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AN INVESTIGATION OF GRIDDING SPECIFICATIONS FOR A NEW HOMOGENEOUS AEROMAGNETIC GRID OF CANADA

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INTRODUCTION

In 1977, the Geological Survey of Canada initiated a project to produced coloured magnetic anomaly maps of Canada at the scale of 1:1,000,000. An additional objective was the creation of an aeromagnetic digital database. Line data were obtained by digitizing contour intercepts along flight lines on previously published 1:50,000 scale or 1 inch: 1 mile aeromagnetic maps. This database was subsequently gridded at an interval of 812m to produce the coloured anomaly maps. The database was intended to be used to produce maps at scales ranging from 1:250,000 to 1:5,000,000. The compilation techniques have been discussed by Dods et al. (1985), but nevertheless, the most important steps are summarized below:

-Digitization of contour intercepts.

-Subtraction of the Definitive Geomagnetic Reference Field for the year of the survey.

-Gridding, with an inverse distance weighted average technique at an interval of 812m.

-Surveys not flown at the nominal altitude of 300m were continued to that altitude.

-Adjustment of survey boundaries.

The development of microcomputer technology and the availability of efficient geophysical and image processing software now makes it increasingly desirable for the individual user to process and interpret digital aeromagnetic data. Thus, the existing digital aeromagnetic database will likely be used to produce maps at scales of 1:50,000 or greater. As it was not designed originally to be used at such fine scales, small digitising errors that could not be detected at large scales will be apparent at small scales and will have to be corrected. Moreover, new imaging techniques (e.g. shadow maps) are very sensitive to any mismatch at the inter-survey boundaries and much finer adjustments than the one that were made for the 1:1,000,000 aeromagnetic colour maps of Canada will be required.

A fine grid of digital data will have to be created to facilitate the correction of the flight line data and the inter-survey adjustment. The reference datum for the survey adjustment should be the existing 1:1,000,000 aeromagnetic maps of Canada. The end result will a homogeneous data base of flight line data and a gridded data set. Subsequent regridding of the flight line data at any interval is then a straightforward process.

It is, therefore, necessary to define new gridding criteria based on the available digitised data and their intended use. The most crucial point is the selection of a gridding interval. In practice, the optimum interval should be as large as possible to reduce computation time and storage space, and small enough to retain maximum information from the profile data.

DETERMINATION OF A GRIDDING INTERVAL

Statistical approach

To determine an optimum gridding interval, we first follow the approach suggested by Reid (1980) to minimise the aliased power fraction of the aeromagnetic energy spectrum. An ensemble of blocks is then used as a model for a statistical estimation of the aliasing effect, and the point magnetic pole as a model for the aliasing of isolated sources. The later model generates the sharpest likely magnetic anomaly.

When an ensemble of magnetised blocks is considered, it can be shown that the aliased power fraction, F_t, is given by:

$$F_t = \exp(-2\pi h/\Delta x),$$

where h= mean value of the elevation difference between the top surface of the magnetic blocks and the sensor,

and Δx= sampling interval.

For the case of an isolated pole the aliased power spectrum is:

$$F_t = [2(\pi h/\Delta x)^2 + 2\pi h\Delta x+1] \exp(-2\pi h/\Delta x).$$

The aliased power fraction has been calculated for different sampling intervals or gridding intervals. A flight line spacing of 800m and a flight altitude of 300m was assumed. The results are as follows

Sampling (m) interval	Aliased power fraction (%)	
	Blocks	Isolated pole
150	0.0003	0.03
200	0.008	0.50
250	0.05	2.0
800	9.5	63.

The 800m sampling interval approximates to the average flight line spacing and is used as a worst case, since surveys are usually flown perpendicular to the general geological strike. Parallel or subparallel structures nevertheless exist and they are likely to have been undersampled by the survey. Gridding programs generally give the best results when the ratio of the line spacing to the gridding interval is 5 or less. For a line spacing of 800m this suggests a gridding interval of 200m or less. In practice one should also consider the amount of high frequency information present in the line data. The analysis of the aliased power fraction for different grid sizes indicates that, for an isolated pole, it is 0.5% for a griding interval of 200m, and 2% for 250m. Although the isolated pole model exemplifies the worst possible case, it is, nevertheless, an good indicator of what the limitations are. These results indicate that the grid spacing should not be greater than 200m to avoid undersampling the information in the profile data.

Spectral Analysis

A second way to study this problem is by using spectral analysis. A few profiles were extracted from the Geological Survey of Canada database and their spectra calculated by standard techniques. One of these profiles is shown in Figure 1. Linear trends were removed and a Hanning window used to taper the data. A typical spectrum is illustrated in Figure 2. The power spectrum decays regularly and then flattens out at the noise level. This is attained at a frequency corresponding to a sampling interval of 125m suggesting that a gridding interval of 125m is adequate.

Gridding and contouring actual data

To validate the above conclusion, line data from two maps were extracted from the Geological survey of Canada database. One of them (NTS-42F2) is from a magnetically active area while the other one (NTS-42N13) is from a quieter area. The maps were gridded with gridding intervals of 100m, 125m, 150m, 200m and 250m, and contoured at the scale of 1:50,000. These maps can be analyzed either qualitatively or quantitatively. The principal qualitative difference is basically aesthetic: maps with a smaller gridding interval look better than the others. A larger gridding interval results in a smoother surface, as not all the data along the flight lines are included into the gridding process. This is easily seen when comparing Figures 3a and b.

Differences of about 20nT are observed over some magnetic highs and lows (Fig.3) when maps with gridding intervals of 125m and 200m are compared. This is for an anomaly amplitude of about 500nT. This is of little consequence for a qualitative interpretation and only a minor problem for quantitative interpretation. Larger differences are to be expected where the anomaly amplitudes are larger.

Profile data were also interpolated at various intervals to help visualize the effect of different gridding intervals. This corresponds to the first step of the line gridding method used by most aeromagnetic contouring software. In this method, data are first interpolated along the measured profile at grid intercepts, then interpolated across the flight lines to produce the grid. Other methods exist, but this one is one of the most efficient. A typical digitized profile is illustrated in Fig.1. It was interpolated at intervals of 125m and 200m using the program published by Akima (1974), which uses a modified cubic spline. An enlarged section of this profile is shown in Fig.4. Interpolated points are joined by straight line segments to emphasize the discrepancies between these points and the data points. When the interpolation interval is 200m, differences as high as 20nT are observed. They are only a few nT for an interval of 125m.

The original maps were not digitized at a constant interval (Dods et al, 1985). For this specific line (Fig. 1) the spacing between the digitized points varies from 76m to 1007m, averaging about 335m. From that perspective, the interpolation interval should be about the same as the smallest spacing in order to fully recover the digitized data.

Gridding method

Various gridding methods exist and line gridding, although widely used for aeromagnetic data processing, is only one of them. The choice of the gridding method is based on the nature of the data, computing cost and even personal preferences. Whatever method is used, it should satisfy some well defined criteria, such as:

-The contour line should honour the data points.

-The continuity between flight lines should be smooth and the gridding should not induce unrealistic trends.

