Data Enhancement Procedures on Magnetic Data from Landfill Investigations

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Abstract

A magnetic study over a landfill in the U.S.A. was performed as part of a multitechnique geophysical investigation. Various magnetic data enhancement procedures were employed to determine their effectiveness in characterizing landfills. Our study has revealed that upward continuation, calculated vertical gradient processing, and wavelength filtering significantly improve the interpretability of magnetic data in terms of discriminating between shallow and deep magnetic sources within the landfill. Furthermore, the vertical gradient calculated from surface observations is comparable to gradients obtained from hi-level surveys, suggesting that the efficiency of surveys can be increased by calculating, rather than observing the vertical gradient.

Introduction

The magnetic method is frequently used in studies over landfills in search of buried magnetic material (e.g., Blasting, 1987; French et al., 1988; and Walsh, 1989). Commonly, the location of shallow (<3 m) magnetic material such as buried barrels, pipes, or domestic waste is the primary concern, and most magnetic data collected in these studies are not subjected to advanced data processing techniques. However, experience in other applications (e.g., Lidiak et al., 1985; Urquhart and Strangway, 1985; and Yarger, 1985) shows that data processing with enhancement procedures substantially improves the interpretability of magnetic data. For example, gradient analysis of total field magnetic measurements increases the resolution of the method for the study of shallow magnetic source anomalies, whereas, upward continuation of data attenuates high wavenumber anomalies generally associated with relatively shallow sources allowing easier interpretation of deep magnetic sources.

In this study, the magnetic method has been applied as part of a multitechnique geophysical study over the Thomas Farm landfill located 2 km west of Purdue University in West Lafayette, Indiana (Roberts et al., this volume). An isopach map of the abandoned landfill which lies within a pre-existing stream valley is shown in Figure I. Both vertical gradient and total field magnetic measurements were made over the landfill and environs which permitted examination of the enhancement capabilities of the magnetic method as well as a comparison of observed and calculated vertical gradient measurements.

Magnetic Survey

Magnetic data were collected digitally using an EG&G Geometries G-856 proton precession magnetometer. The temporal variations in the total field data were monitored with an EG&G Geometries G-826A base station magnetometer located near the landfill. Observations were made at a height of 1 m above the ground surface at stations located on a 2 x 2 m grid. In areas of high local magnetic gradient, additional stations were observed at 1 m intervals. The profile lines were extended from the landfill onto the adjacent glacial sediments. However, the steep topography on the eastern and southern margins of the landfill and nearby metal structures limited the length of the profiles. Total field magnetic measurements also were made at a 2 m height in a 2 x 4 in grid to obtain vertical gradient information.

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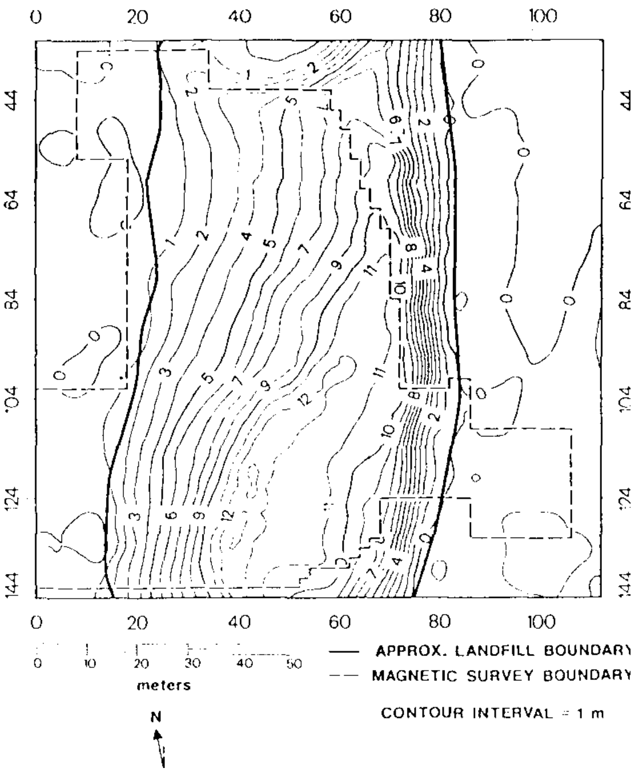

Fig,1. Isopach map of the Thomas Farm landfill from 1958 and 1988 topographic maps.

