UPWARD-CONTINUATION OF THE GRAVITY FIELD OVER THE CAPE FLATTERY TEST RANGE

by

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ABSTRACT

The gravity field over the Cape Flattery Test Range was upward-continued to heights of 50, 300, 1500, and 3000 m. The accuracy of the upward-continued data is believed to be a few milligals. It is shown however that the results are very dependent on the nature of the gravity field outside the region of interest and discrepancies as large as 5 mGal were observed at 3000 m when the surrounding gravity field is ignored.

INTRODUCTION

The Geological Survey of Canada and Questor Surveys of Toronto had planned to test a LaCoste and Romberg Air/Sea gravimeter aboard an airship in the fall of 1986. Unfortunately the test was ultimately cancelled due to the unavailabity of the airship. In preparation for the test however, the gravity field above the Cape Flattery test range (Prahl and Mills, 1974) was upward-continued to various altitudes. The distribution of underwater gravity measurements in the vicinity of the Cape Flattery test range is shown in Fig. 1. The distribution of surface measurements in the same region is shown in Fig. 2. The basic methodology used is two dimensional frequency domain filtering of the gravity field using the Fast Fourier Transform (FFT) as described by Nagy (1986). Before upward-continuing the real data an appropriate gravity model was studied to investigate the precision of the method.

MODEL STUDIES

The model (Gibb and Van Boeckel, 1970) on which some studies were carried out is comprised of 64 blocks extending 80 km by 75 km providing a gravity anomaly of nearly 60 mGal. The gravity at various heights can be calculated analytically (exactly), for this model, and compared with the values obtained numerically from the FFT technique. The difference or residual map is an indication of the error of the numerical procedure to obtain upward-continued gravity. A single measure, the span, S, (maximum change of the residual map) will be used as an overall indication of error.

For input to the numeric process, the gravity model can be sampled at any desired interval. To study the changes in span, a 5 km sampling interval was used. The gravity for various elevations were calculated both analytically and by FFT. The spans obtained from the residual maps are tabulated in Table 1. Since the gravity is practically zero at the borders of the model (Fig. 3), these differences are representative of the errors in the upward-continuation process. Table 1 indicates that even at low altitudes a 1 to 2 mGal error may occur. The residual map at h = 166 m is shown in Fig 4 with a 0.2 mGal contour interval. It is clear from this figure that the errors are not due to edge-effects but to the numerical process (ie. the finite sampling interval).

The effect of the sampling interval on the computed results were studied for three intervals (2.5, 5.0, and 10.0 km) at three elevations (0.16, 1.0 and 5.0 km). The span for each case, obtained from the residual maps, is tabulated in Table 2. As expected, the effect of grid spacing is more noticable at higher elevation, but even at low elevation the error of numerical upward-continuation is clearly a function of the sampling interval. To provide practical guidelines for the optimal sampling interval, taking into account other parameters such as the cost of acquiring additional data and errors in the input data would require much more modelling to be carried out.

DATA PREPARATION

In order to minimize the effects of leakage and wrap-around it is necessary to surround the data in the area of interest with fictitious (padding) or real data. We therefore prepared a data set by combining the Cape Flattery underwater data with a border of surface data having a width approximately equal to the dimensions of the test range. No surface data were used within the area of the test range and no underwater data were used in the border region. The composite data were then gridded at 1.5 km intervals and contoured using a standard contouring package (GPCP). The grid interval was selected as optimal and is commensurate with the spacing of the observations within the test range. The contoured field, the relationship of the test range and border area, and two profiles are indicated in Fig 5. The difference of the upward-continued field, processed with Nagy's software, and the surface field (h=0) are contoured in Figs. 6, 7, 8, and 9 for altitudes of 50, 300, 1500, and 3000 m respectively. As an independent check the data were also processed with a commercial software package known as FILTERS (anon., 1984). No significant differences within the test range were observed, but some differences in the border area were noted.

DISCUSSION OF THE RESULTS

The upward-continued data can best be discussed with the aid of the two profiles A-A and B-B shown in Fig 5. The A-A profile, analyzed with Nagy's software (Fig 10), is characterized by a gravity high towards the south and a low towards the north. The profile consequently resembles one cycle of a sine wave. As the values of gravity at either end of the profile are similar, wrap-around (edge-effect) is not pronounced. As upward-continuation is equivalent to low-pass filtering, the attenuation of the amplitude of the sine wave at increasing altitude is quite apparent. The effect of filtering the gravity high in the border area is to decrease the gravity anomaly within the range area by as much a 5 mGal. Profile B-B (Fig 11) has a steady slope from east to west with few undulations. Wrap-around is very pronounced but does not appear to penetrate the test area.

Results for profile A-A, computed using the FILTERS software is shown in Fig 12. This software imposes a restriction on the matrix size, N, such that $N = 2^m$, where m is an integer. When this condition is not met, the software automatically pads the matrix with zeros to increase its size to the next larger acceptable value of N. Edge-effects appear to be slightly reduced for this case. Profile B-B (Fig 13) also shows less edge-effect. There appear to be no other differences and both methods are consistent within the test range.

It is interesting to ask the question, "What would happen if no surface data were available outside the test area?" To answer this, we upward-continued the test range data alone (a 13 x 16 matrix) using the FILTERS software. Figs. 14 and 15 show the results for profiles A'-A' and B'-B' respectively. Wrap-around is very pronounced for these cases and persists to the center of the test area. The upward-continued values would be subject to very large errors if these results were accepted at face value. One option to deal with edge effects is to remove a surface trend (regional field), upward-continue, and replace the trend. These results (Figs. 16 and 17) indicate that there is no difference between the surface profile and any of the upward-continued profiles. This is not suprising, as removing the surface trend within the test region implies that this trend extends to infinity outside the area, which we know is not valid. In other words, all frequencies remaining in the modified truncated data were passed by the filter. It is therefore evident that differences between the profiles at various altitudes were entirely due to information existing outside the region of interest.

CONCLUSIONS

We have upward-continued the gravity field over the Cape Flattery test range at four different heights. To do so it was necessary to take into account the known gravity field outside the area of the test range. This is natural because upward-continuing is equivalent to low pass filtering and very long wave-length anomalies influence the gravity field within the area of interest. We found that we obtained satisfactory results for this particular case by considering a border of at least 12 grid-spacings (18 km) wide around the test area. To perform upward-continuation in ignorance of the surrounding gravity field is at best hazardous and at worst completely misleading.

REFERENCES

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Nagy, D. Fast Fourier transform in gravity interpretation, Acta Geodaet., Geophys. et Montanist. Acad. Sci. Hung. (in press), (Contribution of the Earth Physics Branch # 1203), 1986.

Prahl, N. A. and G. B. Mills, West coast continental shelf bottom gravity measurements Cape Flattery to Santa Cruz, 1971 NOAA ship McArthur. NOAA technical memorandum, NOS GDR-2, U.S. Dept. of Commerce, Washington, DC., January, 1974.

TABLE 1
VARIATION OF SPAN WITH HEIGHT OF UPWARD-CONTINUATION

h (km)	0.166	0.3	0.5	0.7	1.0	1.5	5.0
S (mGal)	1.23	1.89	2.50	2.79	2.92	2.76	1.02

TABLE 2
VARIATION OF SPAN WITH HEIGHT AND GRID INTERVAL

grid interval (km)	S h = 0.166 km (mGal)	S h = 1.0 km (mGal)	S h = 5.0 km (mGal)
2.5	0.81	1.52	0.75
5.0	1.23	2.92	1.02
10.0	1.43	3.81	3.32

CAPTIONS

Fig 1 Distribution of underwater gravity observations in the vicinity of the Cape Flattery test range. Scale 1:3M

Fig 2 Distribution of surface gravity observations in the vicinity of the Cape Flattery test range. Scale 1:3M

Fig 3 Gravity anomaly model at h = 0. Contour interval = 2.0 mGal; Grid interval = 5 km.

Fig 4 Residual map for the gravity model upward-continued to 166 m. Contour interval = 0.2 mGal; Grid interval = 5 km.

Fig 5 Gravity field at sea level over the Cape Flattery test range. The underwater data of the test range, located inside the square, is surrounded by a border of surface data. Two profiles A-A and B-B are located. The indicated points are not actual observations but rather the grid points to which the data were interpolated. Contour interval = 2 mGal; Grid interval = 1.5 km.

Fig 6 Residual gravity field at an altitde of 50 m. (h=50 minus h=0). Contour interval = 0.2 mGal; Grid interval = 1.5 km.

Fig 7 Residual gravity field at an altitude of 300 m. Contour interval = 1.0 mGal; Grid interval = 1.5 km.

Fig 8 Residual gravity field at an altitude of 1500 m. Contour interval = 2.0 mGal; Grid interval = 1.5 km.

Fig 9 Residual gravity field at an altitude of 3000 m. Contour interval = 2.0 mGal; Grid interval = 1.5 km.

Fig 10 Profile A-A as analysed with Nagy's software.

Fig 11 Profile B-B as analysed with Nagy's software.

Fig 12 Profile A-A as analysed with FILTERS.

