3	19	61 29.57	5 25.30	32V	309523	6823074	72.65	982022.276	8.23	6.22	22.41	9.33
3	20	61 29.57	5 25.30	32V	309528	6823084	67.22	982023.382	7.62	6.33	20.73	9.49
3	21	61 29.59	5 25.31	32V	309541	6823106	64.69	982023.761	7.33	6.37	19.95	9.41
3	22	61 29.59	5 25.32	32V	309546	6823116	61.36	982024.236	6.95	6.22	18.92	9.09
3	23	61 29.60	5 25.33	32V	309552	6823125	58.83	982024.561	6.67	6.29	18.14	8.92
3	24	61 29.60	5 25.33	32V	309559	6823137	53.72	982025.317	6.09	6.11	16.57	8.51
3	25	61 29.61	5 25.34	32V	309566	6823148	52.81	982025.286	5.98	6.42	16.29	8.60
3	26	61 29.62	5 25.35	32V	309573	6823159	52.65	982025.195	5.97	6.14	16.24	8.20
3	27	61 29.62	5 25.35	32V	309578	6823170	53.24	982024.993	6.03	6.46	16.42	8.43
3	28	61 29.63	5 25.36	32V	309585	6823181	54.04	982024.707	6.12	6.70	16.67	8.54
3	29	61 29.64	5 25.37	32V	309592	6823193	54.82	982024.430	6.21	7.01	16.91	8.74
3	30	61 29.65	5 25.38	32V	309604	6823213	55.63	982023.983	6.30	7.46	17.16	8.83
3	31	61 29.66	5 25.39	32V	309616	6823233	61.06	982022.878	6.92	7.54	18.83	8.86
3	32	61 29.67	5 25.40	32V	309628	6823254	68.93	982021.464	7.81	7.35	21.26	8.80
3	33	61 29.68	5 25.42	32V	309642	6823274	75.63	982020.112	8.57	7.10	23.33	8.50
3	34	61 29.69	5 25.43	32V	309653	6823296	78.30	982019.236	8.87	7.22	24.15	8.27
3	35	61 29.71	5 25.44	32V	309665	6823319	81.71	982018.389	9.26	7.54	25.20	8.35
3	36	61 29.72	5 25.45	32V	309677	6823340	88.05	982017.163	9.98	7.17	27.16	7.98
3	37	61 29.73	5 25.47	32V	309691	6823362	95.12	982015.867	10.78	7.01	29.34	7.90
3	38	61 29.74	5 25.48	32V	309703	6823384	101.74	982014.636	11.53	7.03	31.38	7.99
3	39	61 29.75	5 25.49	32V	309716	6823408	111.77	982012.962	12.66	6.71	34.47	7.89