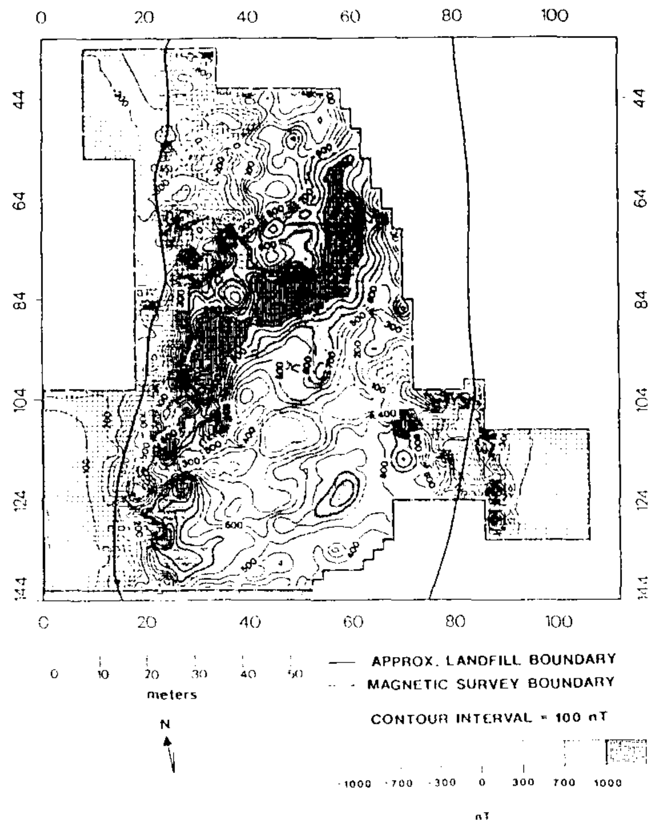

Fig- 2. Contour map of total field magnetic intensity data, observed at 1 m height, at the Thomas Farm landfill site.

Enhancement and Interpretation

The observed magnetic data were corrected for temporal variations recorded by the base station magnetometer and referenced to an arbitrary station located off the landfill. No correction was made for the spatial variation of the core-derived magnetic field because of the limited size of the landfill (approximately 60 m by 150 m). The data were contoured (Figure 2) from a 1 m square grid generated with a minimum curvature interpolation procedure.

Examination of the reduced data contour map shows that the landfill is characterized by a pattern of intense magnetic variations which locally reach amplitudes of 1000 nT or more. The magnetic pattern off the landfill is devoid of anomalies on the 100 nT contour map except where the field is affected by surface magnetic features. A portion of a valley along the eastern edge of the landfill, as shown in Figure 2, is marked by anomalies of high wavenumber over surface iron and steel objects. The western margin of the landfill roughly coincides with an intense discontinuous magnetic minimum and adjacent magnetic maxima over the landfill. In addition, local anomalies derived from numerous shallow magnetic sources are superimposed on the magnetic maxima along the western margin of the landfill. Identification of several of these sources have been corroborated with ground-penetrating radar (Roberts et al., 1989). The magnetic anomalies over the center of the landfill, especially in the southern portion of the abandoned dump where the isopach map (Figure 1) shows the thickest landfill, are comparatively less intense and have broader gradients. The lower amplitude anomalies in the southern part of the landfill are believed to be associated with a change in landfill composition from the domestic trash in the northern part of the landfill to brush, wood cuttings, and construction debris in the southern part.

Upward Continuation

The magnetic data recorded at a height of 1 m were upward continued, 1, 3, and 6 m as shown in Figures 3, 4, and 5, respectively. An east-west profile of the reduced data and the upward continued data along a line

