SOME GEOPHYSICAL PROFILES IN ØSTFOLD

By
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Abstract.

Based on detailed gravimetric observations three profiles are examined, the profiles running some 20 km west—east from Jeløya, Østfold fylke. The magnetic values are taken from maps published by NGU. Geological samples have been collected and the physical properties of the samples have been determined in the laboratory. By application of GIER—ALGOL programmes models have been studied.

The known geological displacement which is estimated to about 1000 m between Jeløya and the main-land is not seen on the gravimetric picture in the northern profile, while the two southerly profiles give displacement values of 800—900 m. In the northern Jeløya a heavy body of a thickness of about 800 m is calculated. A smaller basic body of 100 m thickness is located in the main-land on profile II. Granitic bodies of thickness from 350 to 2000 m are found in profiles II and III. The magnetic values support the interpretation in the Jeløya area, while we have no distinct magnetic anomalies in the main-land.

Introduction.

In a previous paper (Ramachandra et.al. 1967) a preliminary report was given concerning some geophysical measurements in Jeløya. Since that time the gravimetric surveying has continued and by the time of writing the coverage is some 1500 gravity stations in about 450 km^2. Magnetic measurements on the ground have been carried out only in connection with detailed investigations of special geological problems. For this study the aeromagnetic maps published by NGU have been applied.

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Fig. 1 is a location map as far as the three profiles are concerned. In the figure we have marked the sample localities. The geological samples were mainly collected in the 1968 season in such a way that if an outcrop occurred at the gravimetric reading place a sample was taken.

Geology.

The area investigated can geologically be divided into two main groups, the precambrian and the paleozoic-permian. The precambrian rocks cover the area except the island Jeløya, which is situated in the western part of the area. They consist mainly of strongly metamorphic rocks, gneisses of various kinds, with minor occurrence of plutonic rocks like gabbro and peridotite. The rocks have been transformed during several deformations and migmatites are common. At the end of the last deformation granites were emplaced, one of them being the Våler granite, in the eastern part of the area. (See Fig. 3).

The precambrian geology is not known in details, but a new mapping of the area has been commenced (Berthelsen 1967), and it is then to be hoped that more detailed and correct geological information will be available within a reasonable time in order to obtain a more correct geophysical interpretation. For the present study use has been made of the geological maps by Rekstad (1921), Brøgger and Shetelig (1926), and Gleditsch (1960).

The other group of rocks in the area is the above mentioned paleozoic-permian rocks of Jeløya. They belong to the Oslo field and are down-faulted in the precambrian. The main faultline runs north—south between the island and the main-land. For further details on this group see Brøgger and Shetelig (1926) and Ramachandra et.al. (1967).

In table 1 the rock-samples, which were taken at the gravimetric stations where outcrops occurred, are listed together with their physical properties as they are determined in the laboratory. Density has been determined in the usual way, and an Oersted meter has been applied for the determination of susceptibility and remanent magnetism. The accuracy for the density values is better than 0.01 gr/cm^3, while the accuracy for susceptibility and remanent magnetism is not better than 0.00002 c.g.s. units. The location of the samples are plotted on Fig. 1. As far as rhomb-porphyry, basalt, and sandstone are concerned the samples are all collected in Jeløya. Previously (Ramachandra et.al. 1967) physical properties have been given for the same rock-types originating from Jeløya. The Våler granite, migmatite, biotite-hornblende gneiss, quartz-feldspar gneiss, and amfibolite (gabbro and metagabbro) are collected in the main-land. Even if the samples cluster in groups we believe that the physical properties obtained suffice this preliminary study as representative for the geological formations present.

Table 1

Sample No.	Rock-Type	Locality	Density gr/cm^3	R.M. c.g.s.	Suscept. c.g.s.	Q
302	Våler Granite	Langøen	2.60	<0.00002	<0.00002	
1026	—	Haugen	2.61	—	—	
1065	—	Ven	2.61	—	—	
1068	—	Turen	2.60	—	—	
1070	—	Røstad	2.59	—	—	
1071	—	Turen	2.60	—	—	
312	Migmatite	Brasenbogen	2.79	—	—	
315	—	Dillingøen	2.62	—	—	
317	—		2.68	—	—	
318 A	—	St. Kvernø	2.62	0.00005	0.00107	0.10
325	—		2.67	<0.00002	<0.00002	
326	—	Fæøen	2.62	—	—	
1101	—	Oppegård	2.67	—	—	
1474	—	Høiaas	2.84	—	—	
1673	—		2.68	0.00060	0.00006	21.52
9314	—	Laursbakken	2.67	<0.00002	<0.00002	
9107	—	—	2.74	—	—	
9301	—	Patterød	2.67	—	—	
9101	—	Norødegård	2.63	—	—	
314	Biotite-hornblende gneiss	Dillingøen	2.68	—	—	
319	—	Bjørnø	2.69	—	—	
529	—		2.64	—	—	
667	—		2.71	—	—	
721	—	Henes	2.65	—	—	
766	—	Rød	2.74	<0.00002	<0.00002	
1077	—		2.69	—	—	
1147	—	Sjulerød	2.69	—	—	
9404	—	Noretj.	2.73	—	—	
9103	—	—	2.86	—	—	
9405	—	Norødegård	2.80	—	—	
9314	—	—	2.67	—	—	