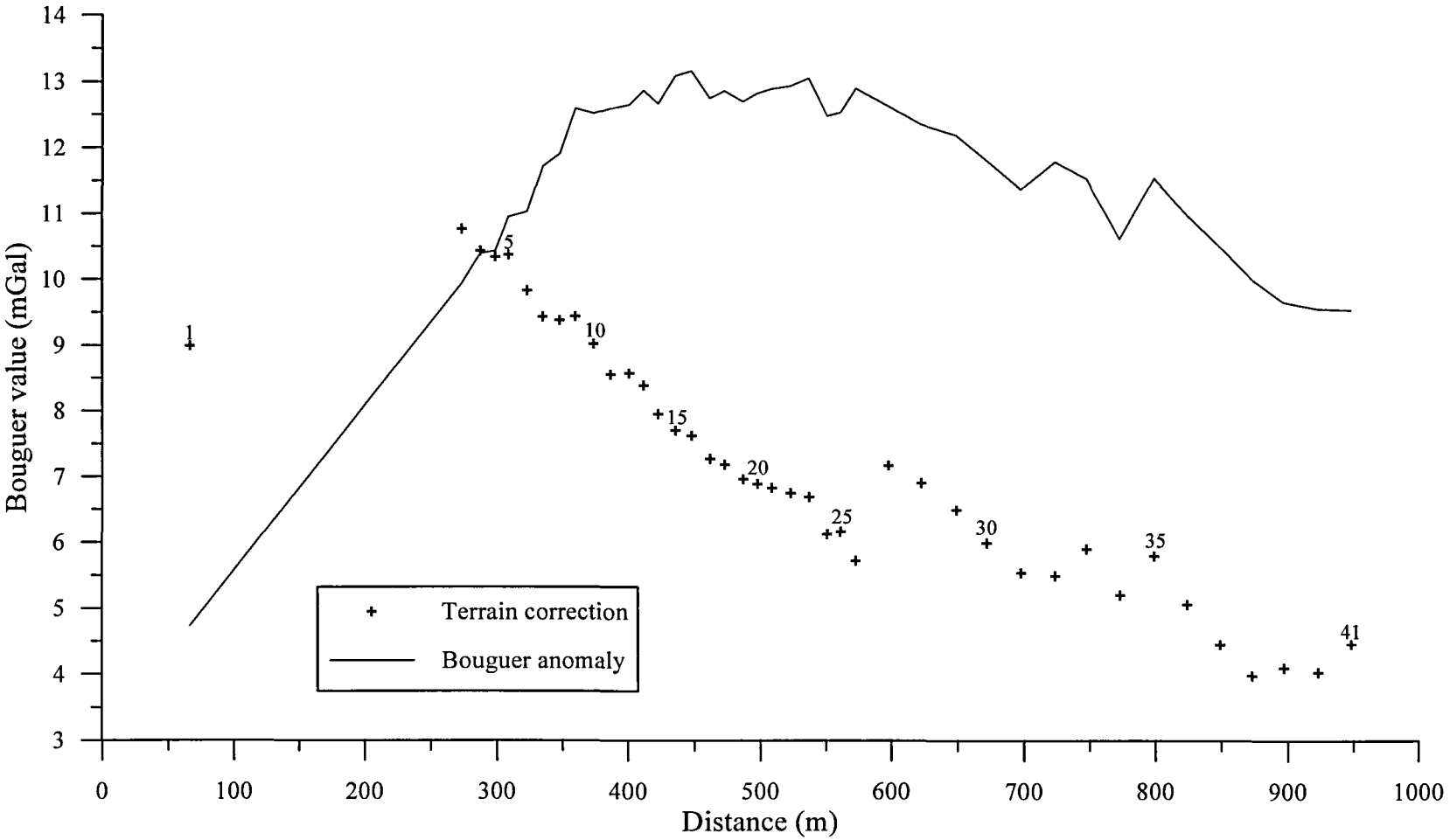
ENGEBØFJELLET, gravity profile 2
Terrain corrected Bouguer anomaly values and regional gradient