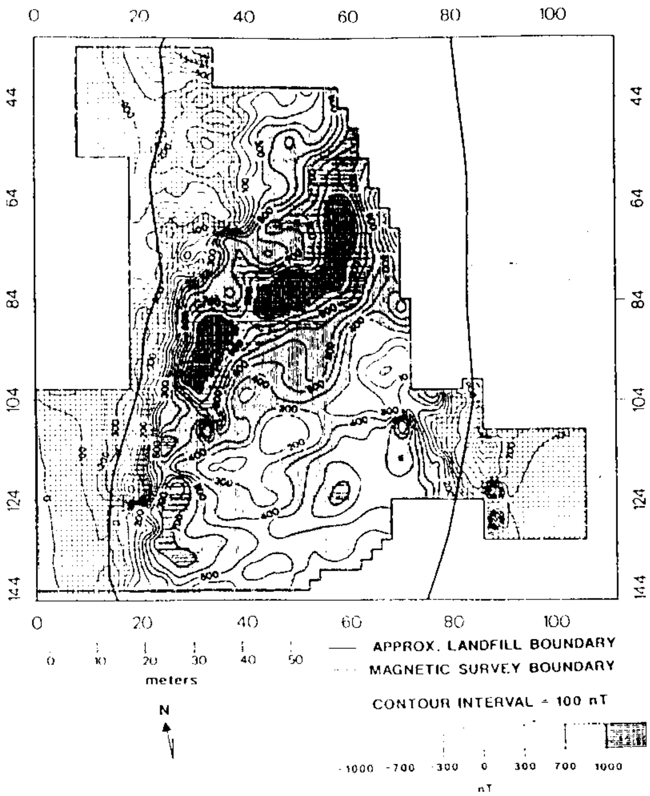

Fig. 3. Contour map of upward continued 1 m magnetic data at the Thomas Farm landfill site.

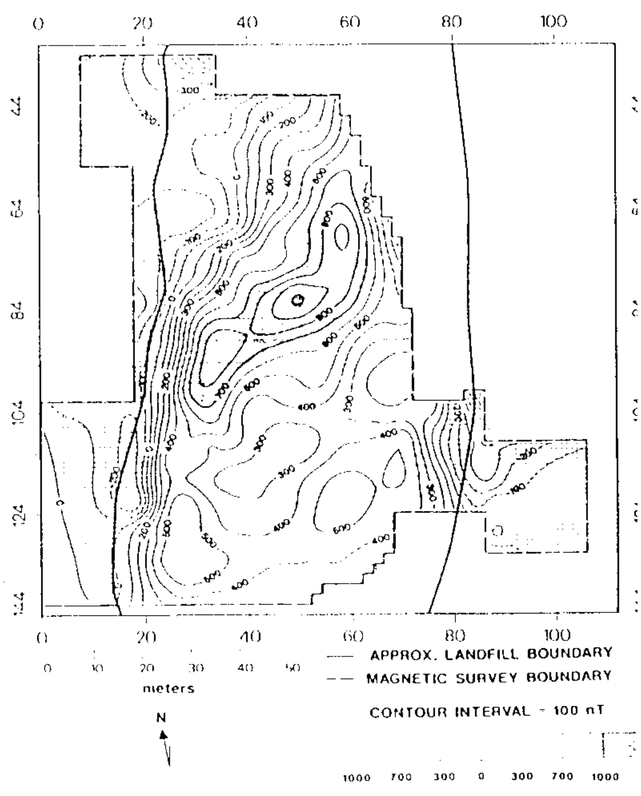

Fig. 4. Contour map of upward continued 3 m magnetic data at the Thomas Farm landfill site.

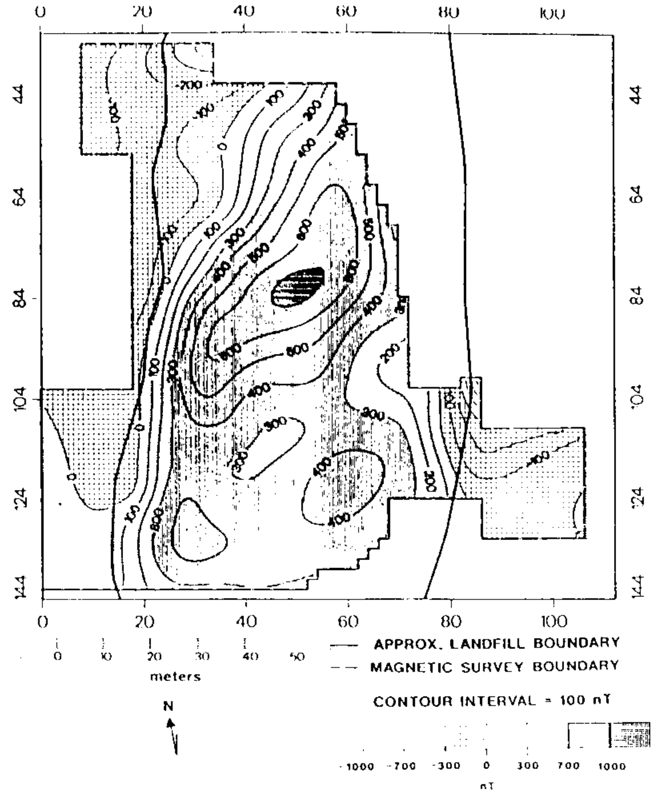

Fig. 5. Contour map of upward continued 6 m magnetic data at the Thomas Farm landfill site.