Sample No.	Rock-Type	Locality	Density gr/cm^3	R.M. c.g.s.	Suscept. c.g.s.	Q
316	Quarz-feld-spar gneiss	Dillingøen	2.64	0.00009	0.00148	0.13
318	—	Kvernø	2.60	$<$0.00002	$<$0.00002	
310	—	Osienrødøen	2.63	—	—	
327	—	Nesengen	2.65	—	—	
1498	—		2.60	0.00009	0.0015	0.11
1499	—	Kjaita	2.62	$<$0.00002	$<$0.00002	
1500	—		2.62	$<$0.00002	0.00043	0.07
9313	—	Laursbakken	2.63	$<$0.00002	$<$0.00002	
9102	—	—	2.64	—	—	
9302	—	—	2.62	—	—	
9303	—	Patterød	2.61	—	—	
9114	—	—	2.62	—	—	
9117	—	—	2.63	—	—	
9120	—	—	2.58	—	—	
9309	—	—	2.65	—	—	
9121	—	—	2.64	—	—	
9312	—	—	2.59	—	—	
164	Amfibolite		3.08	—	—	
222	—	Isdam	3.02	—	—	
1080	— (gabbro)	Risheim	3.07	—	—	
1148	—	Veidal	3.08	—	—	
1468	— (gabbro)	Kaabel	2.88	—	—	
1478	—		3.10	—	—	
9104	—	Europaveg 6	3.07	—	—	
9105	—	—	2.99	—	—	
9316	—	—	2.98	—	—	
9109	—	—	2.96	—	—	
9304	—	—	2.92	—	0.00007	
9110	—	—	2.99	$<$0.00002	$<$0.00002	
9306	—	—	3.04	—	—	
9113	—	—	2.92	—	—	
9305	—	—	3.07	—	—	
9110	—	—	2.98	—	—	
9307	—	—	3.11	—	0.001	
9118	—	—	2.96	—	$<$0.00002	
9119	—	—	3.00	—	—	
9403	—	—	2.95	—	—	
9108	— (meta-gabbro)	Noretj.	3.01	—	—	
9106	— (gabbro)	—	3.22	—	—	

Sample No.	Rock-Type	Locality	Density gr/cm³	R.M. c.g.s.	Suscept. c.g.s.	Q
9112	— (meta-gabbro)	—	3.11	—	—	
9115	— (meta-gabbro)	—	2.96	—	—	
J. 7	Rhomb-Porphyry	Jeløya, Reier	2.68	0.0005	0.0029	0.32
J. 9	—	—	2.62	0.00006	0.0003	0.47
J. 1	Basalt	— Kongshavn	2.88	0.0023	0.0045	1.0
J. 2	—	— —	2.79	0.0028	0.0025	2.3
J. 3	—	— Kullebunden	2.77	0.0016	0.0003	12.5
J. 5	—	— Renneflot	2.77	0.0025	0.0024	2.2
J. 8	—	— Singelsbukta	2.84	0.0097	0.0033	6.1
J. 13	—	— Kippenes	2.77	0.0048	0.0004	24.9
J. 6	— (agglom-erate)	— Kongshavn	2.68	0.00071	0.0030	0.49
J. 11	— (agglom-erate)	— Englevik	2.71	0.0027	0.0019	2.9

Gravity.

The gravimetric readings have been carried out by means of Worden gravimeters W 142, WP 148, WM 653, WM 681, and WM 779. In order to establish a base station net system one or two of the Worden gravimeters have been employed together with LaCoste & Romberg gravimeter 54. A report on the base station net system is under preparation and will be published elsewhere. However, stations previously included in the European Gravimeter Calibration Line (Kejlsø 1958, Saxov 1958 and 1966, Sømod 1957) are included in the base station net system.