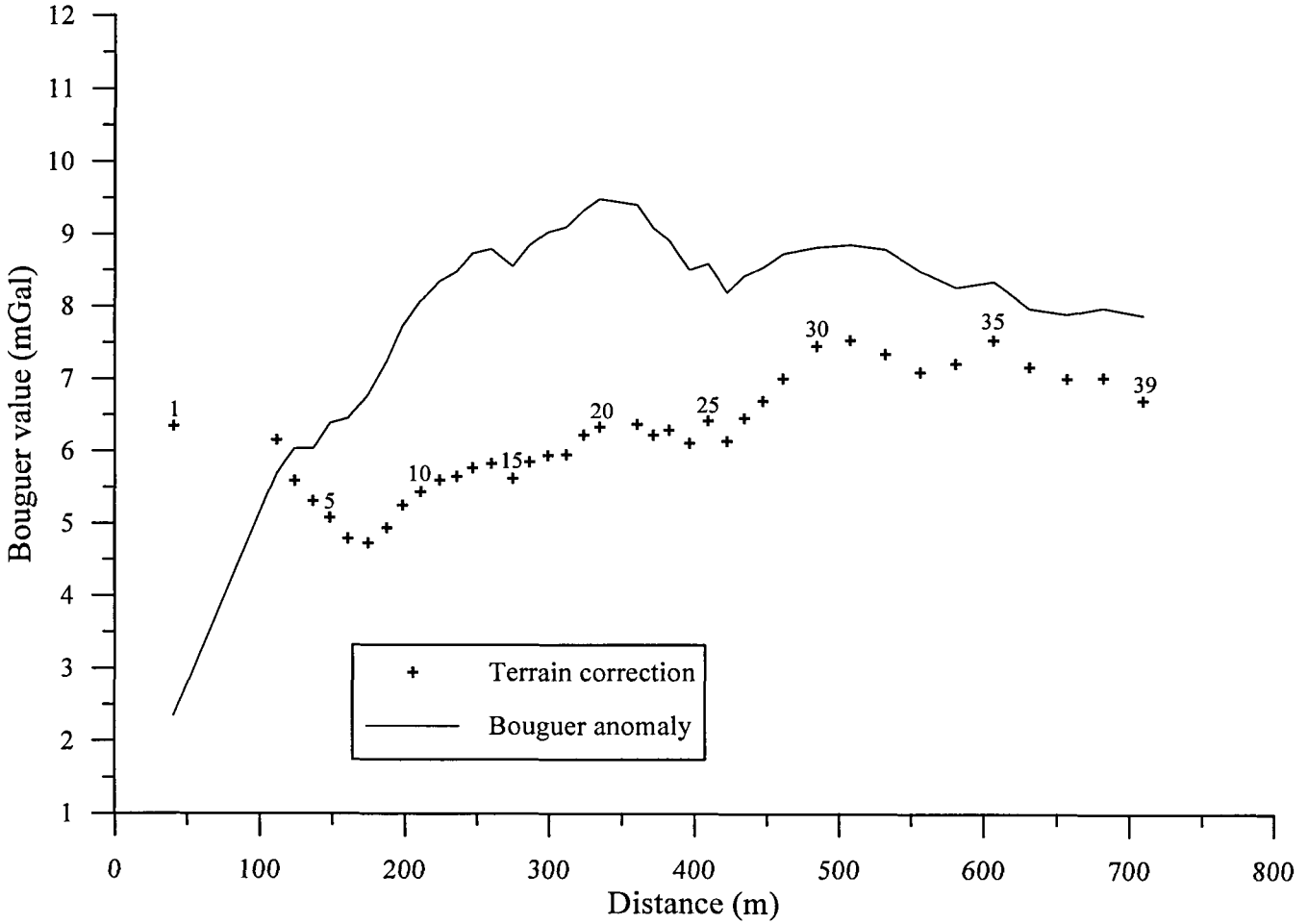
ENGEBØFJELLET, gravity profile 3
Terrain corrected Bouguer anomaly values and regional gradient