-The gridding should not generate anomalies (isolated highs or lows) between the flight lines.

-It should give aesthetically good results.

Line gridding is the most widely used method for gridding aeromagnetic data for it satisfies the above criteria and is computationnally efficient.

Another gridding method that gives excellent results is the minimum curvature method (Briggs, 1974). It minimises the curvature of a surface that honours the data points. However the equations must be solved iteratively resulting in higher computing cost. It has the capability of simultaneously gridding surveys with different flight line orientations; thus, solving the problem of obtaining a smooth join between survey areas. Also, it generally gives better results for anomalies oblique to the flight lines. A fast code has been published by Webring (1981). Tests, however, have shown that the method is, on average, seven times slower than the line gridding method. In many cases this disadvantage in time and cost is offset by the advantages: easy gridding of surveys with different flight line orientation, better results for anomalies oblique to the flight lines.

CONCLUSIONS

Statistical and spectral analysis methods can only be used as indicators of the overall quality of calculated grids. From the profile interpolation and the gridding and contouring of real data it is estimated that the best gridding interval is 125m. By choosing this interval we can be sure that the data will not be degraded by the gridding procedure. However, if one accepts some loss in the resolution of small features to minimise computation time, a gridding interval of 200m could be acceptable. This is an upper limit, since above that the data would definitely be aliased. The most important outcome from this project, apart from the homogeneous aeromagnetic grid of Canada, will be the availability of a data base of flight line data that can be used for subsequent processing at any scale.

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Reid, A., B., Aeromagnetic survey design, Geophysics, **45**, 973-976.

Webring M., 1981, MINC: A gridding program based on minimum curvature, U.S.G.S. Open file report 81-1224.

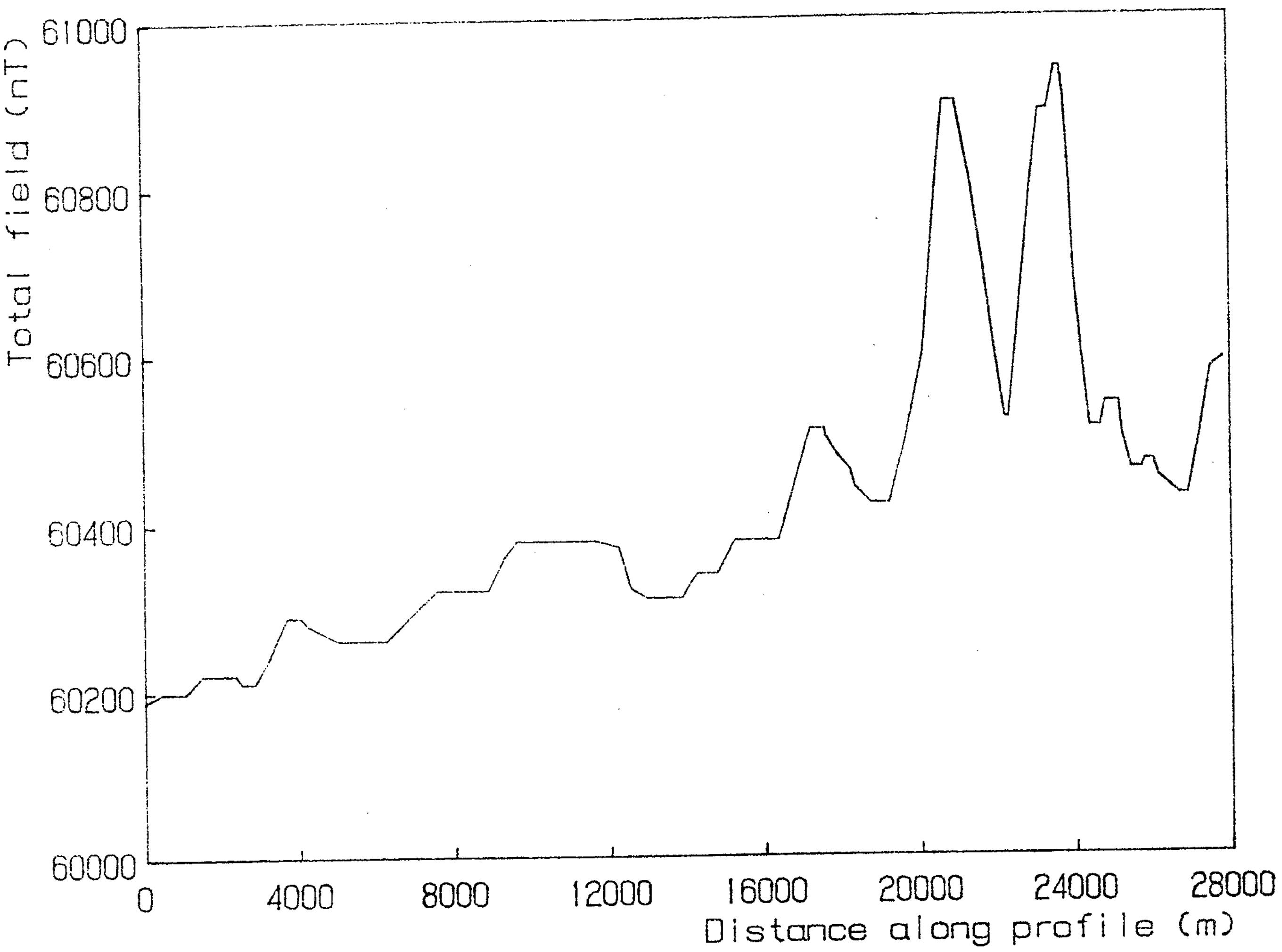

Figure 1. Typical digitised magnetic profile from the total field magnetic map of NTS-42F2.