All the gravimetric observations are referred to Oslo Fundamental Gravity Station with G=981.92815 Gals. A density value of 2.67 gr/cm³ has been employed in the computation of the Bouguer correction. The coordinates are taken from the topographical/economic maps in the scale of 1 : 5 000 or 1 : 10 000. The elevation values are taken partly from bench-marks and polygon-points, the heights being known in millimetres or centimetres, and partly from dot-points in the topographical maps, the heights then being in metres or half-metres. No topographic correction is applied. Theoretical gravity values are taken from the tables by Andersen (1956).

In Figs. 2, 3, and 4 the profiles are presented. It is not possible to obtain a proper regional gravity trend from the present gravity map (NGO 1960) due to too few gravity stations and a non-representative coverage of the area in question. The regional gravimetric trend has therefore been drawn graphically in the usual manner, see e.g. Dobrin (1960). This means that the regional trend concerns the area close to the profiles. The residual effect is thus the difference between the computed Bouguer anomalies and the regional trend. The residual anomalies are caused by shallow bodies in the outer crust. In the interpretational studies due respect is taken to the density value which according to table 1 and to previous values (Ramachandra et.al. 1967) can be summarized as follows:

Table 2.

Rock-Type	Sample No.	Density Range gr/cm^3	Density Mean gr/cm^3	Stand. Dev. gr/cm^3
Jeløya				
Rhomb-porphyry	18	2.56—2.68	2.60	0.04
Basalt	23	2.62—2.88	2.76	0.06
Sandstone	5	2.63—2.69	2.66	0.02
Main-land				
Våler granite	6	2.59—2.61	2.60	0.01
Amfibolite	24	2.88—3.22	3.02	0.08
Migmatite	13	2.62—2.84	2.68	0.07
Biotite-hornblende gneiss	12	2.64—2.86	2.70	0.06
Quarz-feldspar gneiss	17	2.58—2.65	2.62	0.02
Migm.-biot.-Quarz	42	2.58—2.86	2.66	0.06

In comparison with the values listed by Ramachandra et.al. (1967) it is seen that the addition of two samples to the rhomb-porphyry group has caused no change in the mean density value. Likewise for the basalt group, where 8 additional samples have increased the total number from 15 to 23, the mean density value being unaltered as 2.76 gr/cm^3. As far as sandstone is concerned no additional samples have been collected. The spread in the density values is also the smallest in that group.

Looking into the samples from the main-land we have only 6 Våler granite pieces. However, collected within a larger area the granite seems to be very uniform. The amfibolite group has a large spread, the mean value, however, seems to fit well with the conventional value. Concerning the migmatites and the gneisses we have given values for each group as well as for the total group. Evidently the quarz-feldspar gneisses have a smaller spread and are lighter than the two other groups. We have, however, felt that for the present study it would be reasonable to consider migmatites and gneisses as one group. That means that we count on three groups in the main-land, granite with a density value of 2.60 gr/cm^3, amfibolite with 3.02 gr/cm^3, and migmatite/gneiss with 2.66 gr/cm^3.

By inspection of the gravimetric profiles we find on profile I four anomalies numbered from A to D. Anomaly A has a counterpart in the magnetic anomaly I, and it is also seen in the previous paper (Ramachandra et.al. 1967). Anomalies C and D have the character of a fault structure, however, they may also be effects from geological structures which seems to be supported by magnetic anomaly J. Anomaly B has no analogous magnetic anomaly and is not correlated with any known geological evidence.

In profile II we have three interesting anomalies, E, F, and G. As was the case in profile I gravity anomaly E in Jeløya corresponds to magnetic anomaly K. No magnetic anomalies are seen in the eastern part of the profile. There exists a possibility that one or two of the small gravimetric peaks between anomalies E and F correspond to anomaly B in profile I.

Even if the regional gravimetric trend is seen in profiles I and II it is more clearly demonstrated in profile III. This profile has consequently been deciding in the determination of the regional gravimetric effect. The residuals are all small except anomaly H. Once again a small peak to the east of anomaly H is seen analogous with the two other profiles.

Magnetics.

The magnetic data applied in this study originate from aeromagnetic maps published by NGU (1966/67). The measurements are carried out partly by means of a flux-gate magnetometer type AN/ASQ-3A partly by a proton magnetometer type ELSEC 592. The flight-lines are orientated east-west, the distance between flight-lines being about 1000 m. The heights are between 100 and 150 m. The values shown on Figs. 2, 3, and 4 are the total magnetic force in gammas.