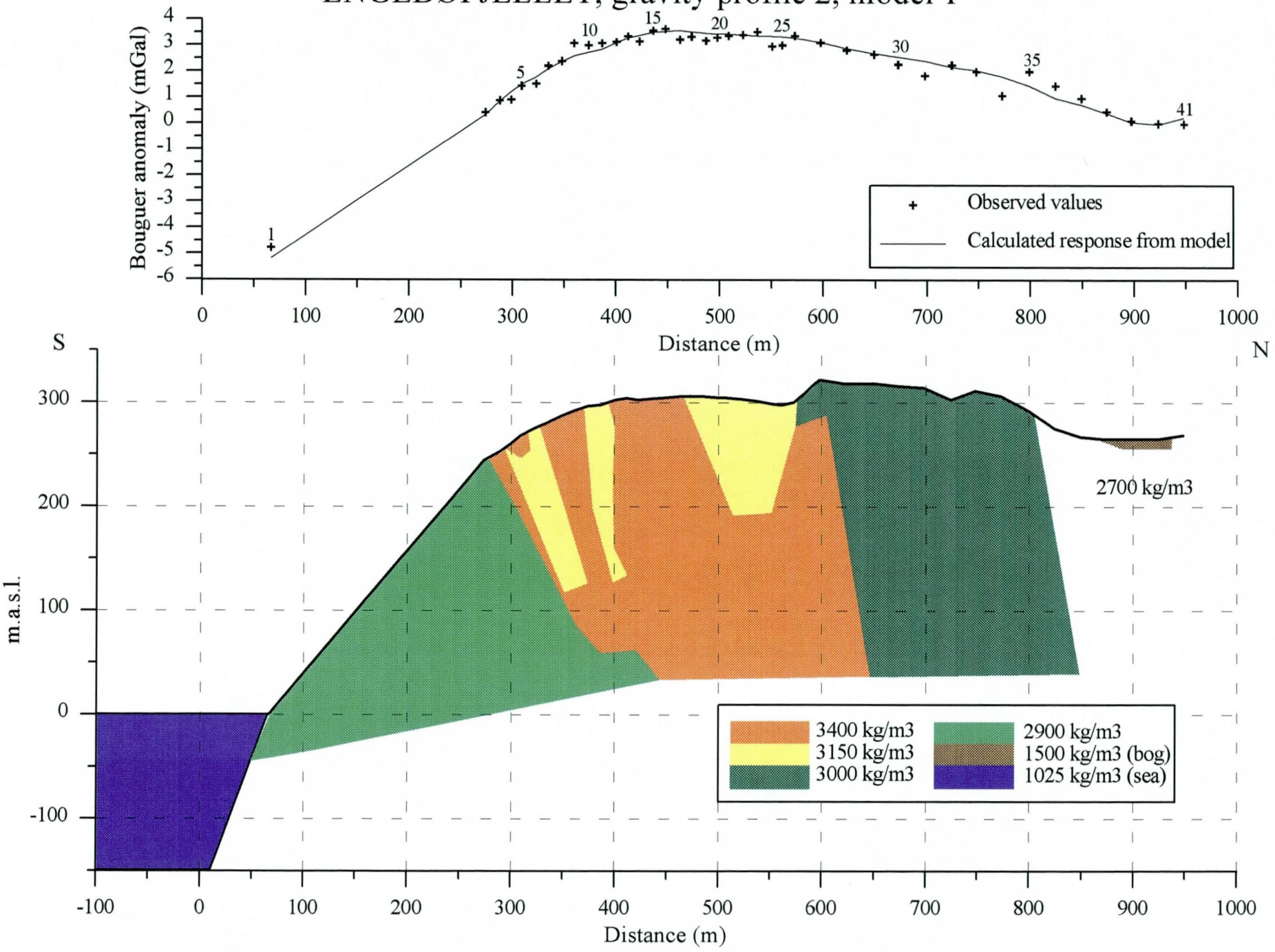
ENGEBØFJELLET, gravity profile 2, terrain correction and Bouguer anomaly values