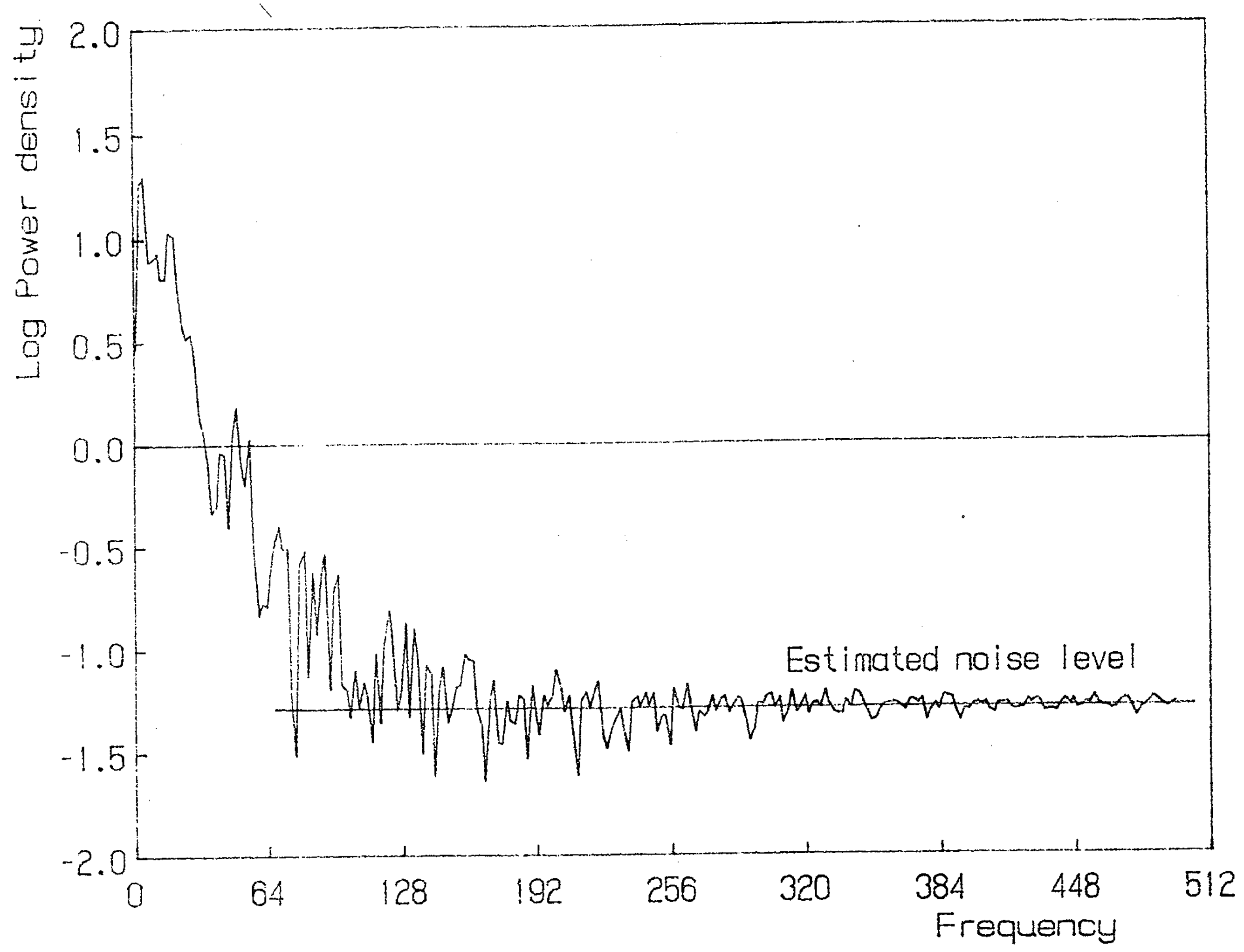

Figure 2. Power energy spectrum of the profile of Figure 1.

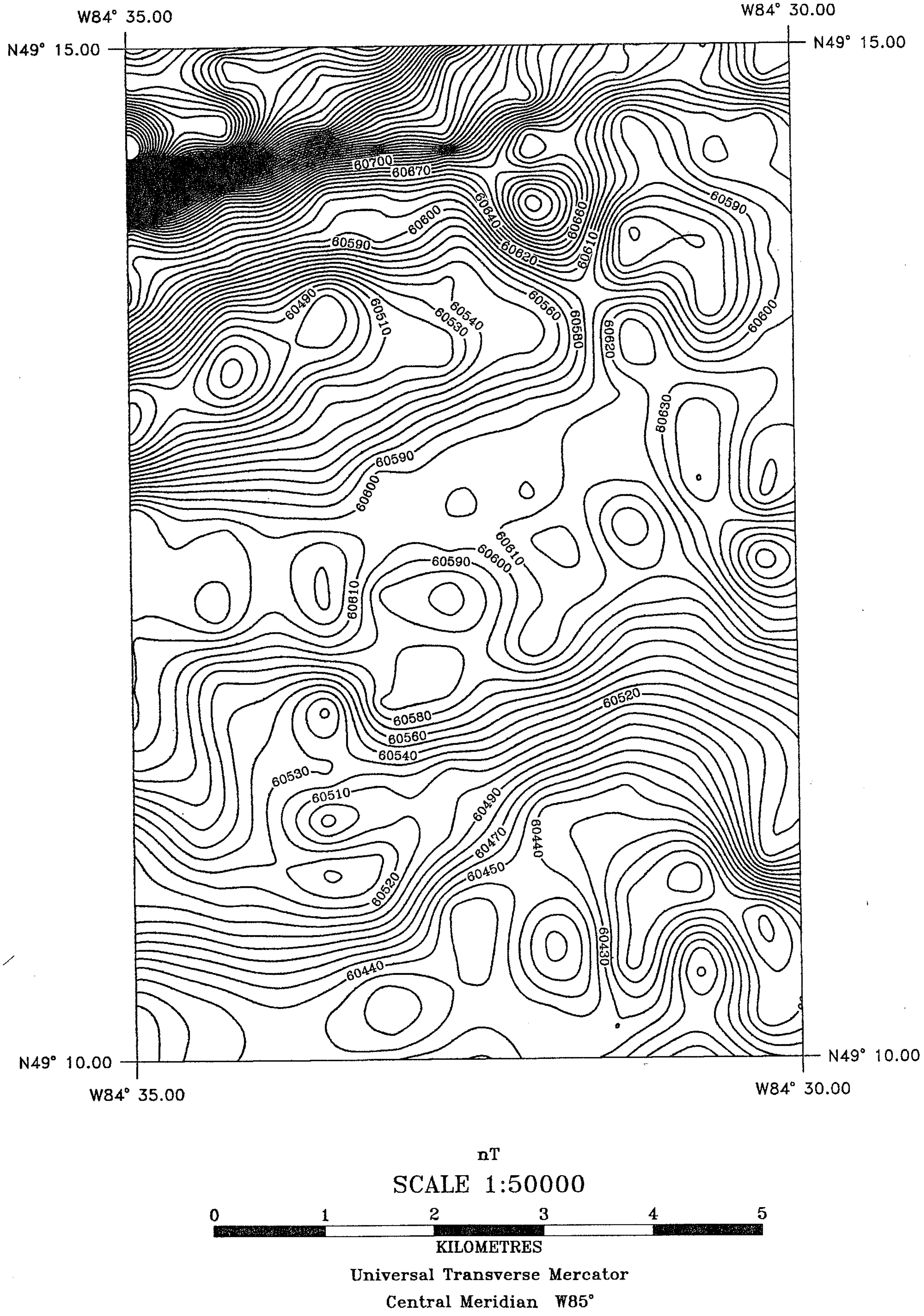

Figure 3a. Contour map of a portion of the digitised data from NTS-42F2 gridded at an interval of 125m.