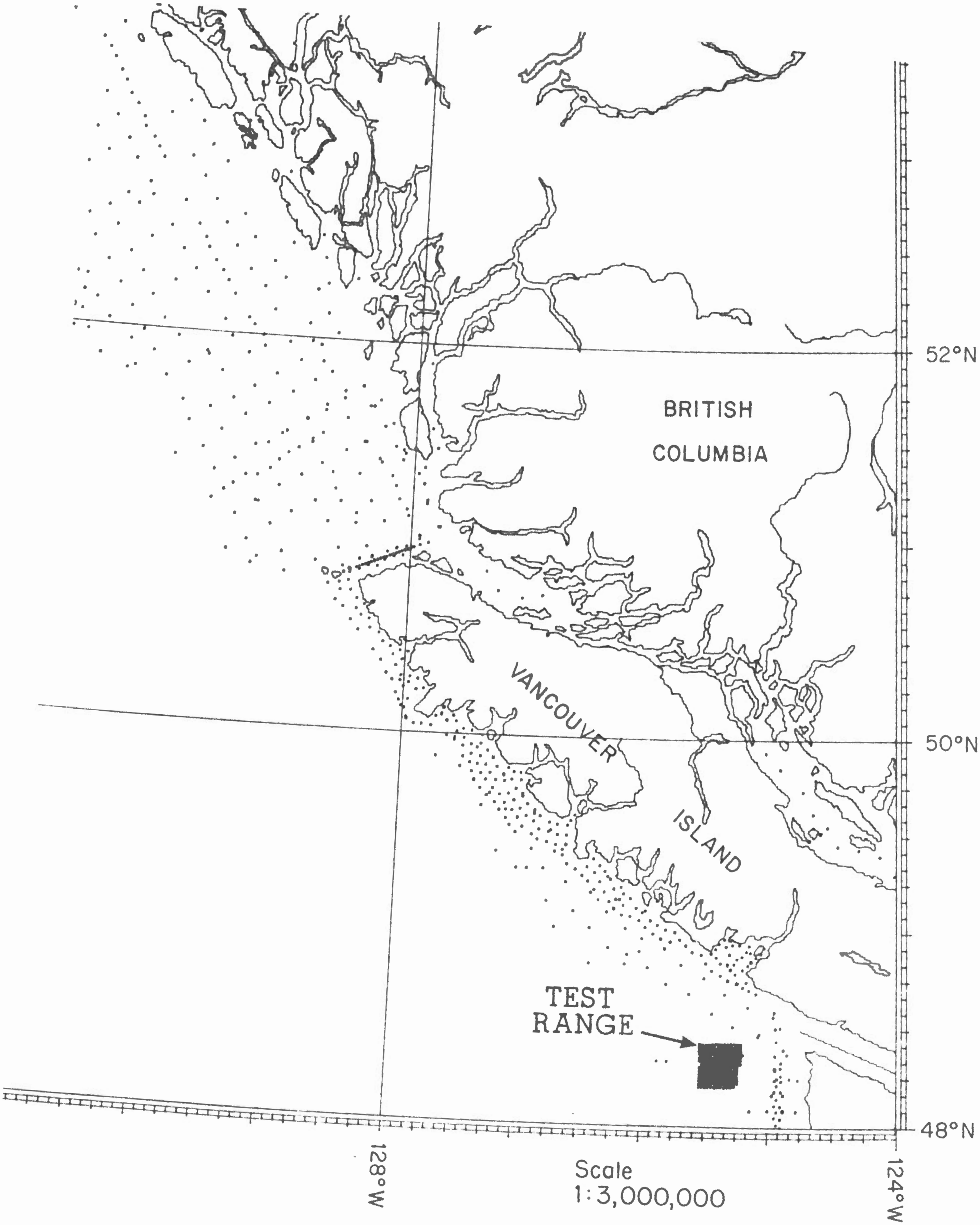
Fig 13 Profile B-B as analysed with FILTERS.

Fig 14 Profile A'-A' as analysed with FILTERS using test range data only.

Fig 15 Profile B'-B' as analysed with FILTERS using test range data only.

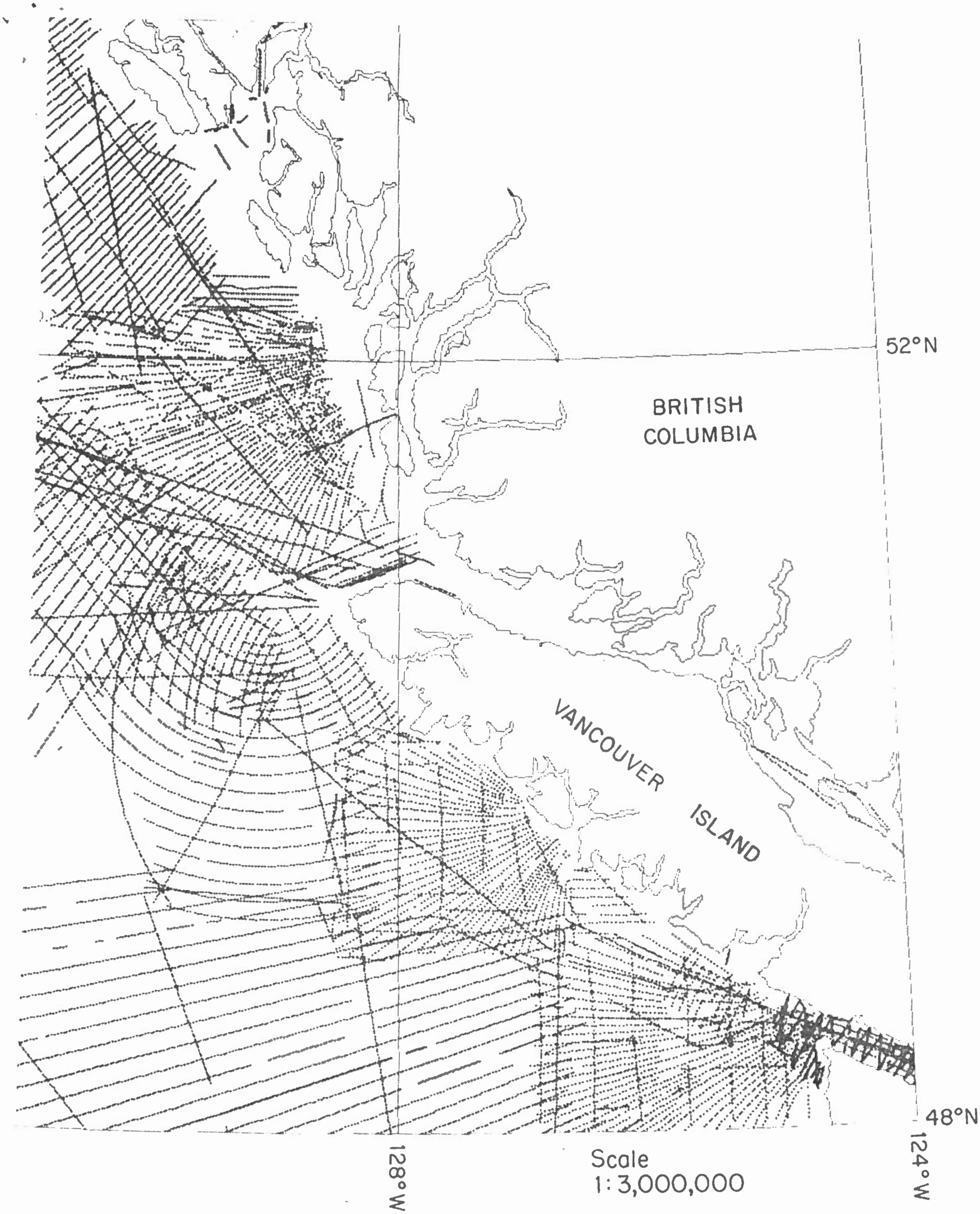
Fig 16 Profile A'-A' as analysed with FILTERS by removing and replacing a regional trend.

Fig 17 Profile B'-B' as analysed with FILTERS by removing and replacing a regional trend.