ENGEBØFJELLET, gravity profile 3, terrain correction and Bouguer anomaly values

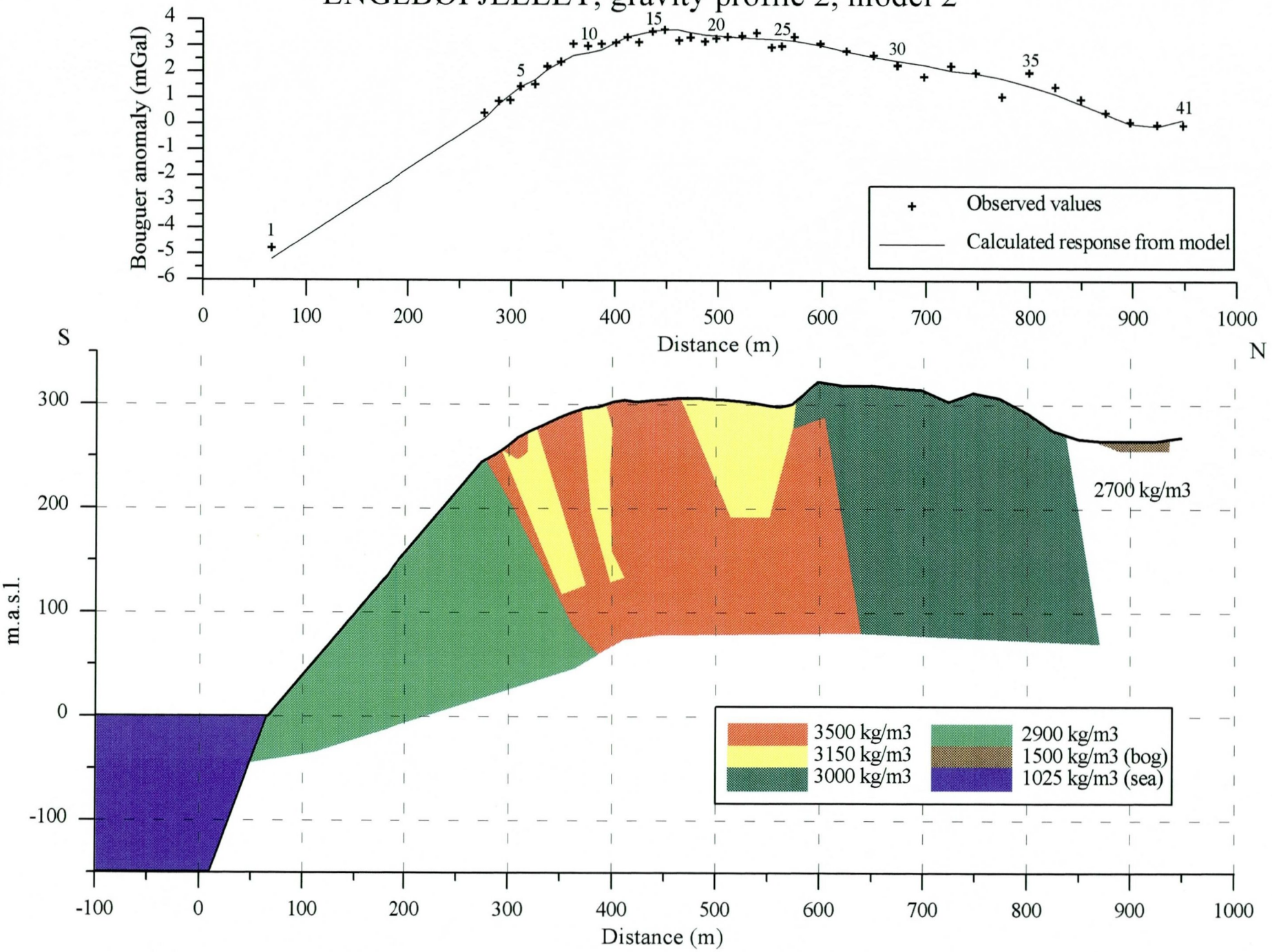


ENGEBØFJELLET, gravity profile 2, model 1



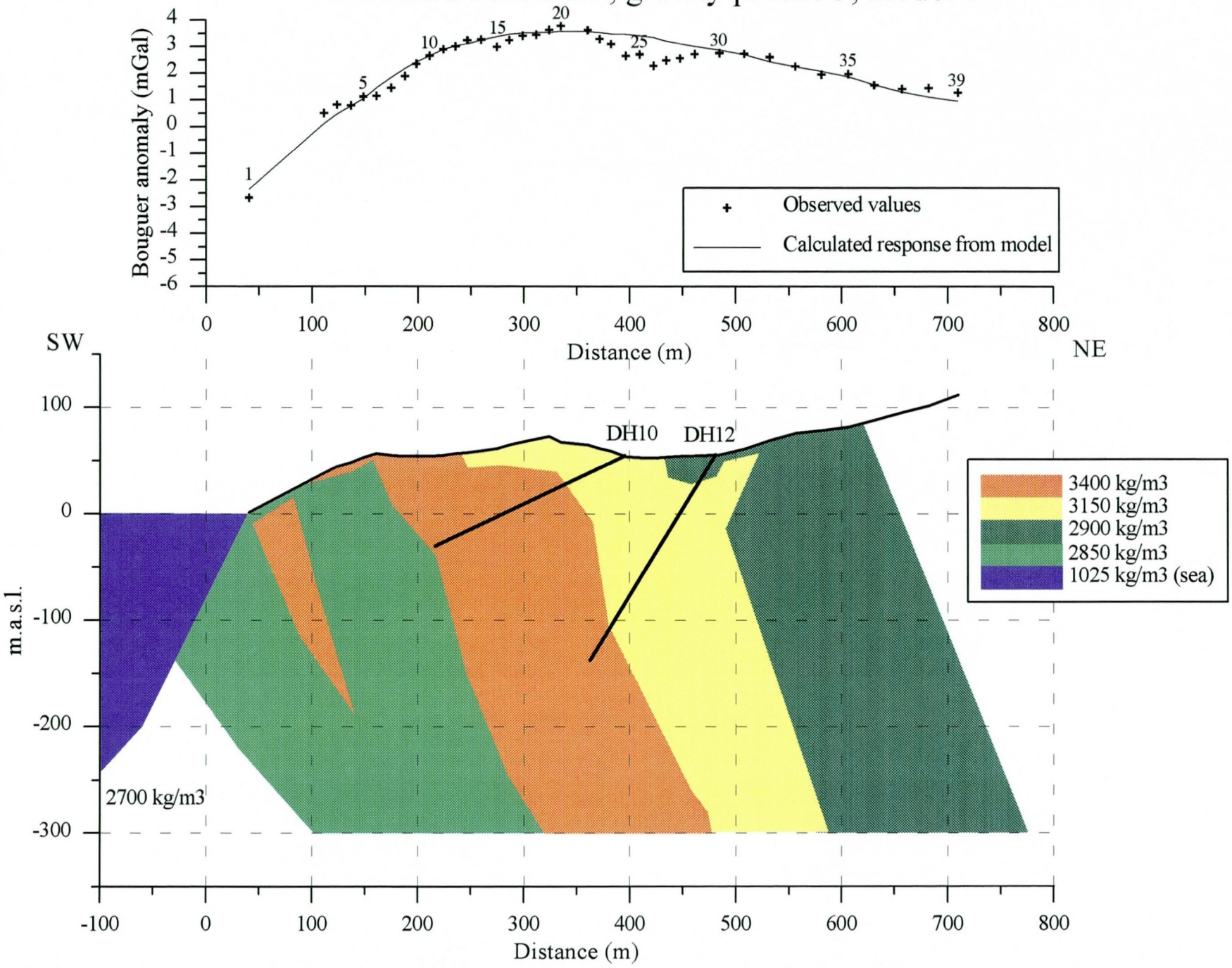
NGU Report 97.002
Appendix 5

ENGEBØFJELLET, gravity profile 2, model 2