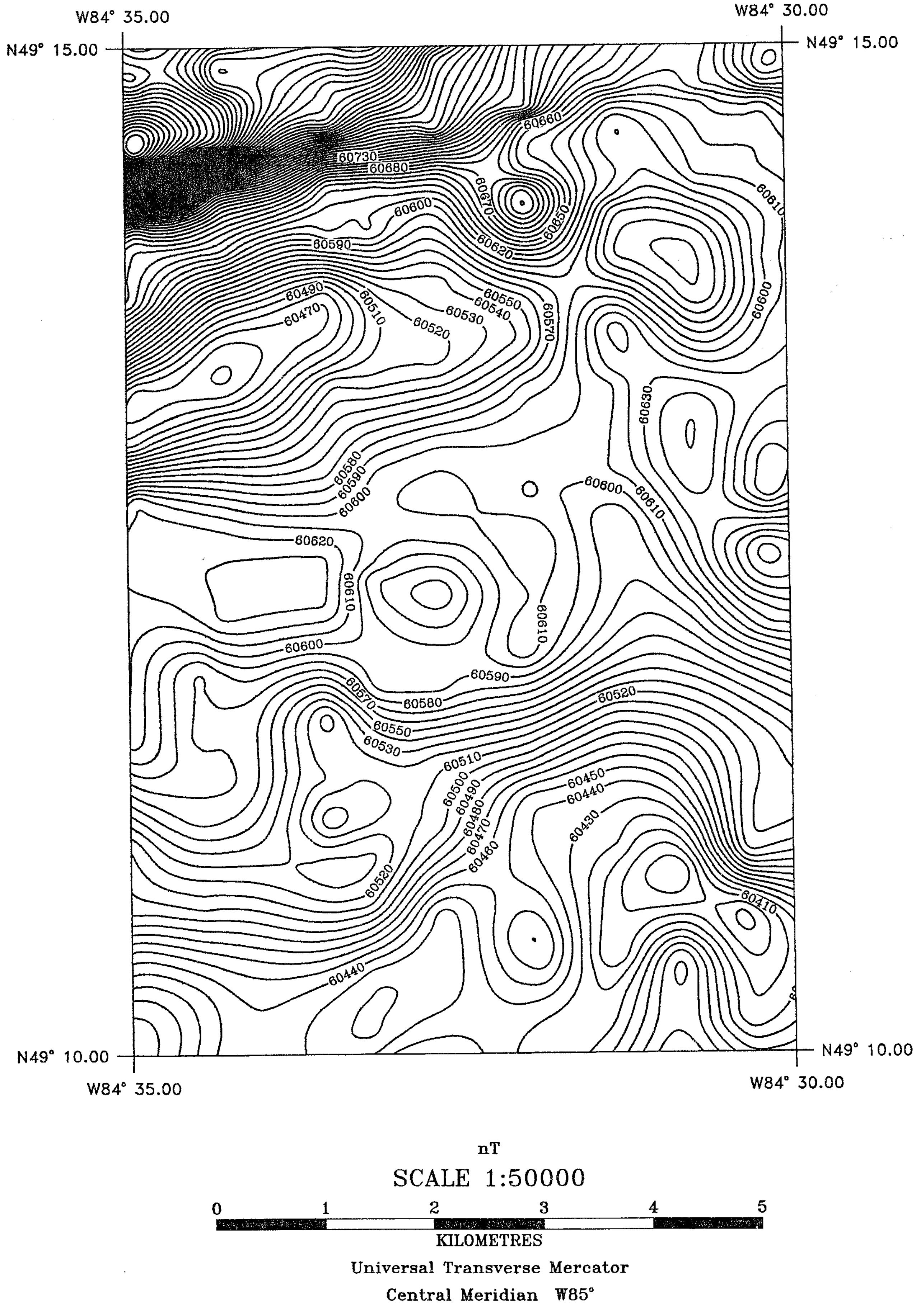

Figure 3b. Contour map of a portion of the digitised data from NTS-42F2 gridded at an interval of 200m.

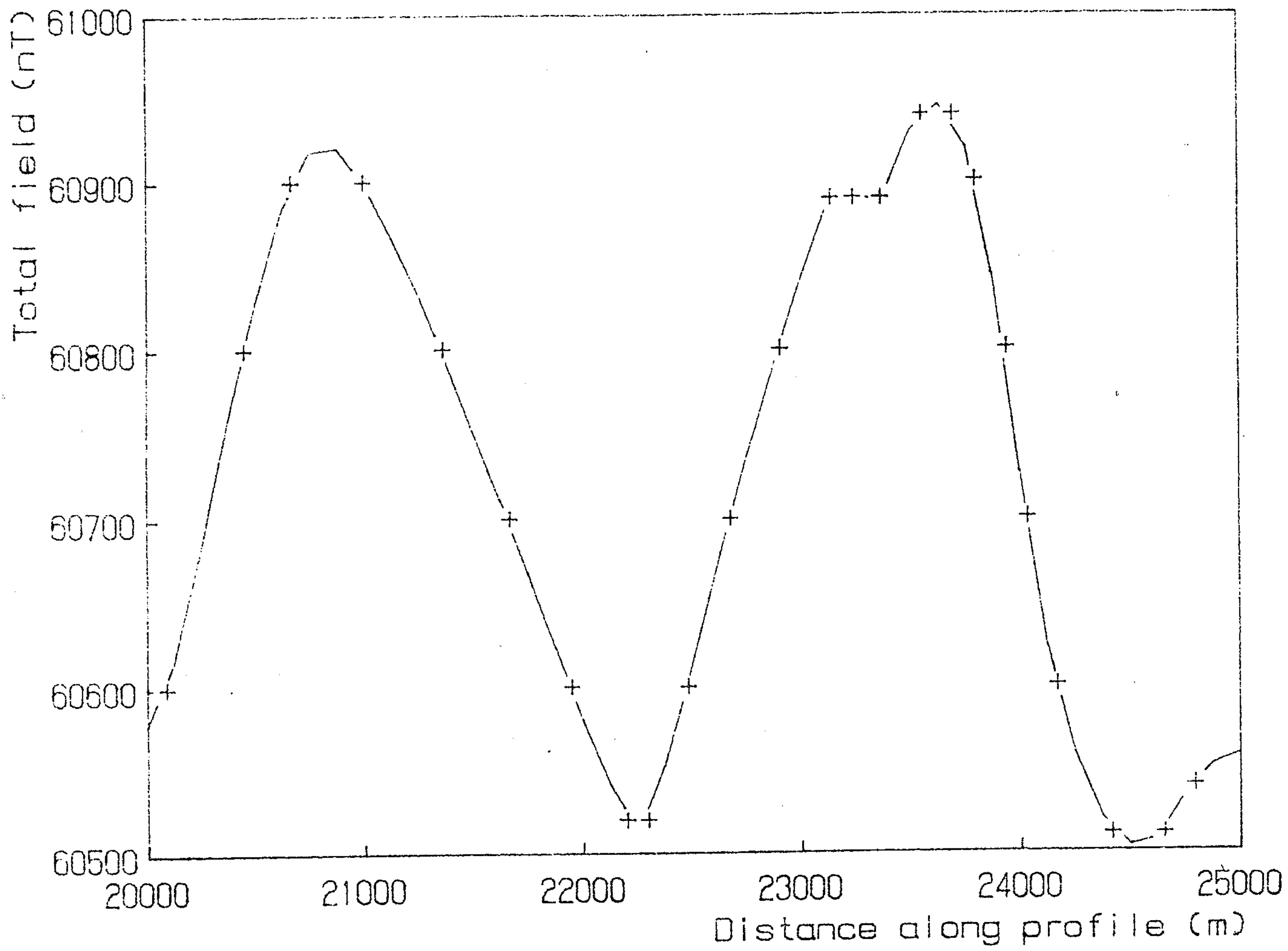

Figure 4a. Enlarged section of a section of the profile of Figure 1 interpolated every 125m. Data points are indicated by crosses (+).