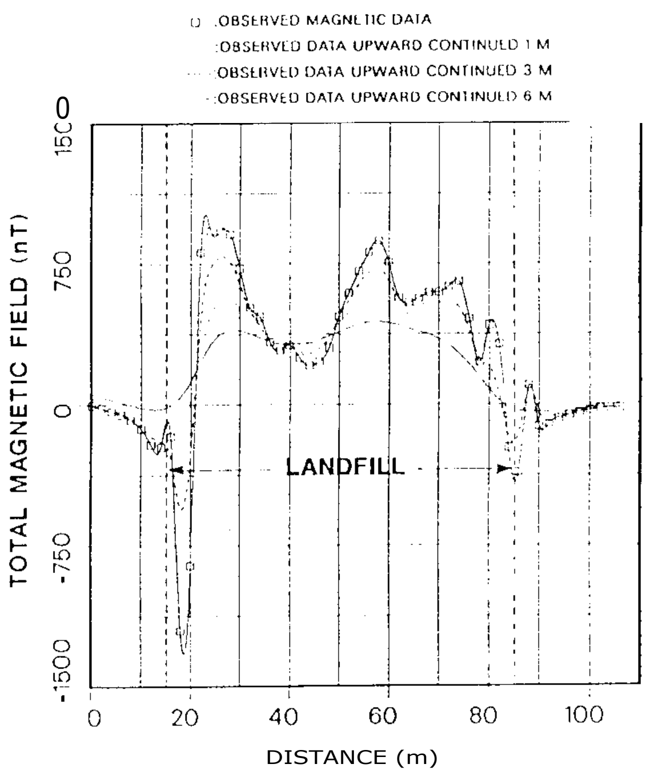

Fig. 6. Observed total field and upward continued 1, 3, and 6 m magnetic data along profile line 124.

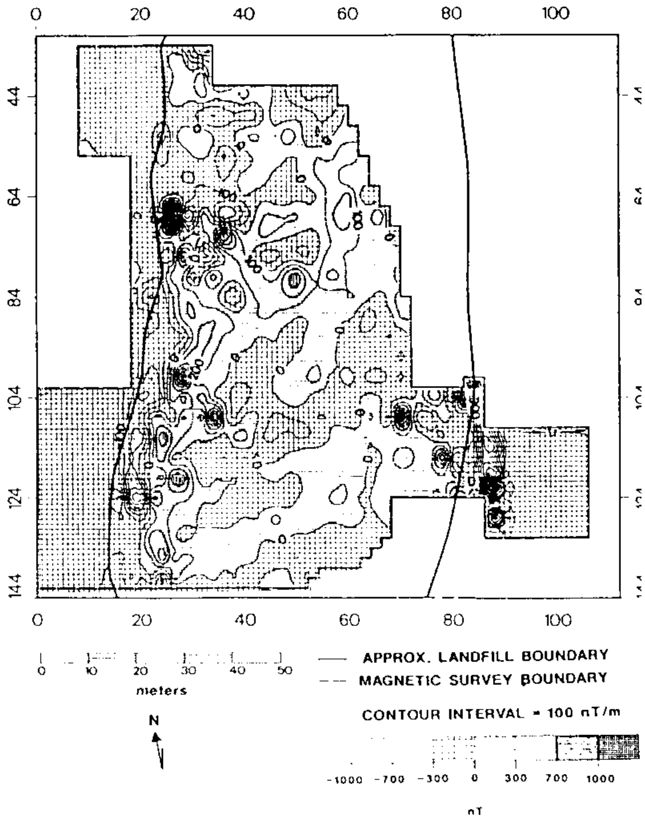

FIG. 7. Contour map of observed vertical-gradient magnetic data from the Thomas Farm landfill site.