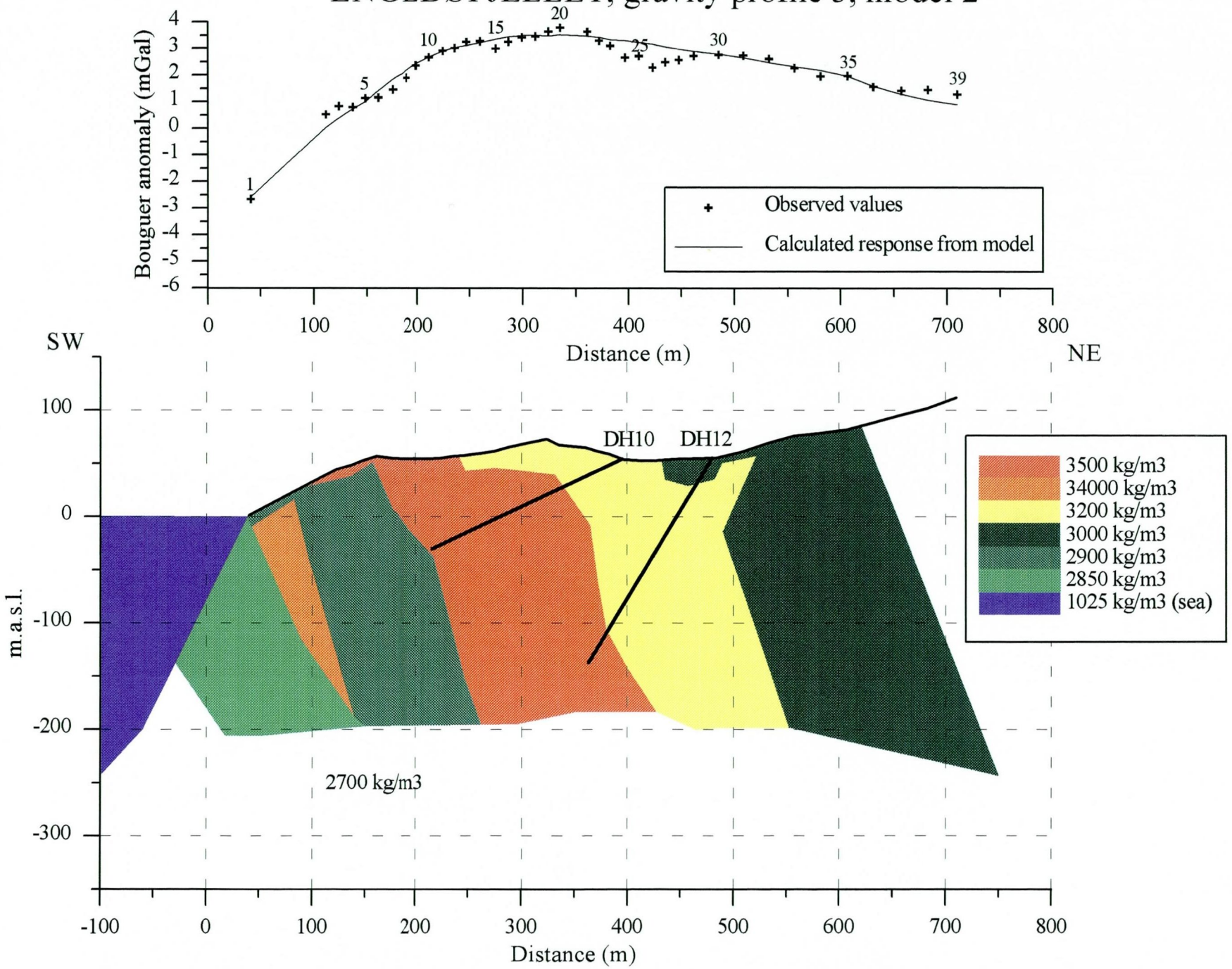


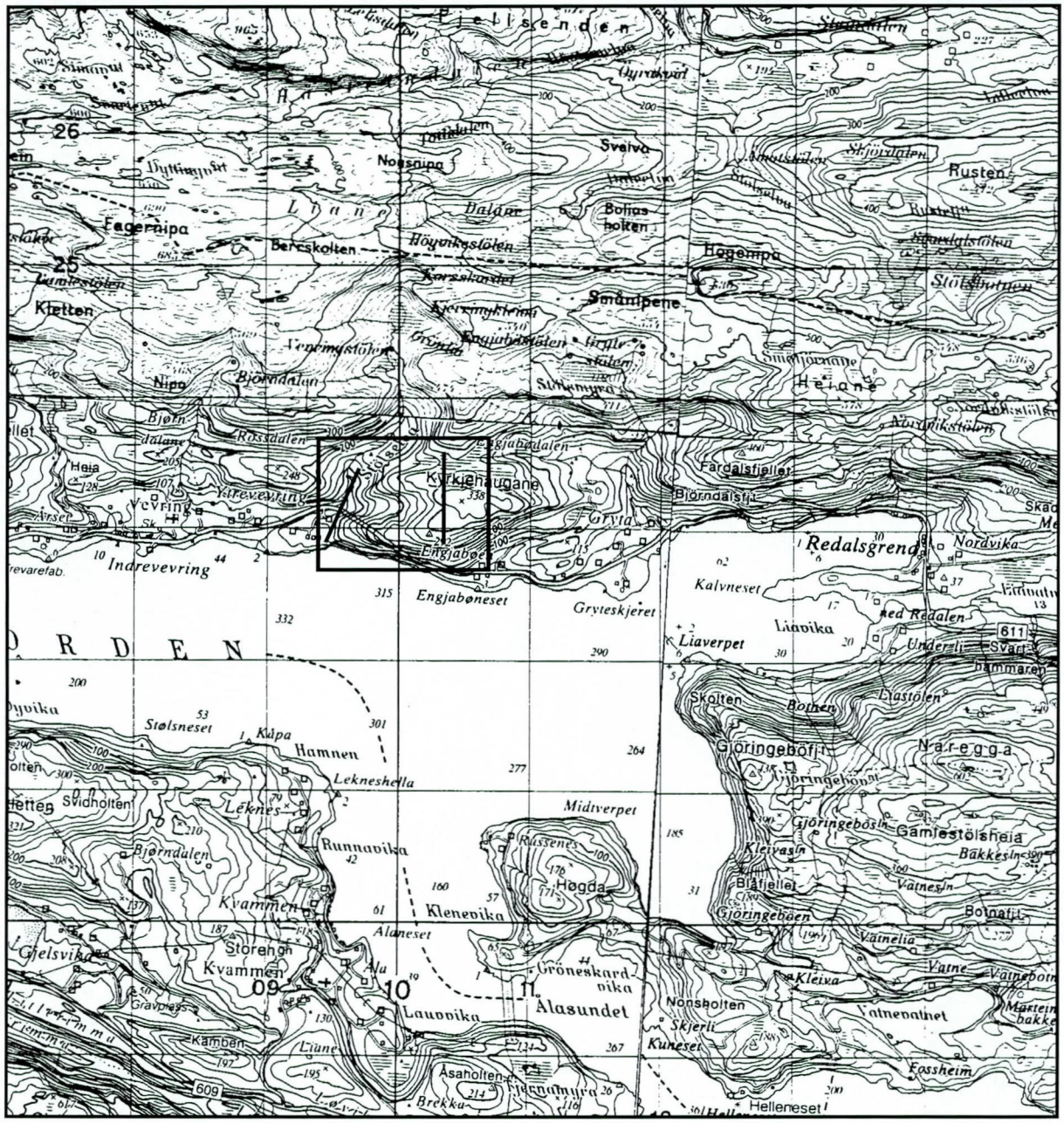
NGU Report 97.002
Appendix 6

ENGEBØFJELLET, gravity profile 3, model 1



ENGEBØFJELLET, gravity profile 3, model 2

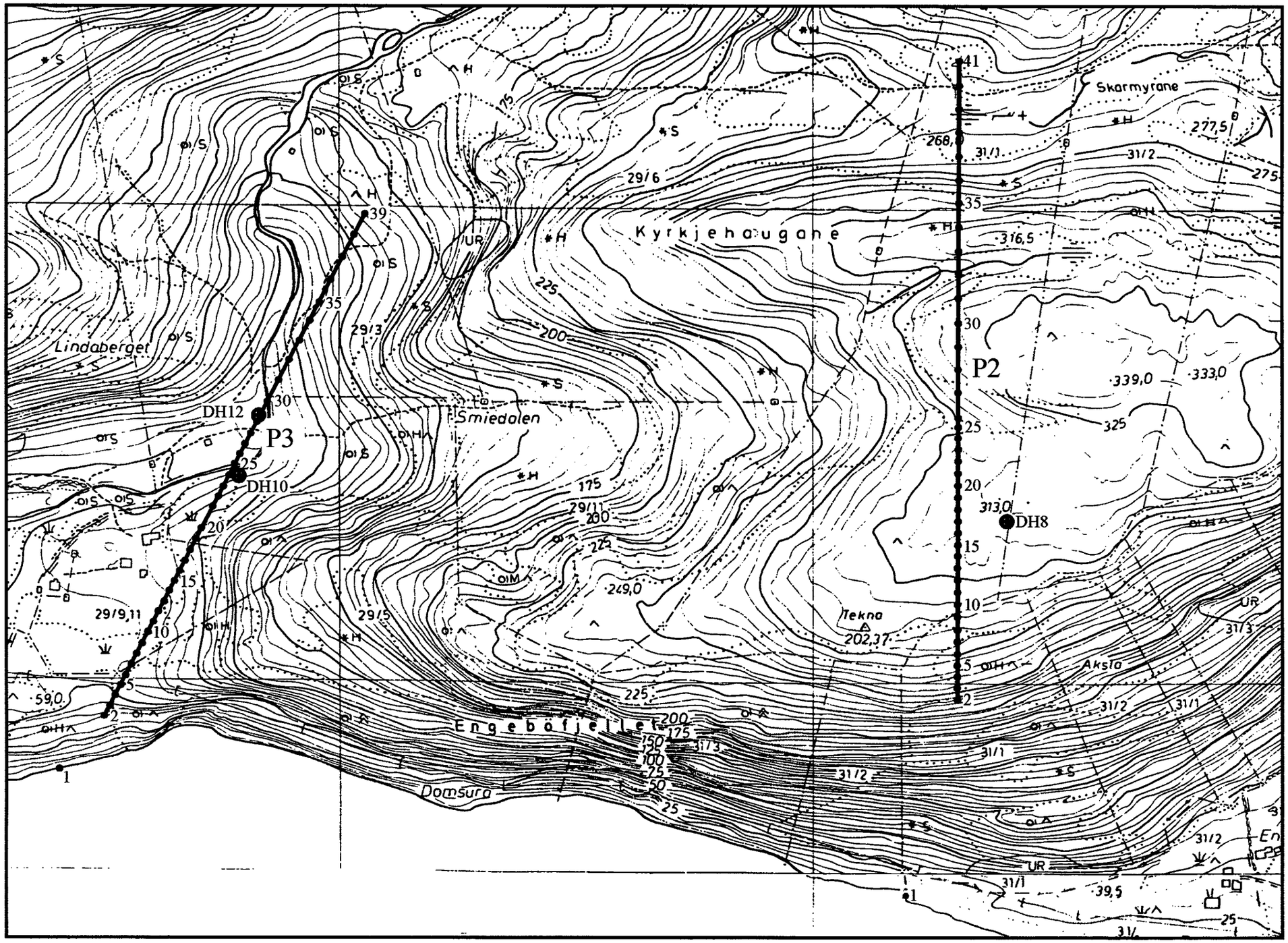




Gravity profile

Area enlarged in map -02

NGU/DuPont LOCATION MAP **ENGEBØFJELLET** SOGN & FJORDANE, NORWAY	SCALE 1:50 000	OPER JG	Aug. -96
		DRAW EM	Jan. -97
		TRAC	
GEOLOGICAL SURVEY OF NORWAY TRONDHEIM	MAP NO. 97.002-01	MAP 1:50 000 1117 I, 1118 II 1218 III, 1217 IV	



P2 Gravity profile no.

DH10 Position of drillhole

•5 Gravity station no.

NGU/DuPont GRAVITY PROFILES AND STATIONS ENGEBØFJELLET SOGN & FJORDANE, NORWAY	SCALE 1:5000	OPER JG	Aug. -96
		DRAW EM	Jan. -97
		TRAC	
GEOLOGICAL SURVEY OF NORWAY TRONDHEIM	MAP NO. 97.002-02	MAP 1:50 000 1117 I	