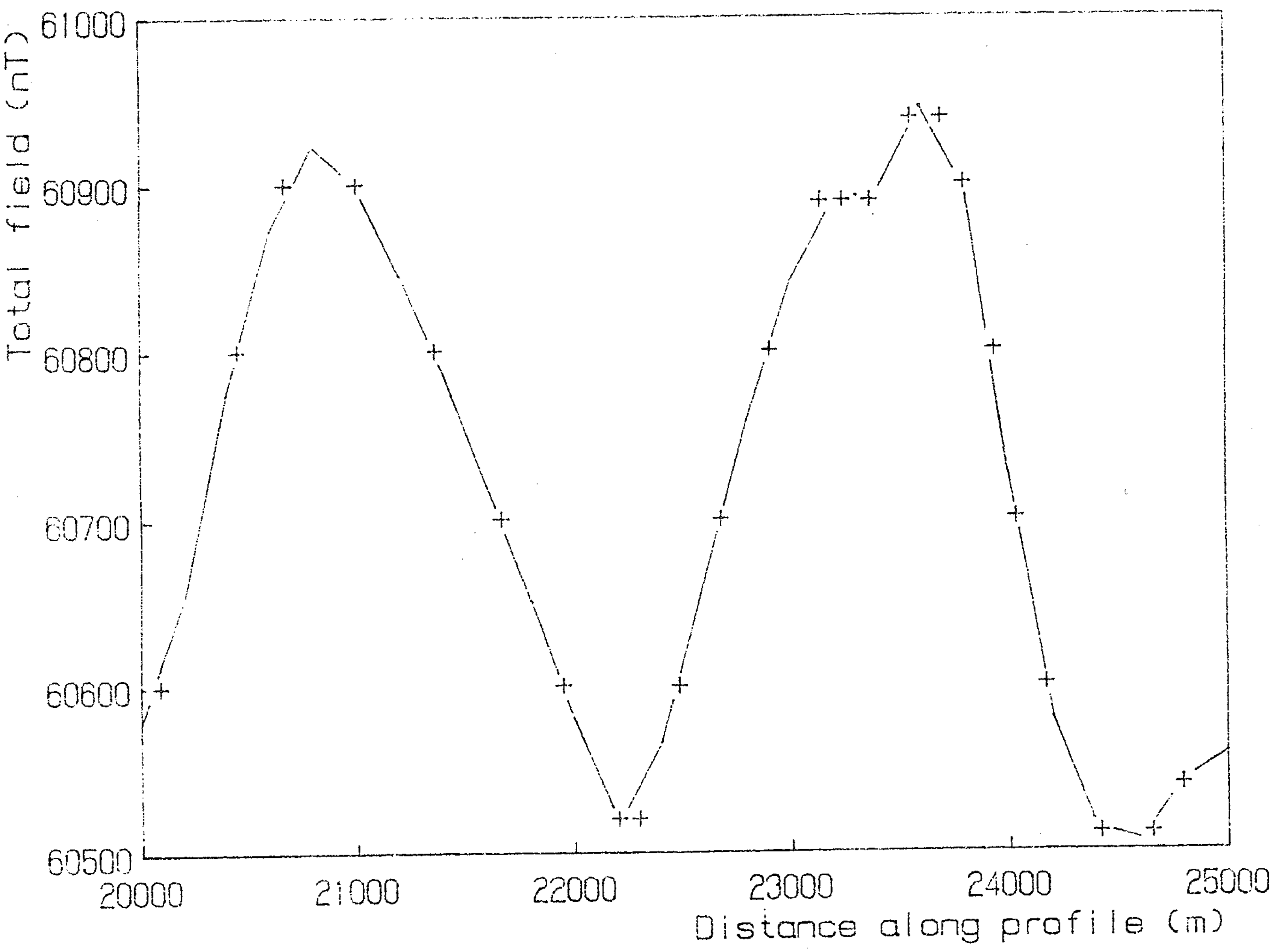

Figure 4b. Enlarged section of a section of the profile of Figure 1 interpolated every 200m. Data points are indicated by crosses (+)

Figure captions

Figure 1. Typical digitised magnetic profile from the total field magnetic map of NTS-42F2.

Figure 2. Power energy spectrum of the profile of Figure 1.

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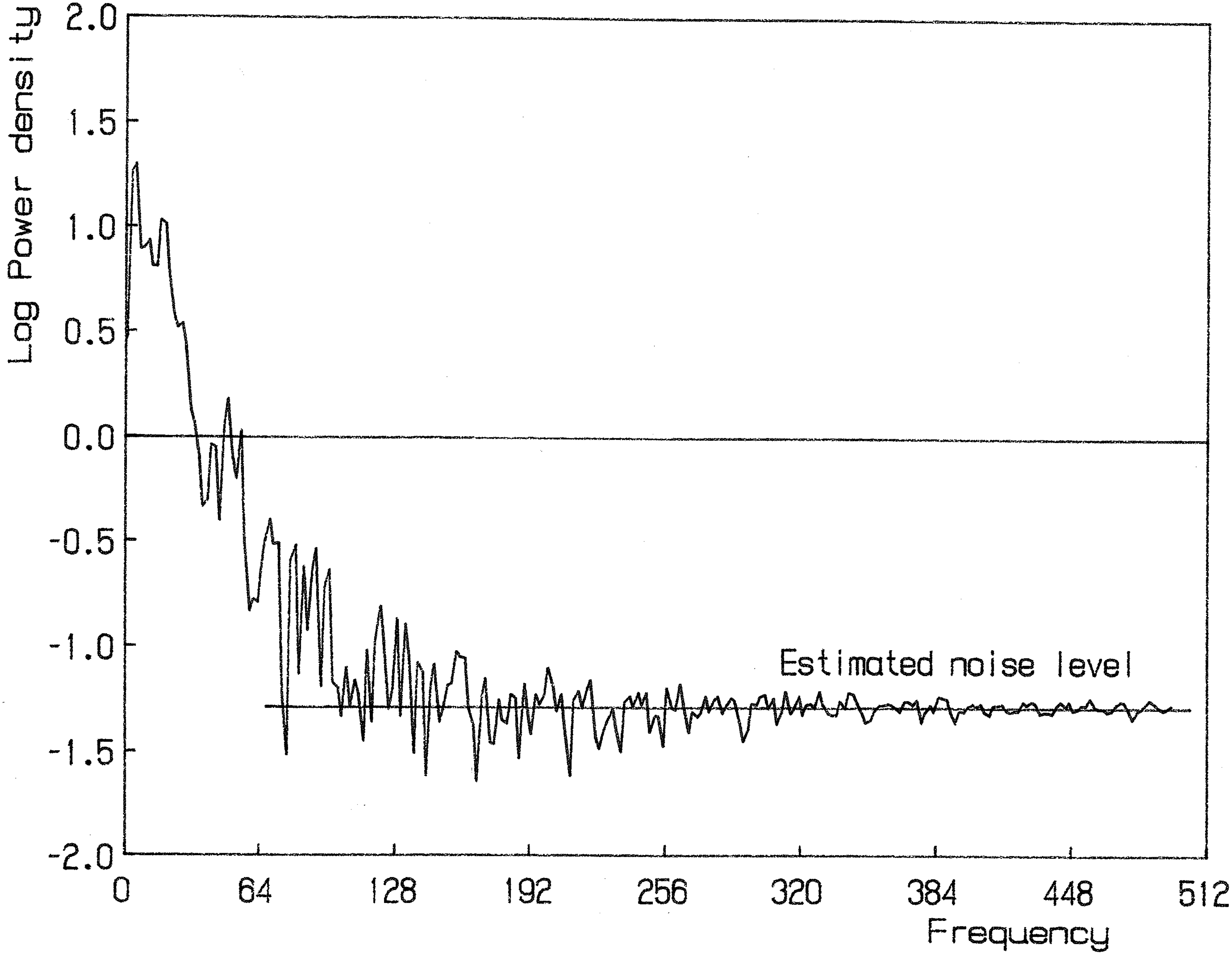
Figure 4a. Enlarged section of a section of the profile of Figure 1 interpolated every 125m. Data points are indicated by crosses (+).