By inspection of the magnetic properties in Table 1 we find that granite, biotite-hornblende gneiss, and sandstone give no response at all, that of migmatite, quarz-feldspar gneiss, and amfibolite only 2, 4, and 2 samples out of 13, 17, and 24 respectively give magnetic indication — and that they all show very weak magnetic properties. As far as rhomb-porphyry and basalt are concerned we have the same picture as found previously (Ramachandra et.al. 1967) that basalt is stronger magnetized than rhomb-porphyry which is rather weak magnetically. The following table summarizes the values:

Table 3.

Rock-Type	Sample No.	R.M. — cgs units Range	Mean	Suscep. — cgs units Range	Mean
Jeløya					
Rhomb-porphyry	12	0.00006—0.00129	0.00067	0.00004—0.0029	0.00055
Basalt	21	0.00032—0.01484	0.00247	0.00008—0.0065	0.00299
Main-land					
Migmatite	2	0.00005—0.00060	0.00032	0.00006—0.00107	0.00062
Quarz-feldspar gneiss	4	0.00002—0.00009	0.00007	0.00002—0.0015	0.00088
Amfibolite	2			0.00007—0.001	0.00054

It is a general trend in the aeromagnetic profiles that the magnetic curves are very uniform in the main-land with exception of the small anomaly J in profile I and a weaker, more broad, anomaly M in profile III. As mentioned earlier anomaly J seems to be correlated with a geological border, while apparently no gravimetric anomaly is corresponding to anomaly M. That only small magnetic disturbances are to be found in the main-land is in confirmation with the magnetic properties of the rock samples. The magnetic anomalies I, K, and L are presumably all related to the down-faulted rocks at Jeløya.

Some of the permian lava samples were taken orientated and the magnetic results show a reversed magnetization direction for these samples. This fact may contribute to the explanation of some of the peculiar shapes of the magnetic curves.

Interpretation.

To avoid mistakes or misinterpretations due to terrain effects only gravimetric anomalies where terrain effects are supposed not to disturb the anomaly picture have been treated. It has to be pointed out that due to the scarcity of geological evidence some of the models shown are interpreted by application of the geophysical anomaly curves only and they should therefore be looked upon with this point in mind. The calculations have been carried out by application of a GIER-ALGOL programme developed by Henkel (1969) for two-dimensional bodies making use of the formula according to Talwani et.al. (1959). In cases where the anomalies are not of true two-dimensional shape end-corrections according to Nettleton (1940) have been applied.

Turning now to a discussion of the residual anomalies seen in the three profiles it must be stated that none of the four anomalies A to D in profile I can be directly correlated to known geology. The narrow positive anomaly A of about 2 mgals has been considered as due to a local thickening of the basalt, however, the relief could also be due to a disturbance from a heavier body of the essexite type. The shape of anomaly A suggests a shallow structure. The total magnetic field curve with anomaly I shows strong disturbance at the same locality and the sample J. 8 (basalt) shows typical magnetic properties. The model applied is based on a density contrast of $+ 0.10$ gr/cm^3. The fit between the measured and the calculated points is not too satisfying for the present model, which gives a thickness of about 800 m. It may therefore be more reasonable to assume that the density contrast is a little higher. East of anomaly A runs the geological fault-line between the younger rocks in Jeløya and the precambrian in the main-land. The gravimetric field does not show much relief in this respect, probably mostly owing to too few measurements in connection with the strait.

The gravimetrically fault-like anomalies (B, C, and D) in the gravity curves in the eastern part of profile I have no known geological explanation. The anomaly features C and D have been interpreted as a vertical contact between a heavy basic body and a granitic body. Both types of these rocks are known from the area concerned, however, their exact location is unknown so far. By application of a density contrast of $+ 0.30$ gr/cm^3 the basic body (anomaly C) is estimated to have a thickness of about 100 m, while the granitic body (anomaly D) with a density contrast of $- 0.07$ gr/cm^3 shows an asymmetric character with a thickness of about 800 m in the western end and of about 300 m in the eastern end. Anomaly B could be interpreted in a similar way as has been done for anomaly C and the result would be a smaller asymmetric basic body.