52°N
BRITISH
COLUMBIA
VANCOUVER
ISLAND
50°N
TEST
RANGE
48°N
128°W
Scale
1:3,000,000
124°W

Fig. 1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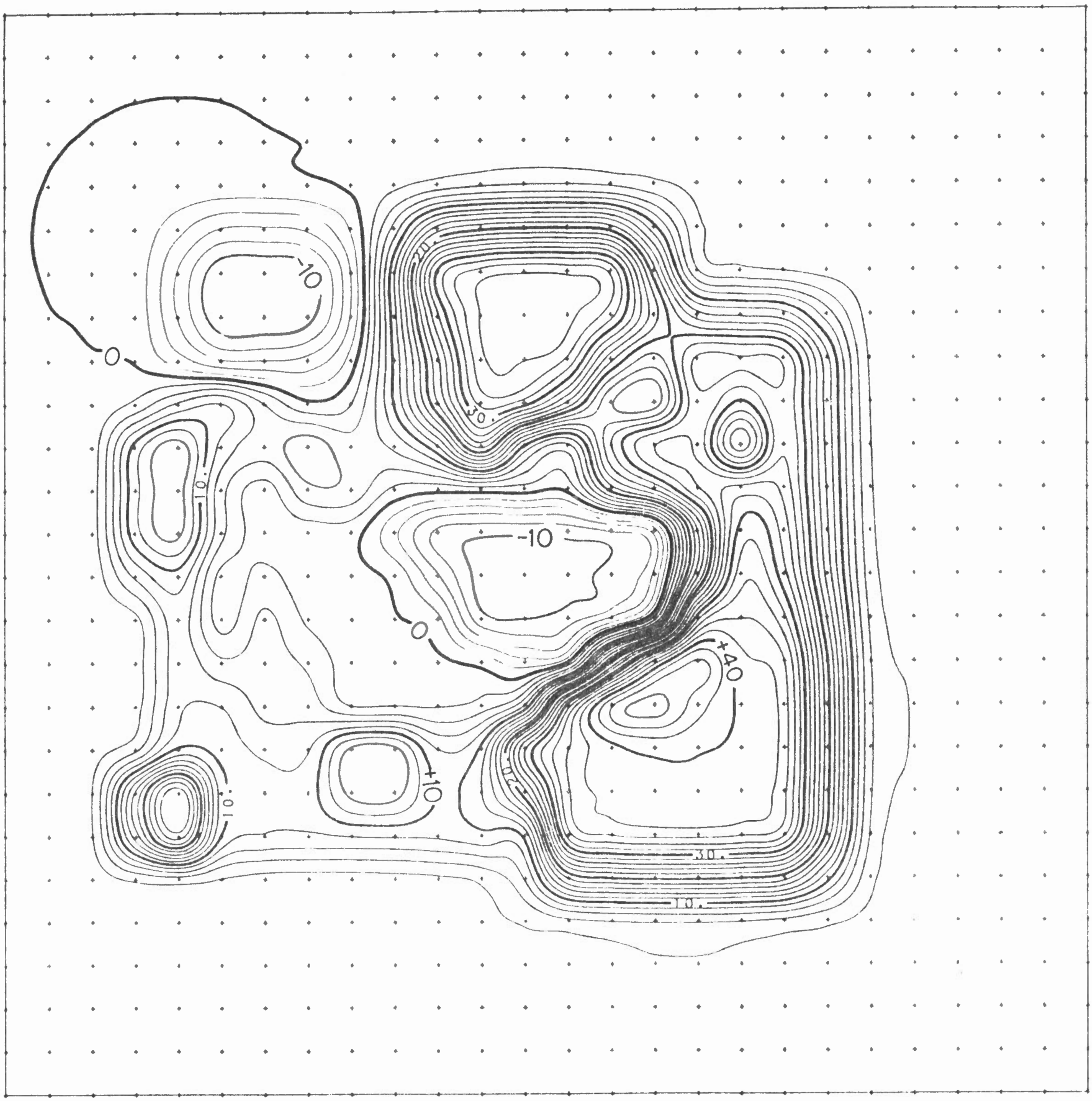
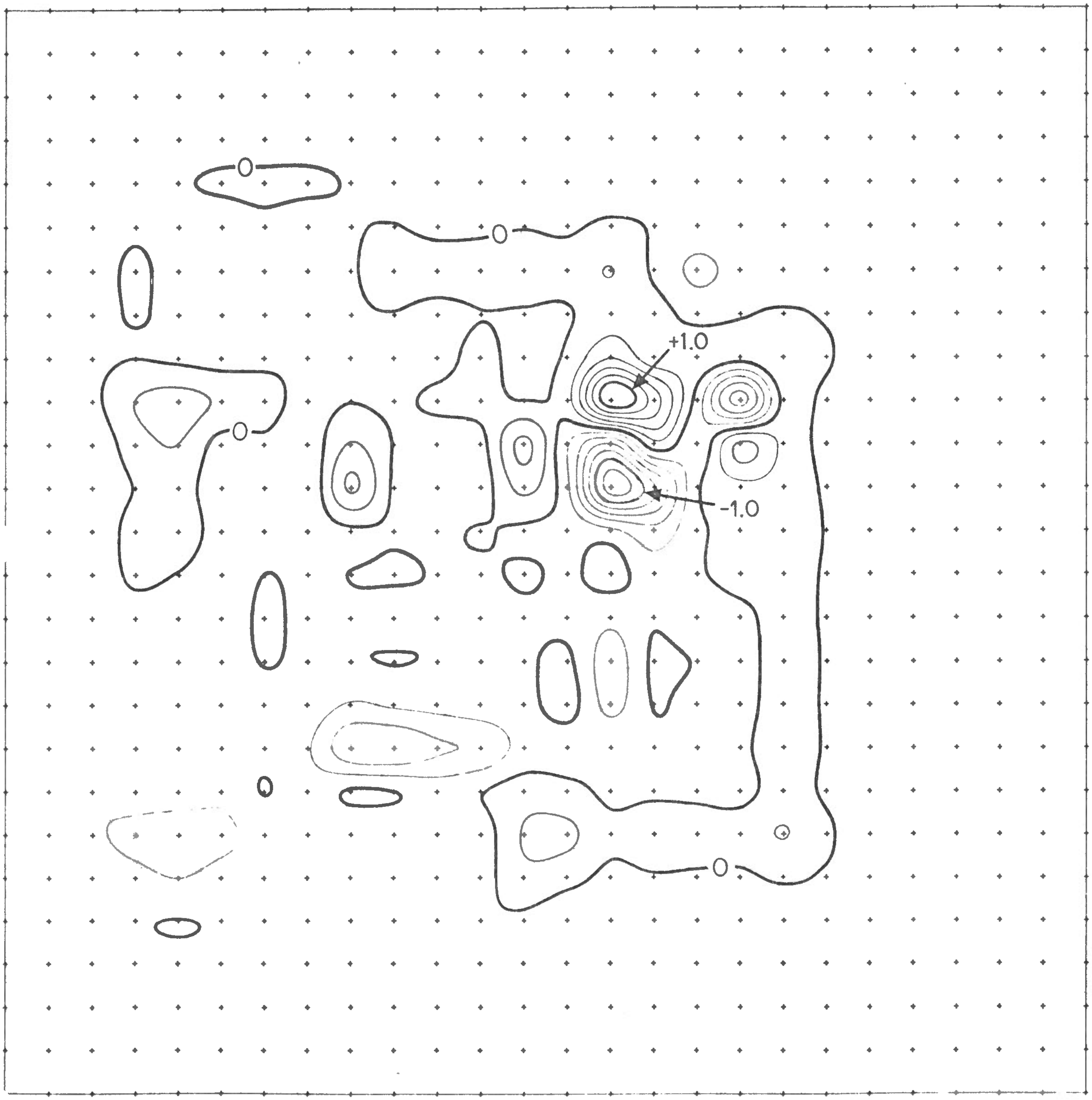
48°N
128°W
124°W
Scale
1: 3,000,000