Figure 4b. Enlarged section of a section of the profile of Figure 1 interpolated every 200m. Data points are indicated by crosses (+)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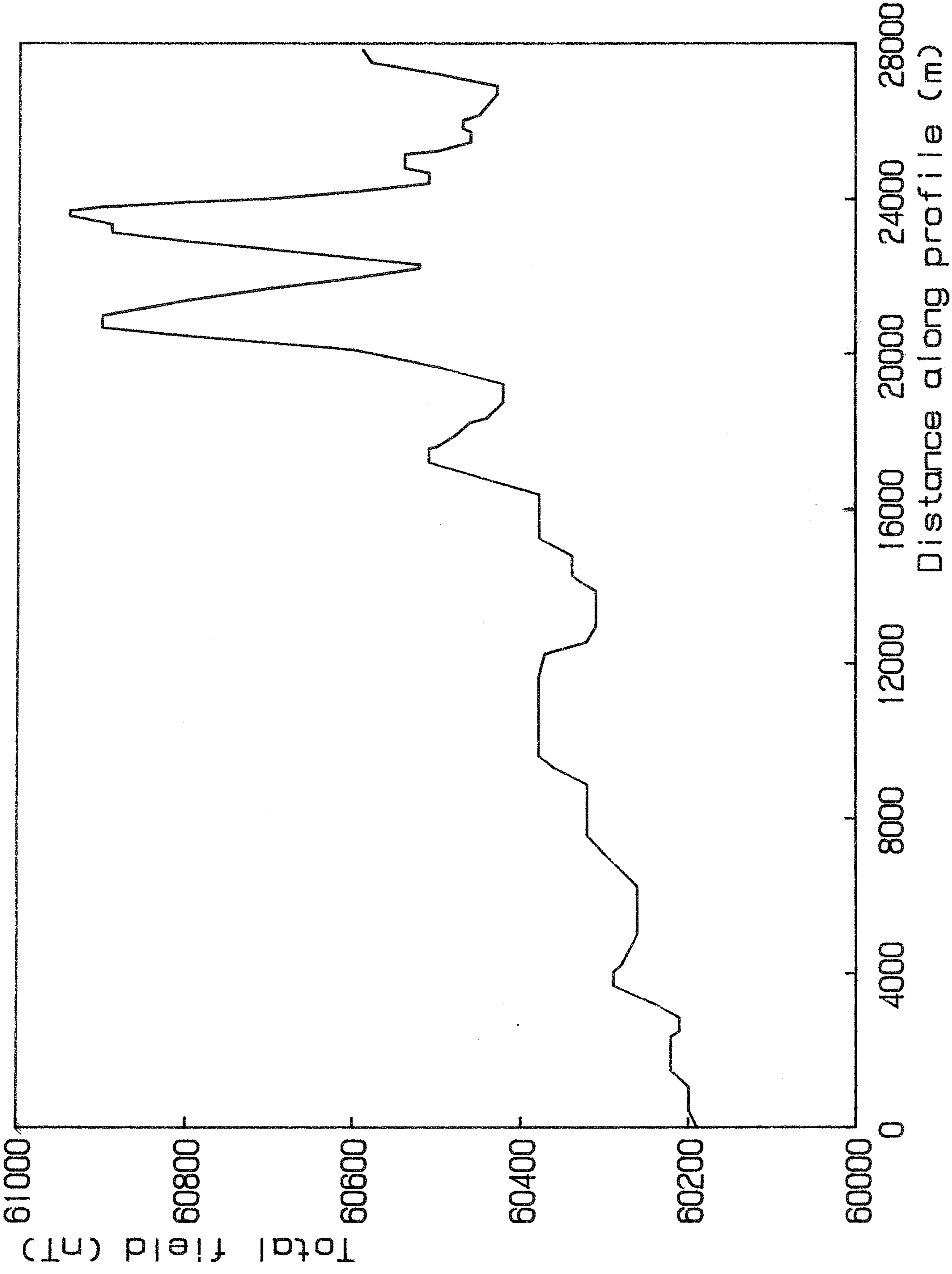
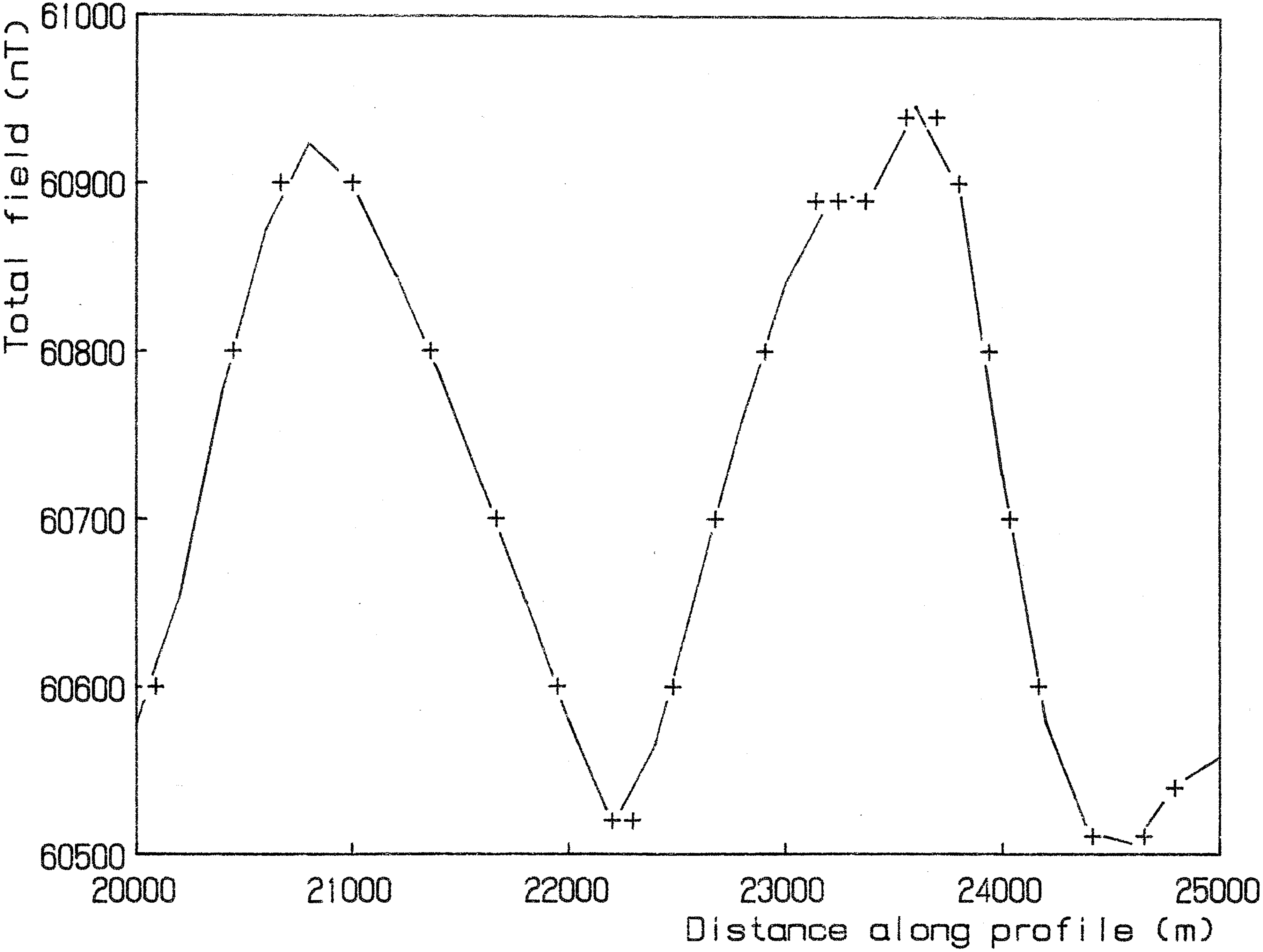
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0
64
128
192
256
320
384
448
512
Frequency
Estimated noise level