When we now turn to profile II it is of interest to note that gravimetric anomaly E consists of a broad negative anomaly of 4—5 mgals with a distinct positive peak of about 3 mgals almost in the middle. The negative anomaly is probably due to the down-faulted paleozoic sedimentary rocks and has been interpreted this way. The density contrast is not known except for the upper devonian sandstone, but the displacement of about 800 m by application of a density contrast of -0.10 gr/cm^3 is in accordance with the geological estimation of about 1000 m. It is seen that the calculated points fit well with the measured curve. The influence from the lavas has not been taken into consideration as the lavas are believed to be thin thus their gravimetric effect is of smaller amplitude. The positive gravimetric peak inside anomaly E could be due to the basalt, but terrain effects may change the picture why no interpretation has been carried out. The terrain effect problem is the reason why the fit of the calculated curves and the measured curves have not been driven too far.

The anomaly K of the total magnetic field force shows a broader positive value with a negative value in the middle. The western positive peak could be correlated with the basaltic formation in Jeløya. This anomaly coincides with the gravimetric anomaly. According to the method described by Bean (1966) the depth to the disturbing body (basalt?) is about 50 m below the surface. The sloping values on the western flank of the magnetic anomaly is probably due to the sandstone. The eastern feature of anomaly K is related to the displacement.

Gravimetric anomalies F and G have been correlated with known outcrops of granite, the Våler granite. The borders against the gneisses are unknown in details and have been fixed from the gravimetric profiles. Using a density contrast of -0.07 gr/cm^3 the granitic body from anomaly F seems to be very regular with a thickness of about 350 m, while the anomaly G granitic body is more irregular of shape. The maximum thickness is about 2000 m.

As stated earlier the regional gravimetric trend is demonstrated most clearly in profile III and the trend dominates the picture. Except anomaly H the residual curve is slightly undulating. Anomaly H has a similar shape as anomaly E except that H has a large negative value in the eastern end. That may be due to lesser terrain effect combined with thicker quaternary cover. The geological conditions in anomaly E and anomaly H are very similar and by application of a density contrast of -0.10 gr/cm^3 we obtain a thickness of about 900 m. When we analyse the aeromagnetic anomaly L according to the method by Bean (1966) we get a depth of about 200 m to the top of the disturbing body.

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Part of the gravimetric measurements in 1967 and 1968 was carried out by cand. real. I. Ramberg, and H. Henkel, M.Sc., is responsible for part of the gravimetric readings from 1968.

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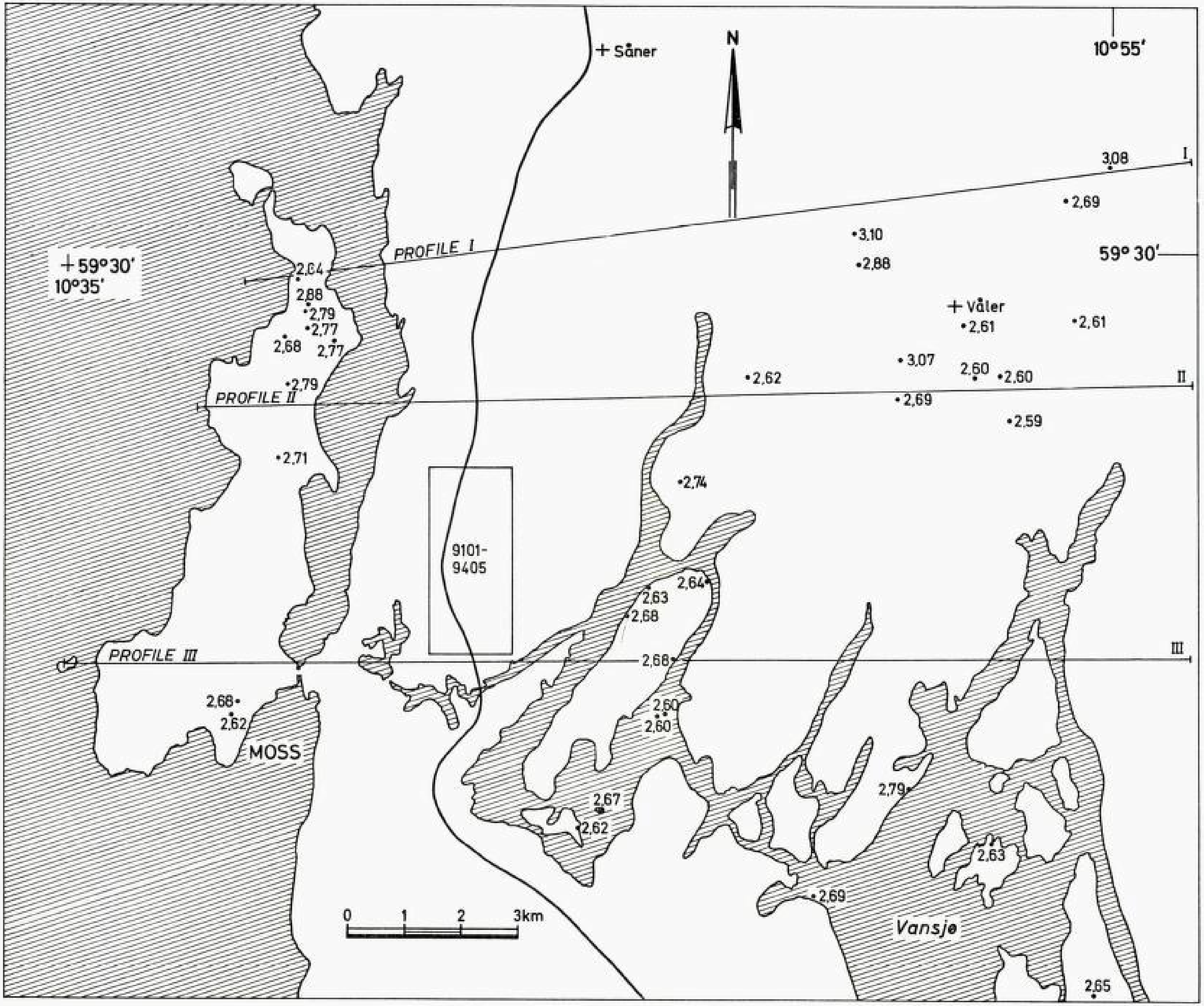