Fig. 2



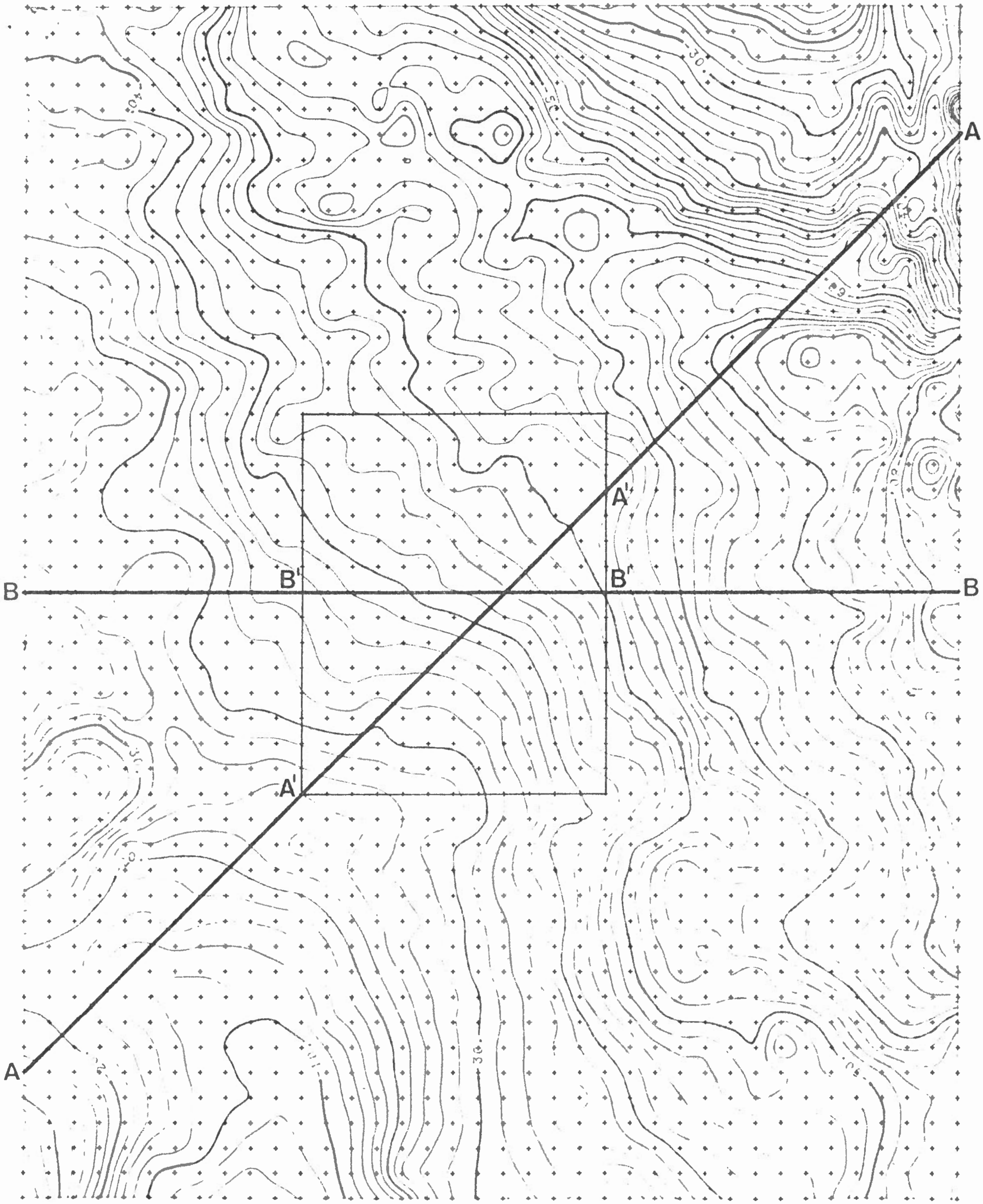
Contour interval 2.0mGal

Fig. 3



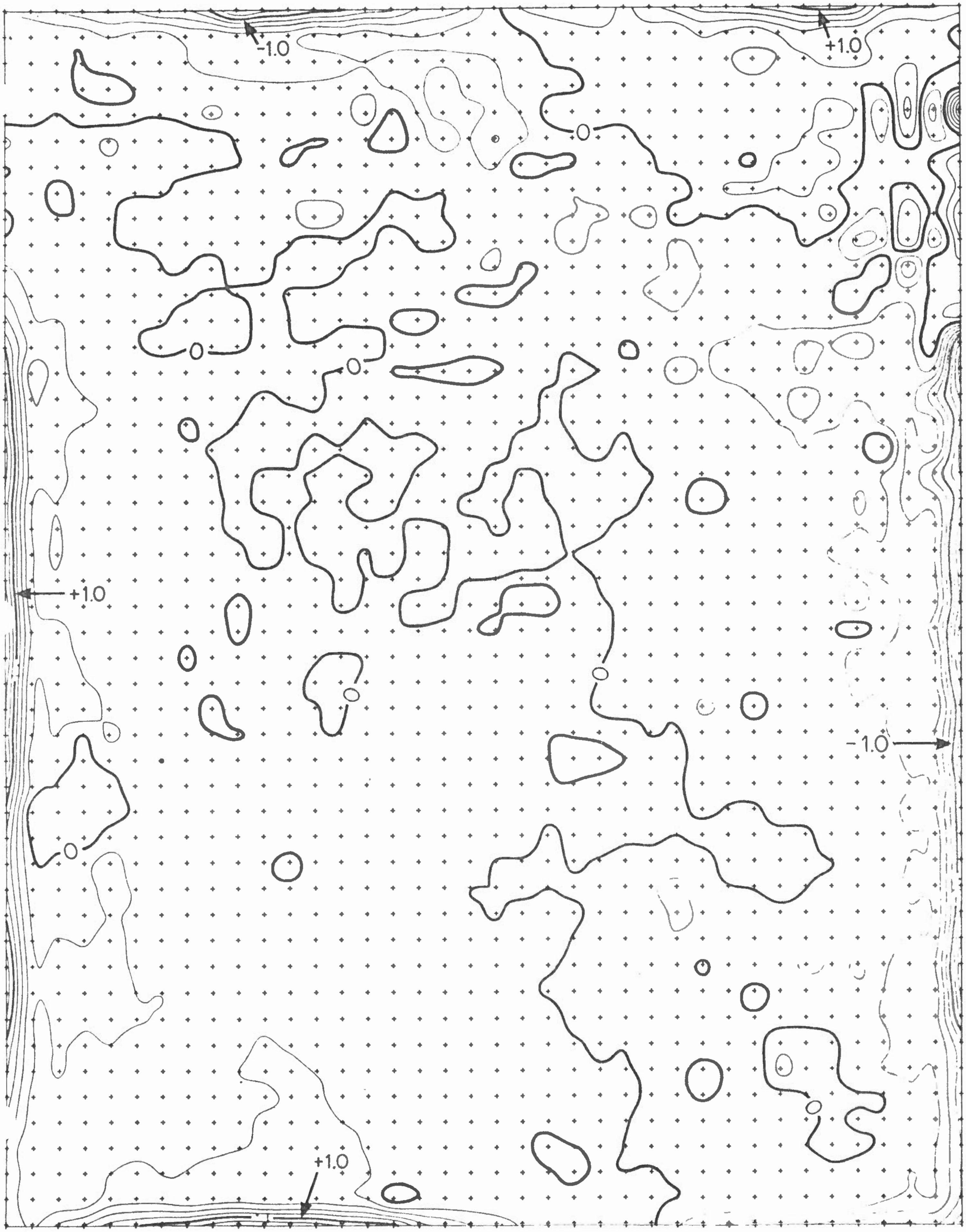
Contour interval 0.2mGal

Fig. 4



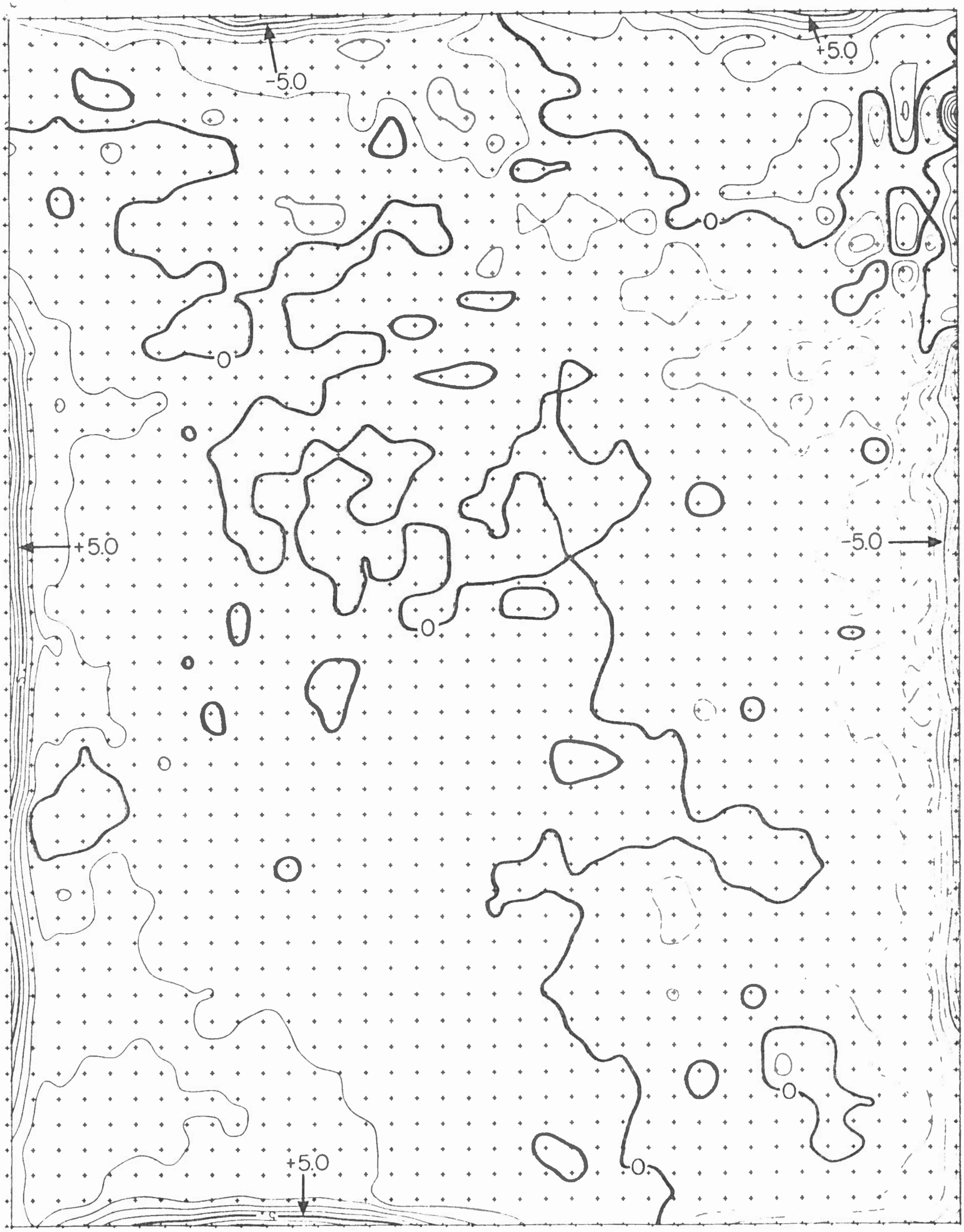
Contour interval – 2.0 mGal

Fig. 5



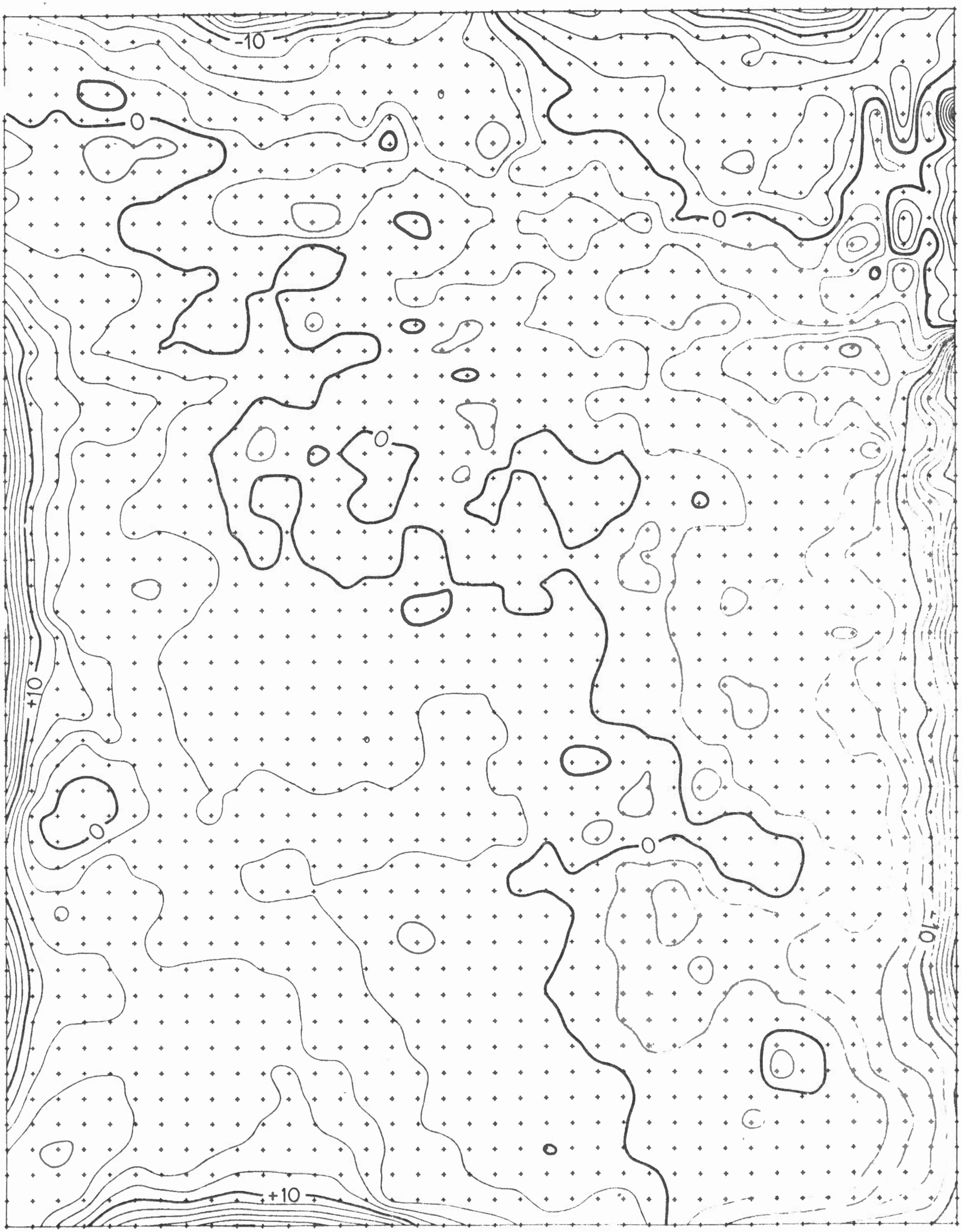
Contour interval 0.2 mGal

Fig 6



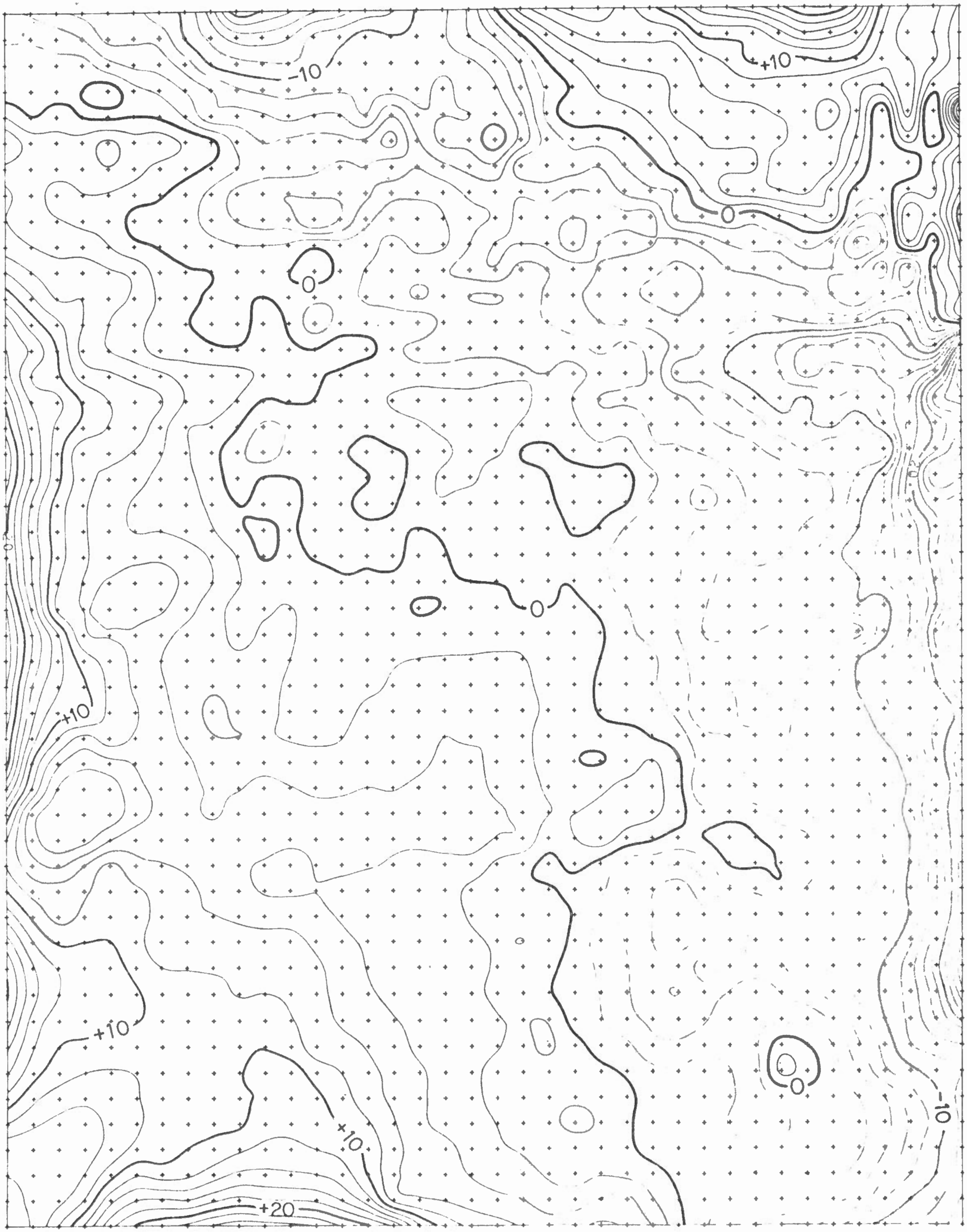