Total field (nT)
61000
60800
60600
60400
60200
60000
0
4000
8000
12000
16000
20000
24000
28000
Distance along profile (m)


Total field (nT)
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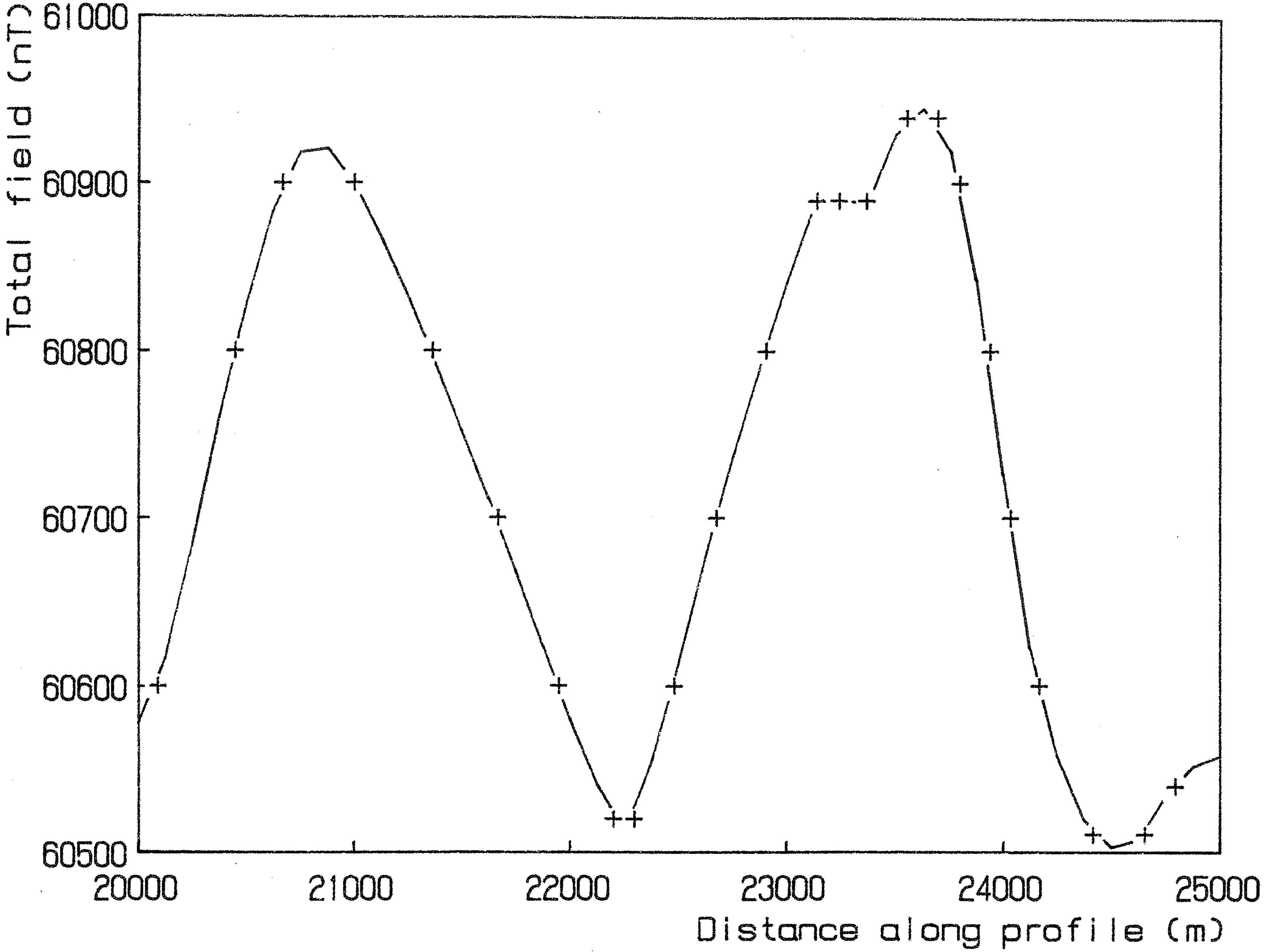
60800
60700
60600
60500
20000
21000
22000
23000
24000
25000
Distance along profile (m)