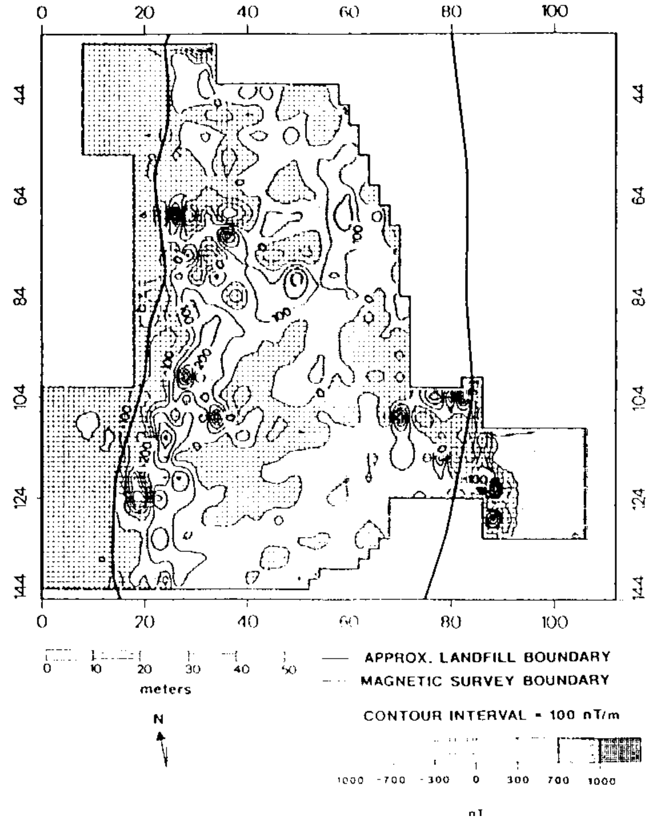

Fig . 8. Contour map of calculated vertical derivative of magnetic data (sampled at a 2 x 4 m grid spacing) at a height of 1.5 m.

at the 124 m location is shown for comparison purposes (Figure 6). The upward continued data reveal increasing attenuation and broadening of the high-wavenumbcr anomalies with increasing height above the landfill. We note that at the 6 m continuation level the negative anomalies at the landfill margins are essentially eliminated.

These upward continued maps and profiles illustrate the change in anomaly character with increasing observation to source distance, and also arc useful as a low-wavenumber pass filter. As such, the 6 m upward continued data provide an excellent integrated view of the landfill undistorted by the local, high amplitude, high gradient anomalies of the magnetic sources in the shallow portion of the landfill. Assuming the landfill is relatively homogeneous with regard to magnetic source content, we would anticipate the highest amplitude anomaly on the upward continued 6 m contour map (Figure 5) to occur over the thickest portion of the landfill (Figure I). This is roughly the observed situation. It is apparent that the attenuation of the shallow-source anomalies in the upward continuation process permits a clearer or enhanced view of the deeper anomaly sources.

Vertical Gradient and Wavelength Filtering

Observed vertical gradients were obtained by subtracting the magnetic data measured at a height of 2 m, from the data measured at a height of I m. These data (Figure 7), which approximate the vertical gradient at 1.5 m by assuming a linear decrease in the magnetic values with increasing elevation, reveal enhanced resolution of the high-wavenumber anomalies as compared to the magnetic anomaly data presented in Figure 2. The vertical gradient can also be calculated from the observed magnetic values by wavenumber-domain processing (Dean, 1958). For purposes of comparing the observed and calculated gradients, the data obtained at a height of were upward continued to 1.5 m by wavenumber-domain processing and converted to vertical-gradient values (Figure 8). The observed gradient (Figure 7) subtracted from the vertical gradient magnetic data, calculated from 1.5 m (Figure 8) illustrates that there is good agreement between the two data sets (Figure 9). The major differences occur in areas of extremely high gradients where the assumption of linear variation between the 1 in and 2 m height is violated and errors (Inc to the inaccuracy of the proton precession magnetometer in regions of very high gradients and in the wavenumber-domain processing procedure. A comparison of the vertical gradient is well illustrated in Figure 10 for a single profile line.

These results lead to two important conclusions. First, the vertical gradient increases the resolution of the magnetic observations by emphasizing the effect of the near-surface anomalous sources. Second, the observed and calculated vertical gradients are quite similar. Thus, where high-density surface observations are available, it is possible to calculate the vertical gradient from observations at one height, eliminating the need for observations of the field at two heights at each station. The observed vertical gradient data does have the advantage of minimizing the effect of temporal magnetic variations. However, this is an advantage only if observations are made during magnetically disturbed periods. Normal temporal variations can be readily monitored and eliminated from the data by repeated reoccupation of a base station or by use of a base-station magnetometer.