Contour interval 1.0 mGal

Fig. 7



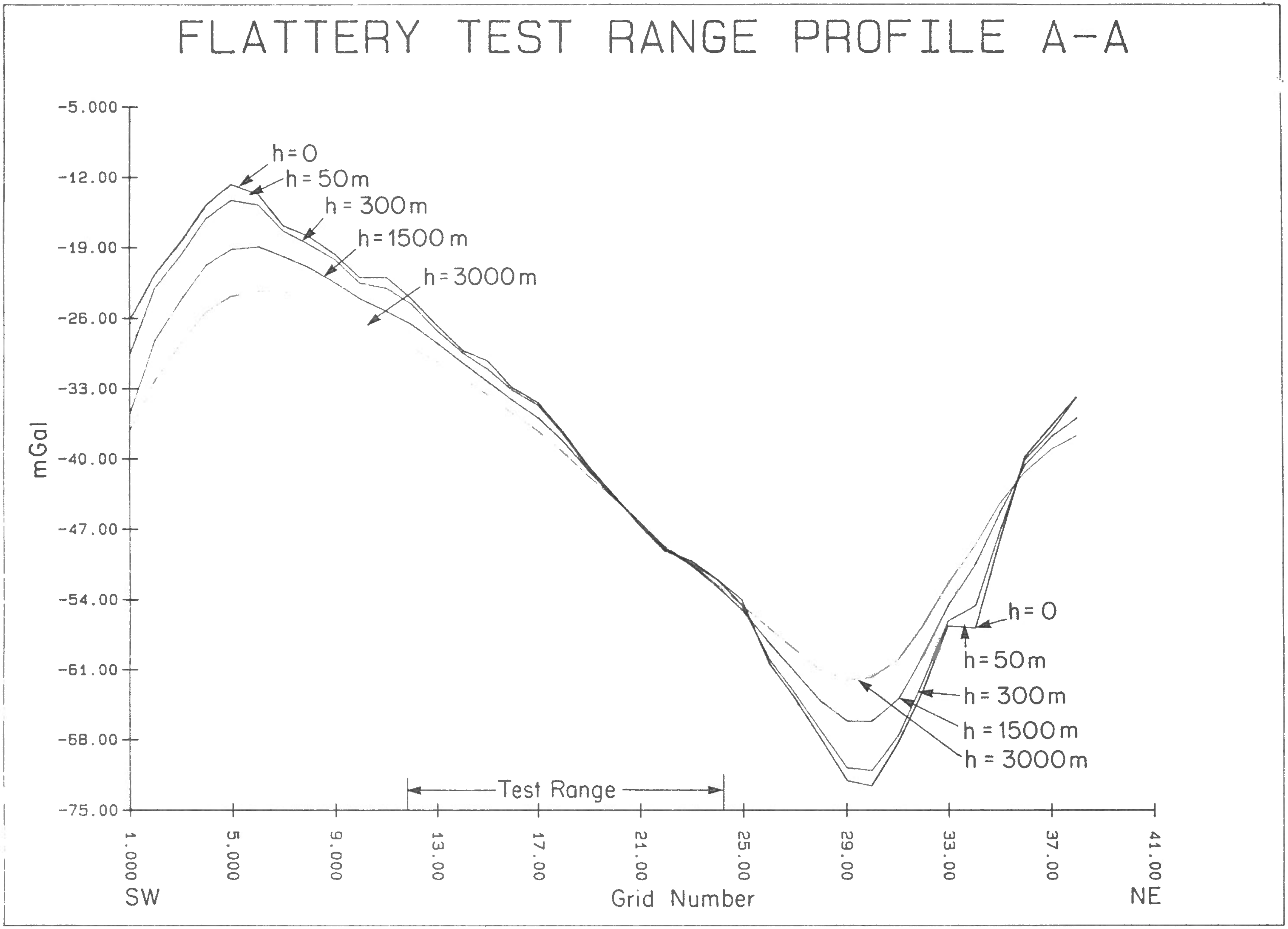
Contour interval 2.0 mGal

Fig. 8



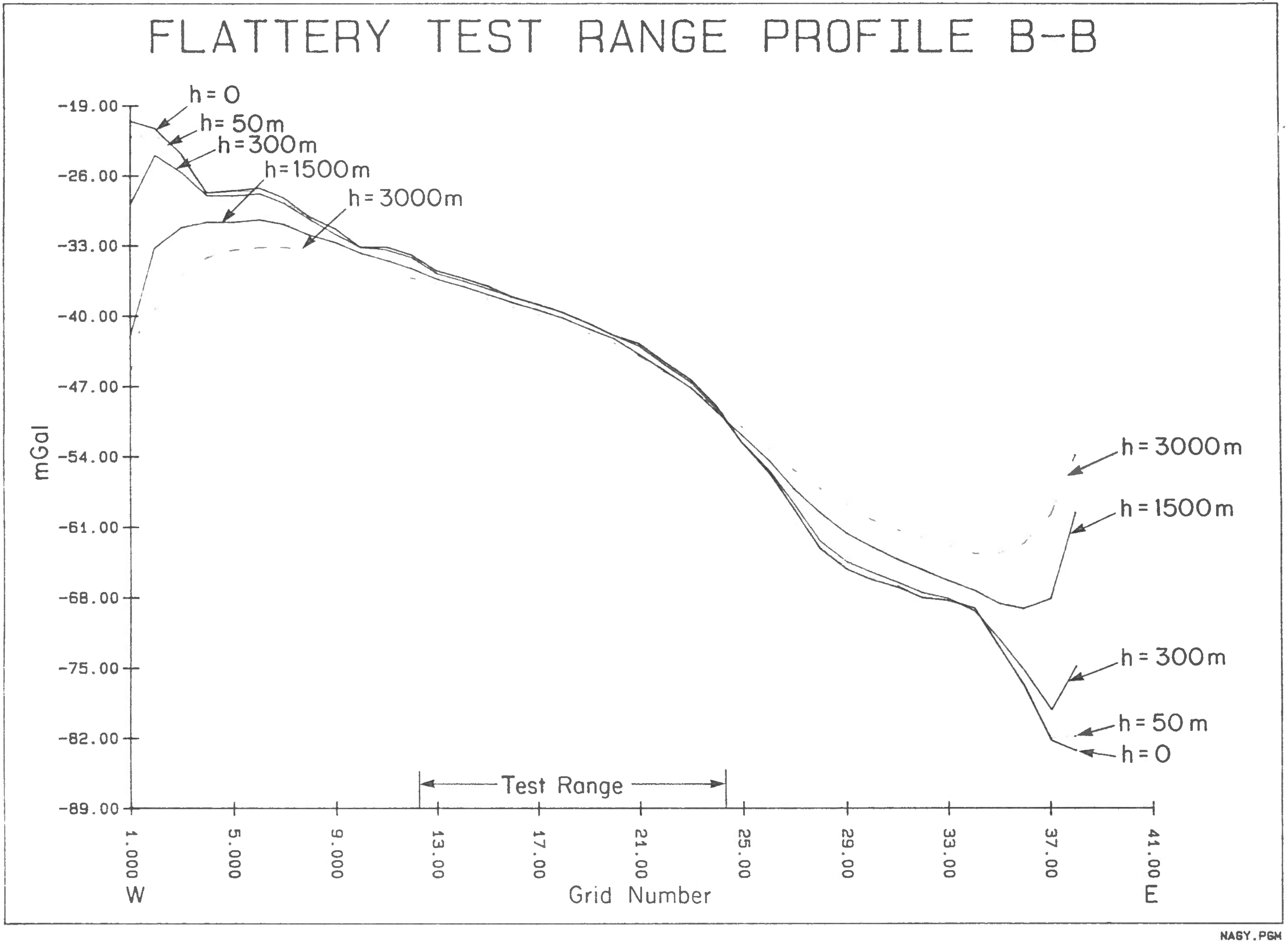
Contour interval 2.0 mGal

Fig. 9



NAGY.PRG

Fig. 10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h = 300m
h = 1500m
h = 3000m
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-33.00