Total field (nT)
61000
60900
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60700
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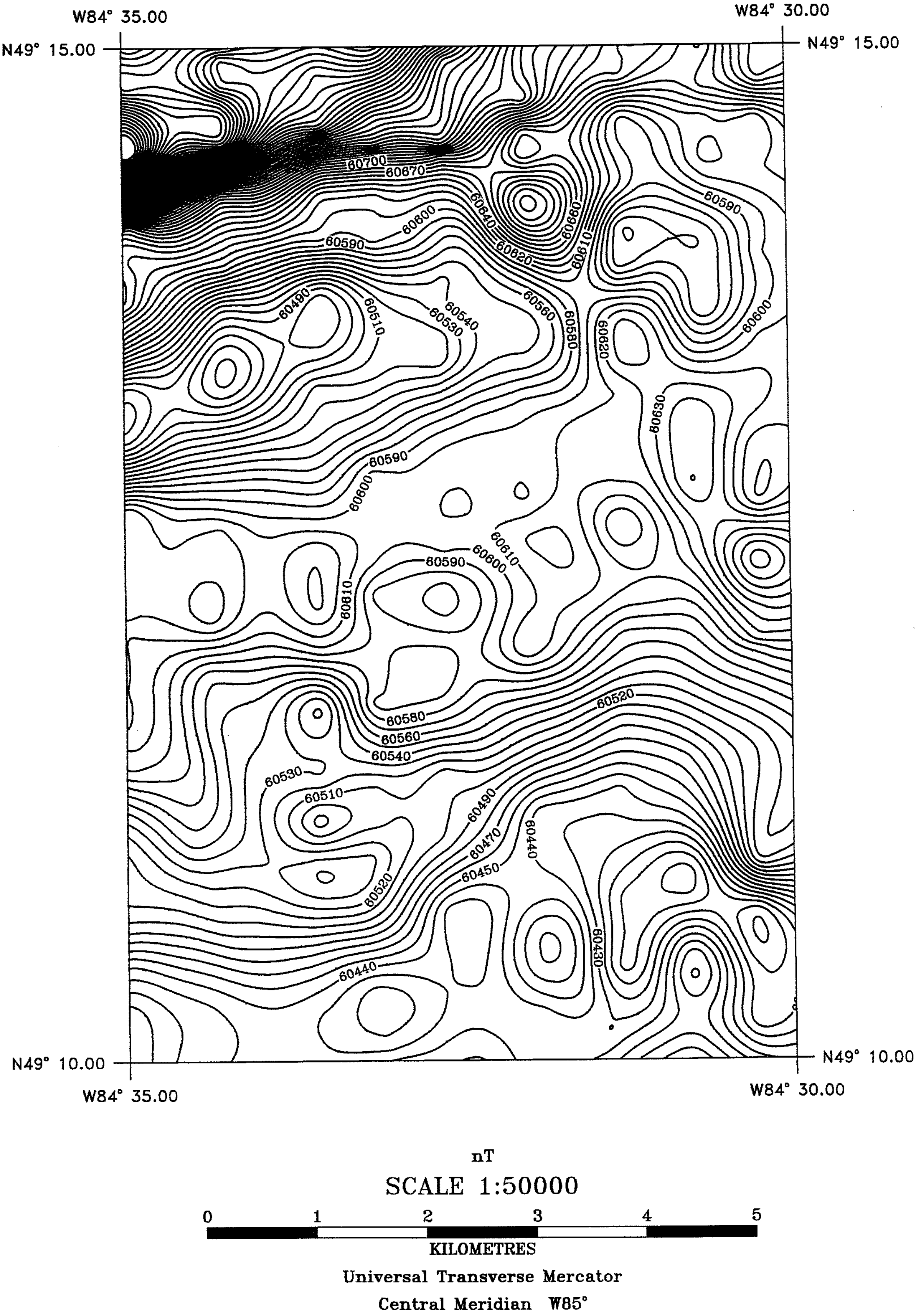

Figure 3a. Contour map of a portion of the digitised data from NTS-42F2 gridded at an interval of 125m.

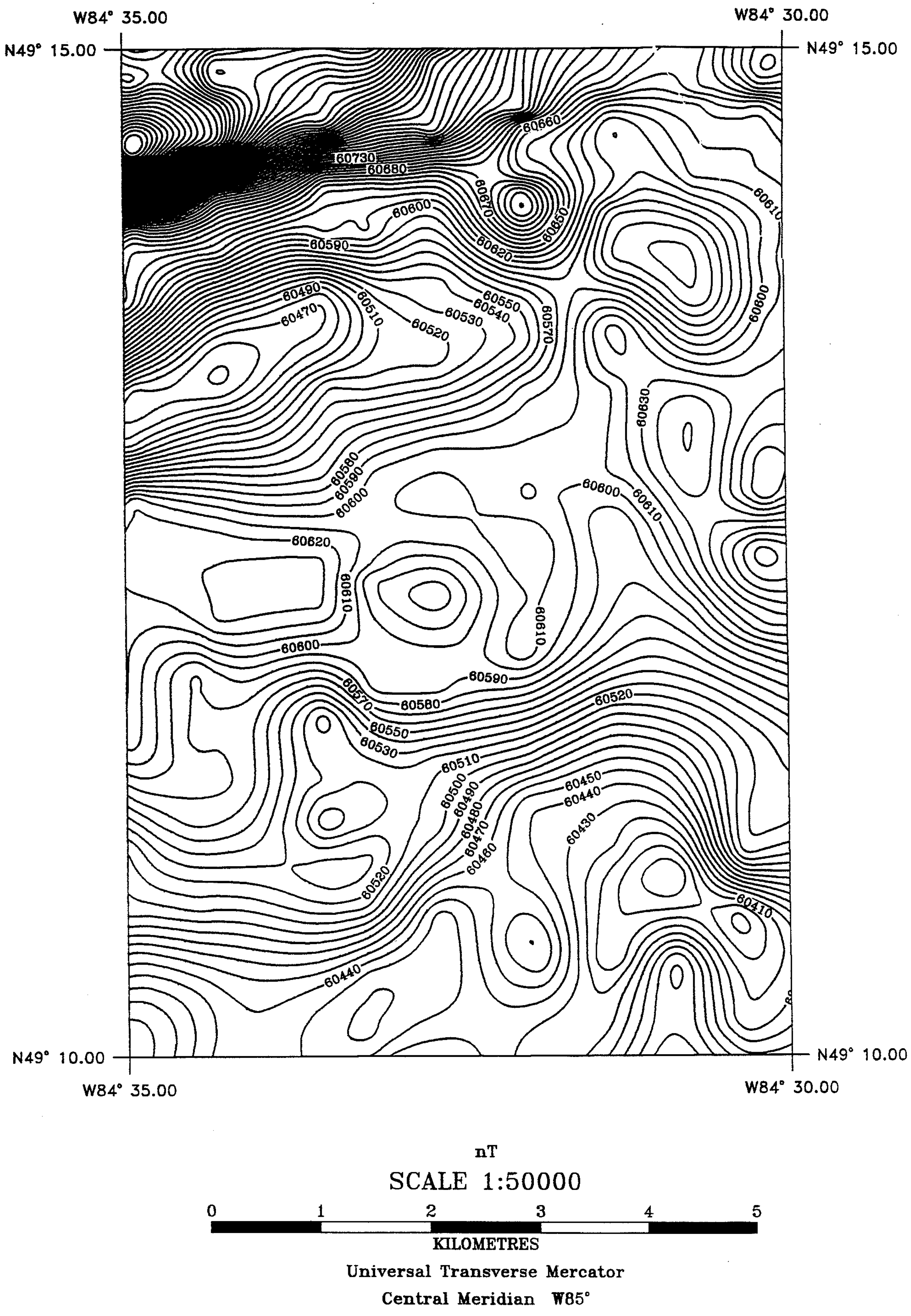

Figure 3b. Contour map of a portion of the digitised data from NTS-42F2 gridded at an interval of 200m.