Fig. 1. Location map for profiles I, II, and III is shown. Density values are given.

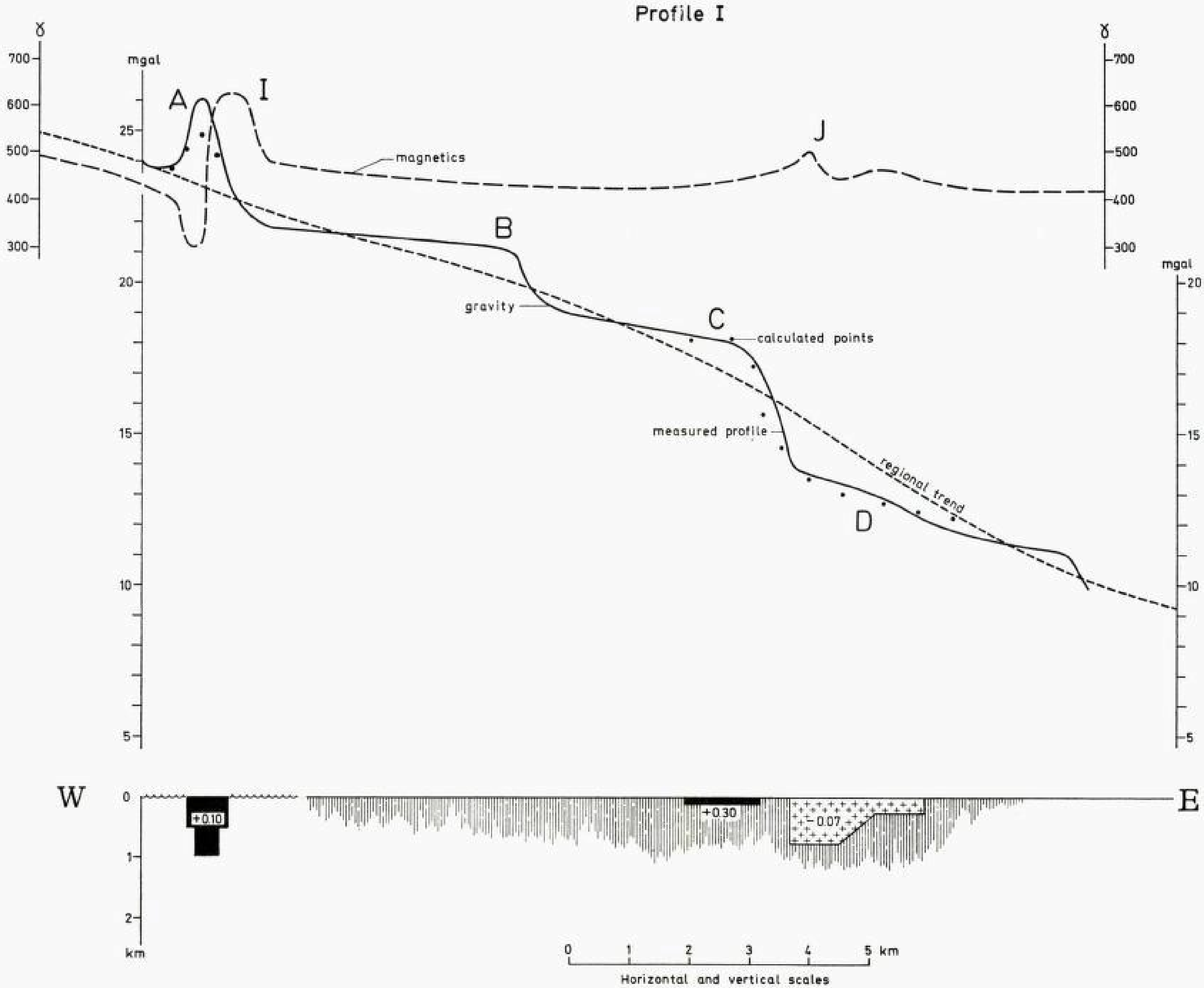

Fig. 2. Profile I showing the gravimetric and magnetic values. In the