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-47.00
-54.00
-61.00
-68.00
-75.00
-82.00
-89.00
mGal
Test Range
1.000
5.000
9.000
13.00
17.00
21.00
25.00
29.00
33.00
37.00
41.00
W
Grid Number
E
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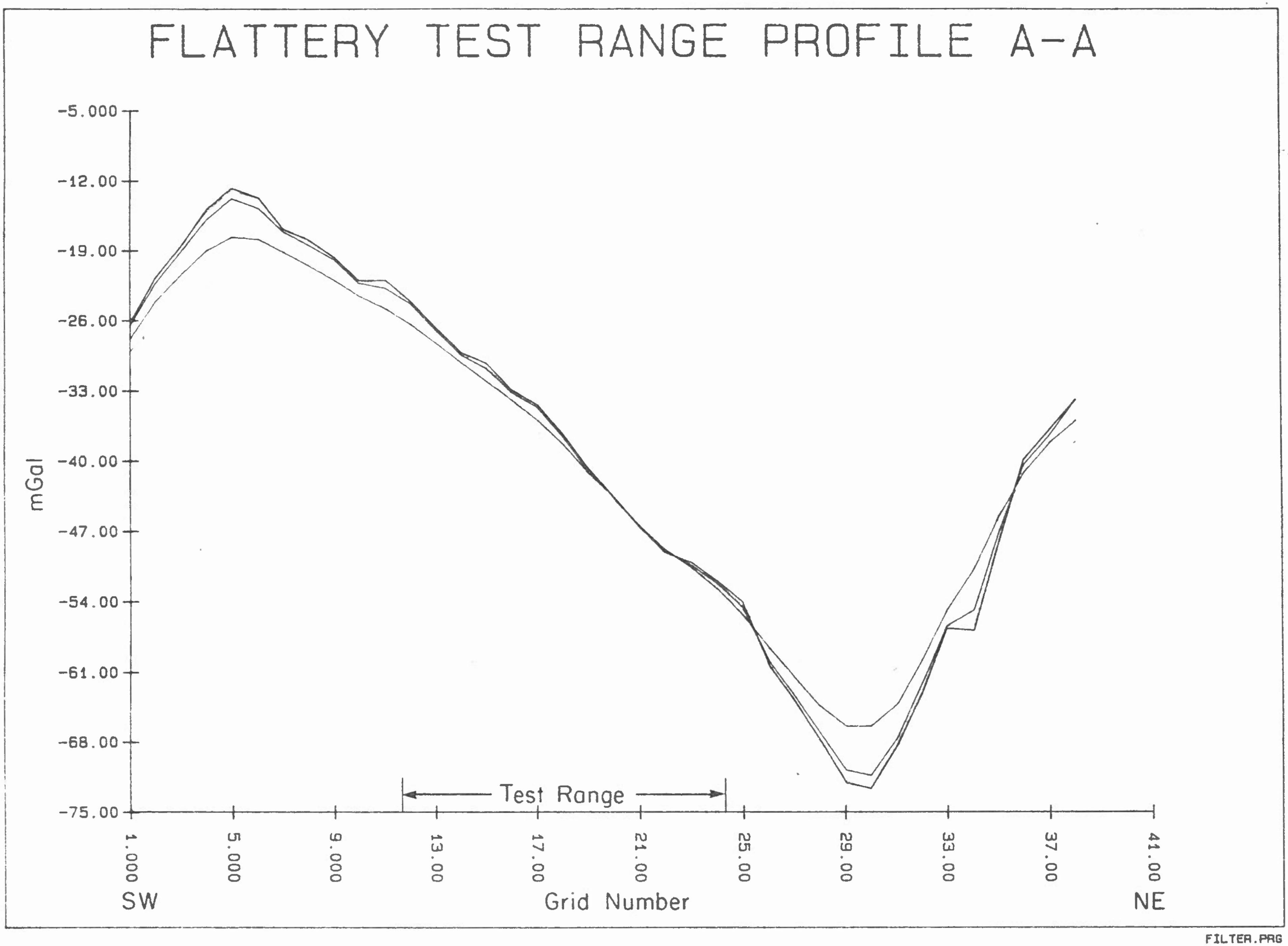
h = 1500m
h = 300m
h = 50 m
h = 0
NAGY.PGM