lower part the geological bodies are shown.

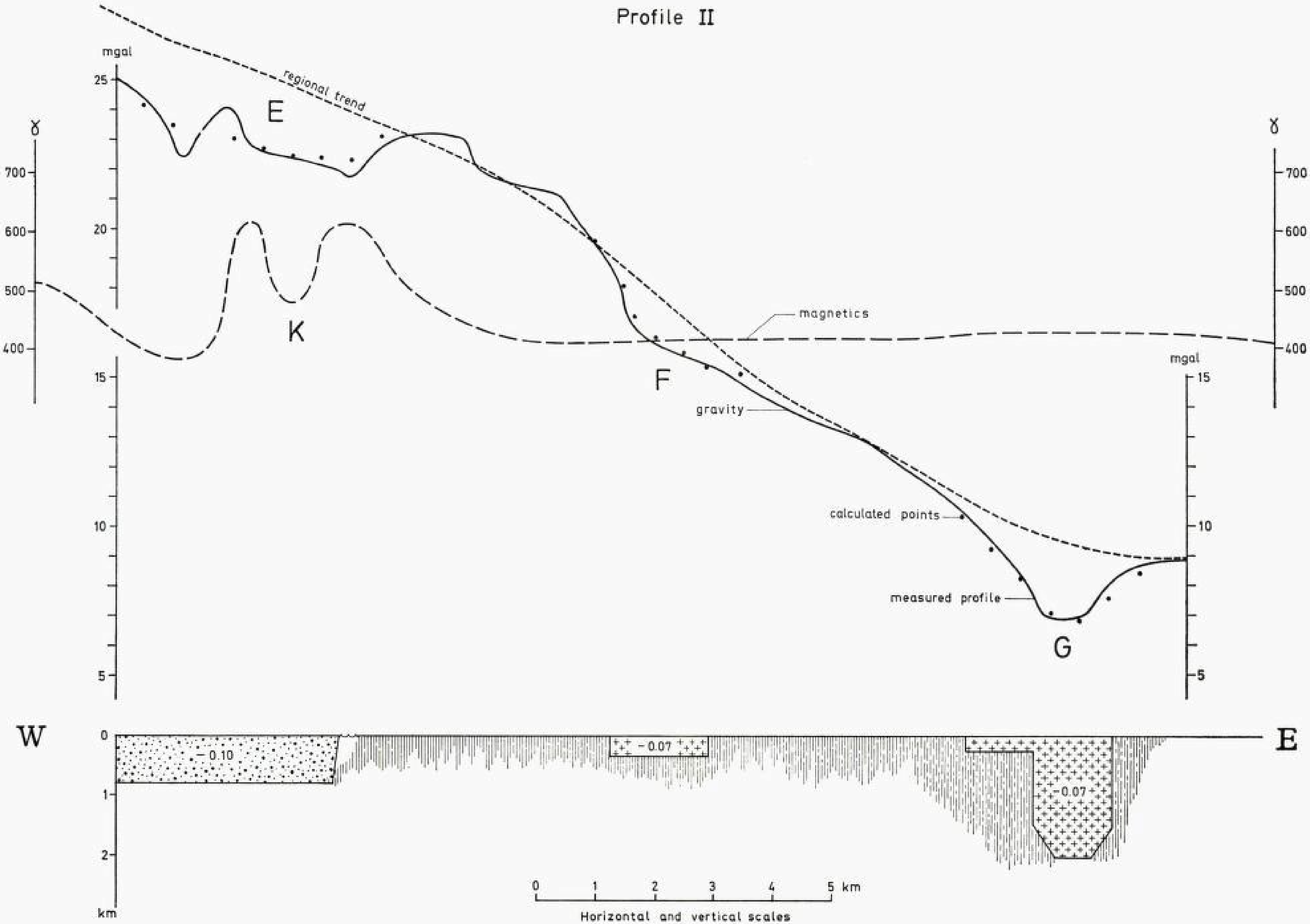

Fig. 3. Profile II showing the gravimetric and magnetic values. In the lower part the geological bodies are shown.

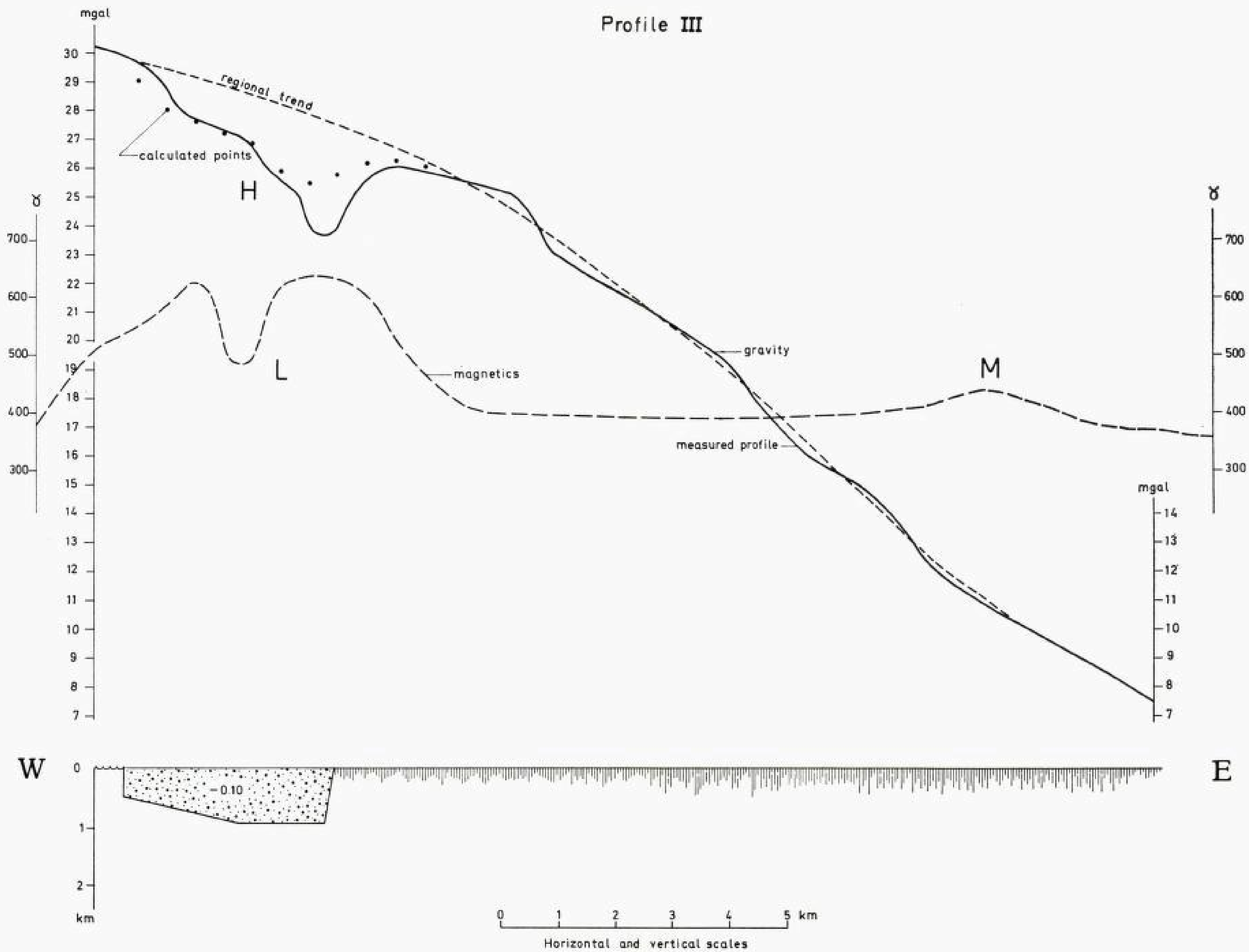

Fig. 4. Profile III showing the gravimetric and magnetic values. In the lower part the geological bodies are shown.