Fig. 11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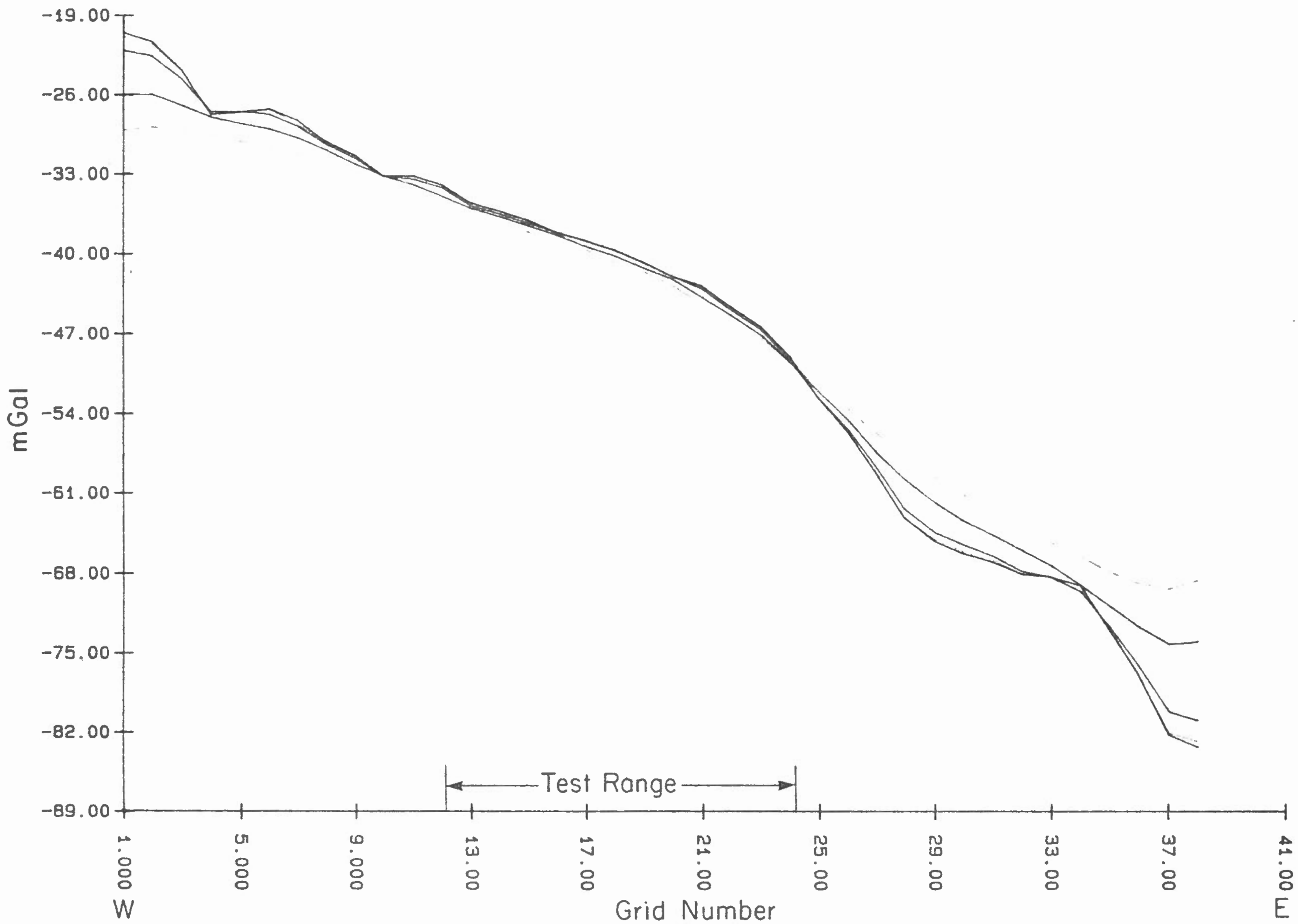
mGal
Test Range
1.000
5.000
9.000
13.00
17.00
21.00
25.00
29.00
33.00
37.00
41.00
SW
Grid Number
NE
FILTER.PRG

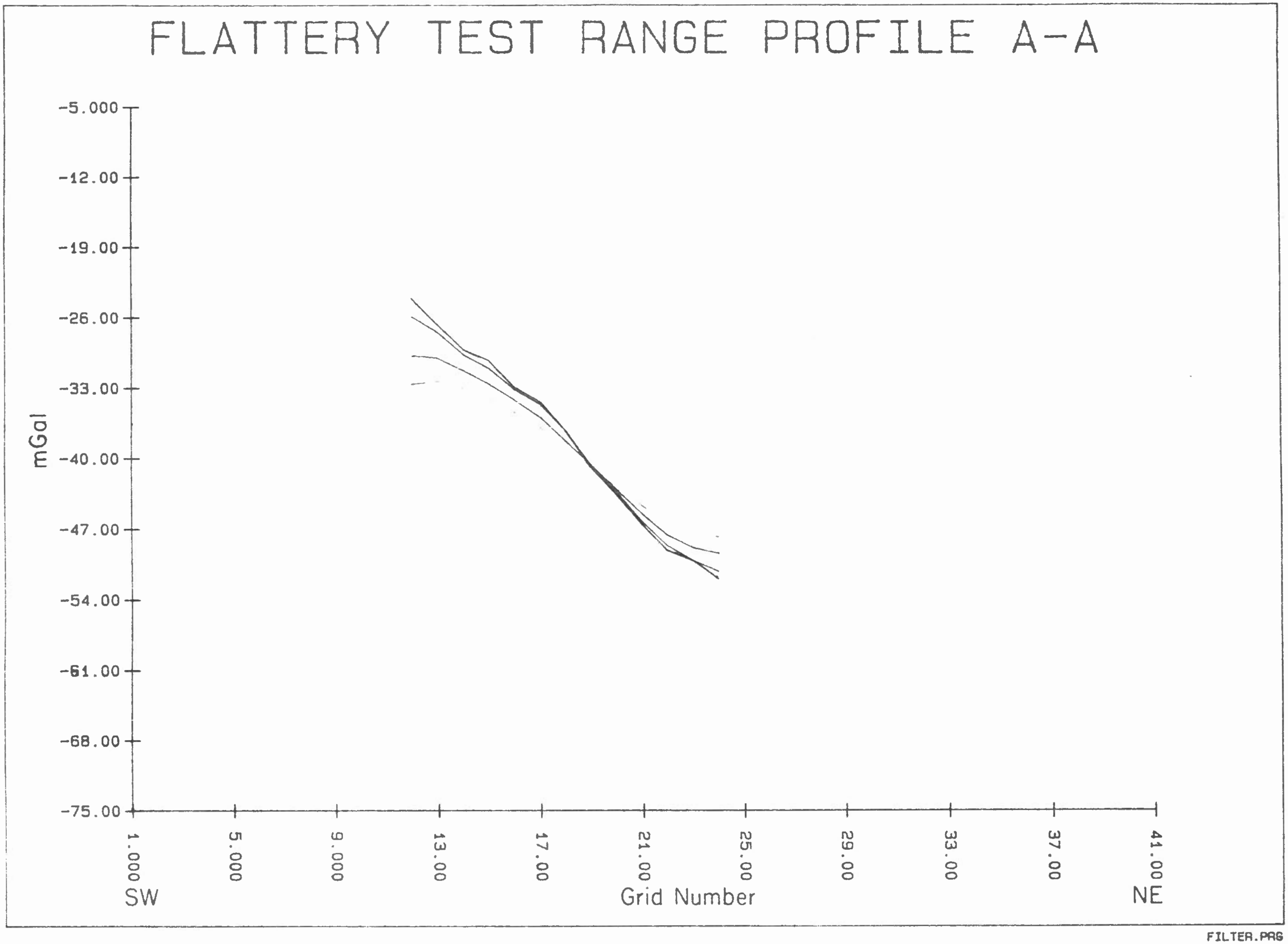
Fig. 12

FLATTERY TEST RANGE PROFILE B-B



FILTER.PRG

Fig. 13


FLATTERY TEST RANGE PROFILE A-A
mGal
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-33.00
-40.00
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-68.00
-75.00
1.000
5.000
9.000
13.00
17.00
21.00
25.00
29.00
33.00
37.00
41.00
SW
Grid Number
NE
FILTER.PRG

Fig.14

FLATTERY TEST RANGE PROFILE B-B

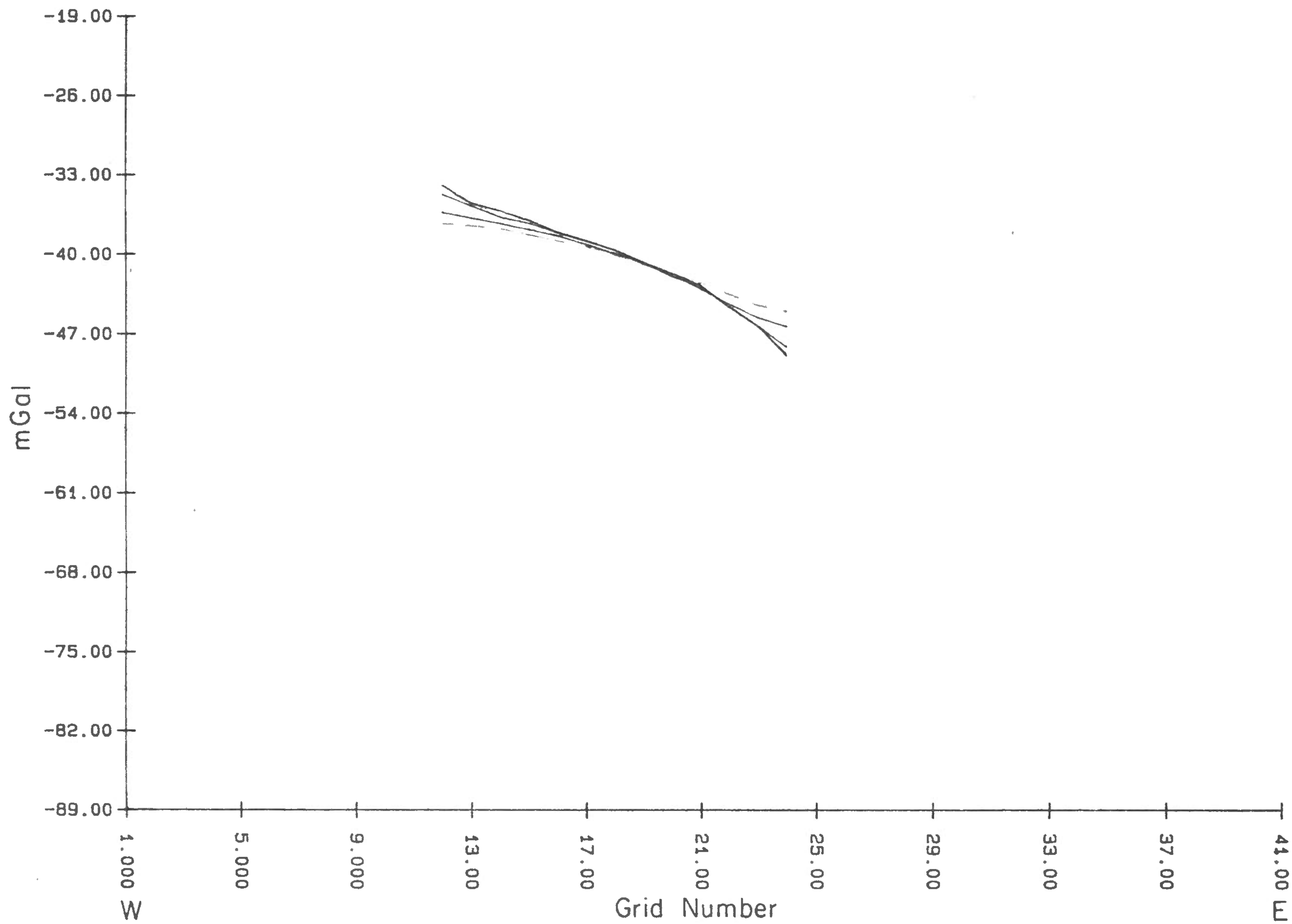
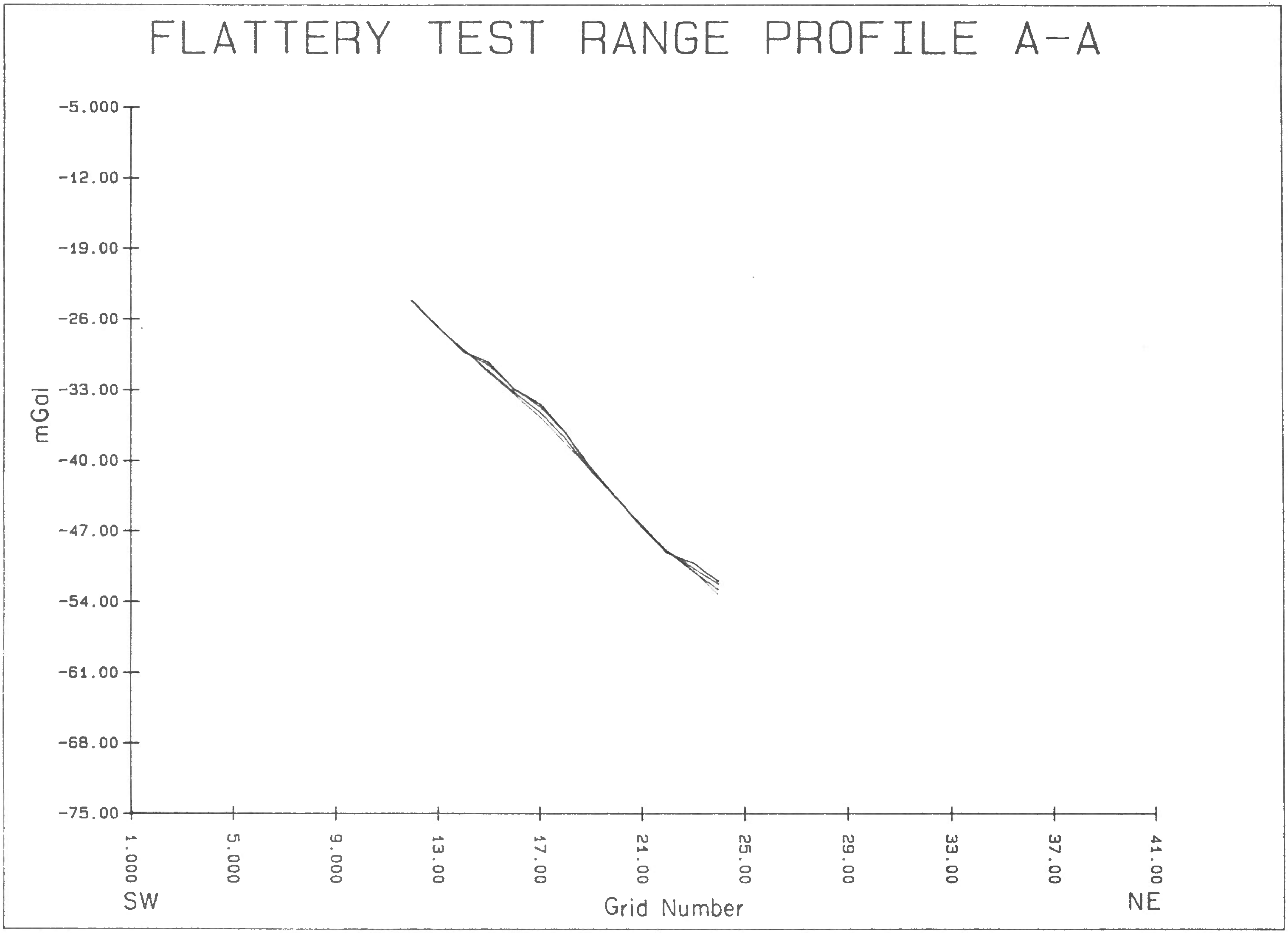


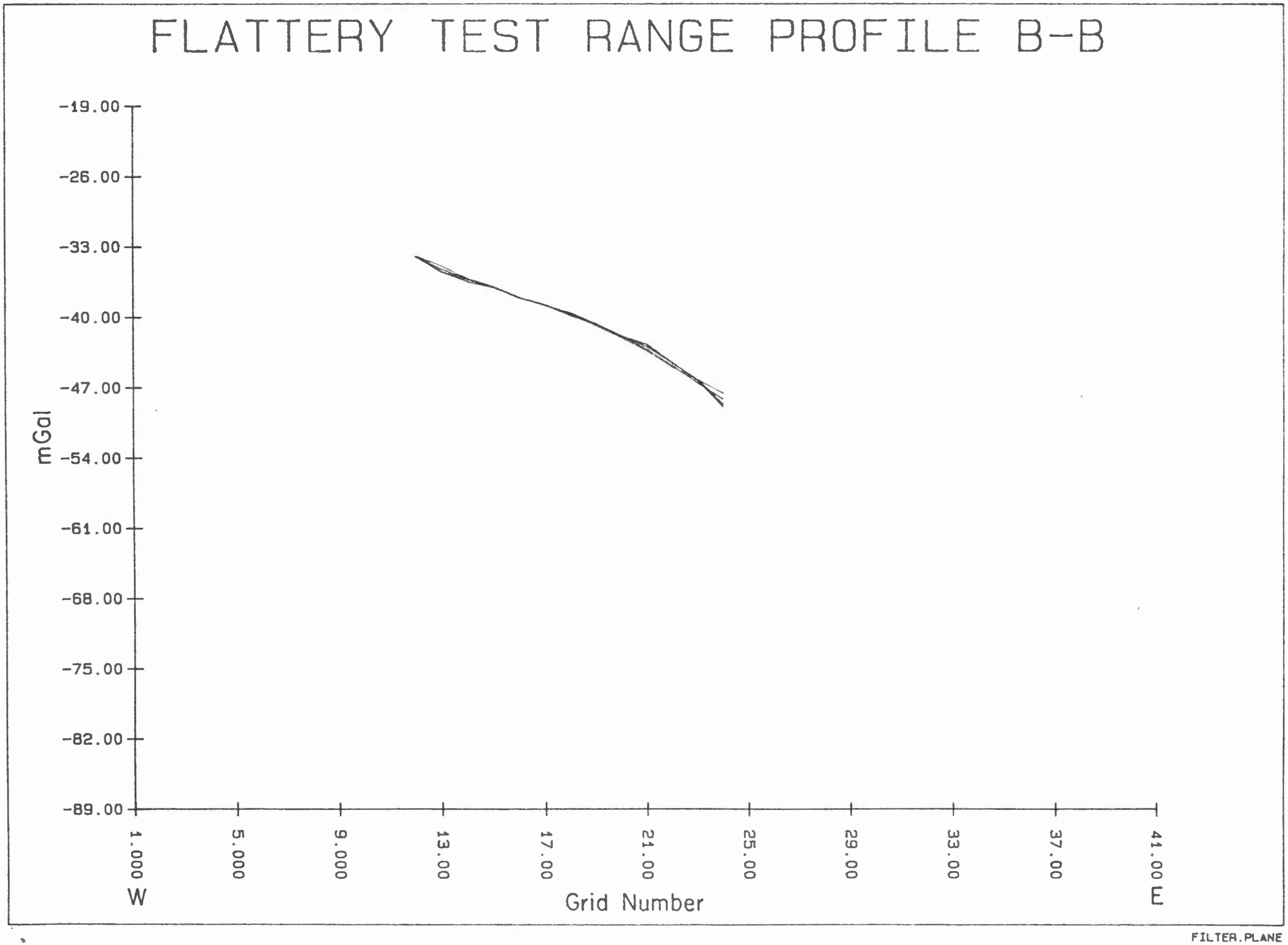
Fig.15

FILTER.PRG



FILTER.PLANE

Fig. 16



FLATTERY TEST RANGE PROFILE B-B
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-33.00
-40.00
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-61.00
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-82.00
-89.00
mGal
1.000
5.000
9.000
13.00
17.00
21.00
25.00
29.00
33.00
37.00
41.00
W
Grid Number
E
FILTER.PLANE

Fig. 17