The resolution of the magnetic observations can also he enhanced with the use of wavelength filtering. Figure 11 illustrates the results from a wavelength filter which minimizes all wavelengths greater than 5 m in the data obtained at 1 m height. Comparison of Figure 11 with the vertical-gradient maps (Figures 7 and 8) shows that high-pass wavelength filtering is very effective in isolating the near-surface anomalous sources. Similarly, a low-pass wavelength filter will enhance the longer wavelength anomalies derived from deeper anomalous sources. This enhancement is illustrated in Figure 12 which has been prepared by emphasizing all wavelengths greater than 20 m. The results are quite similar to those obtained by upward continuation of the data obtained at I m height by 3 m (Figure 4). However, wavenumber filtering distorts the magnetic data set so that only nonquantitative interpretation is possible. In contrast, vertical-gradient and upward continuation processing are quite amenable to modeling and other quantitative analyses.

Conclusions

In conclusion, wavenumber-domain processing of magnetic data observed over landfills will enhance particular attributes of the magnetic field which will aid in the interpretation of the anomaly sources. Upward continuation, vertical gradients, and wavelength filtering are shown to be effective procedures. Furthermore, the calculated vertical gradient is comparable to the observed gradient suggesting that the dual observations at a station which are needed to obtain the observed vertical gradient can be eliminated except during periods of extreme temporal magnetic-field variations.

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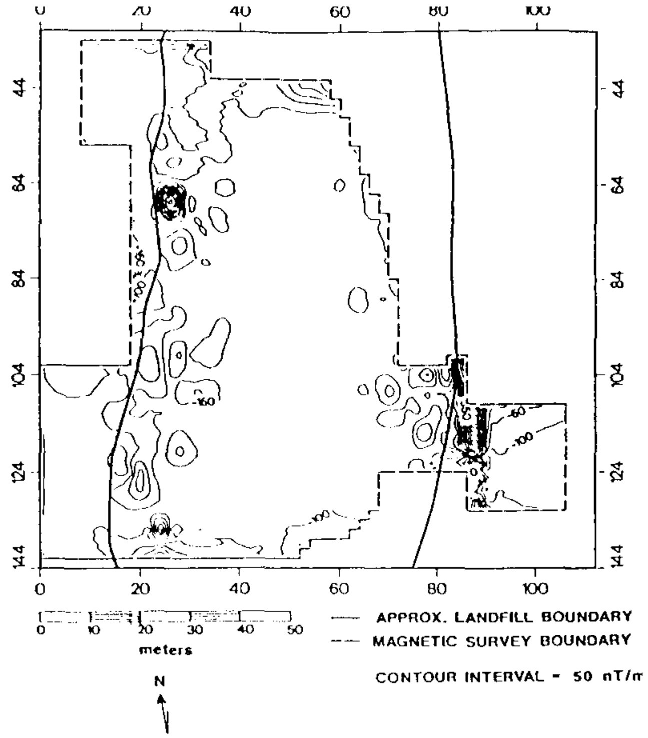

FIG. 9. Contour map of the observed magnetic-gradient data subtracted from calculated-gradient data at a height of 1.5 m.

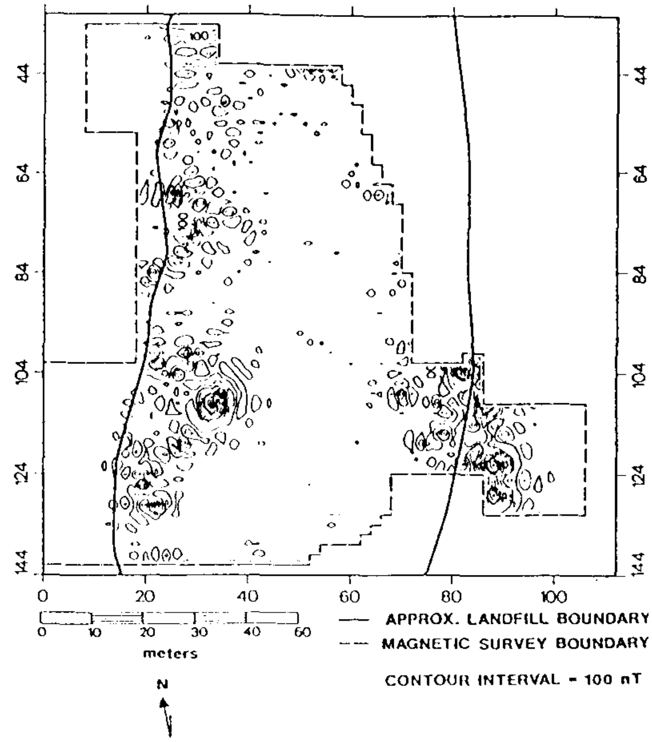

FIG. 11. Contour map of high-pass wavenumber filtered (wavelengths < 5 m) magnetic data from the Thomas Farm landfill site.

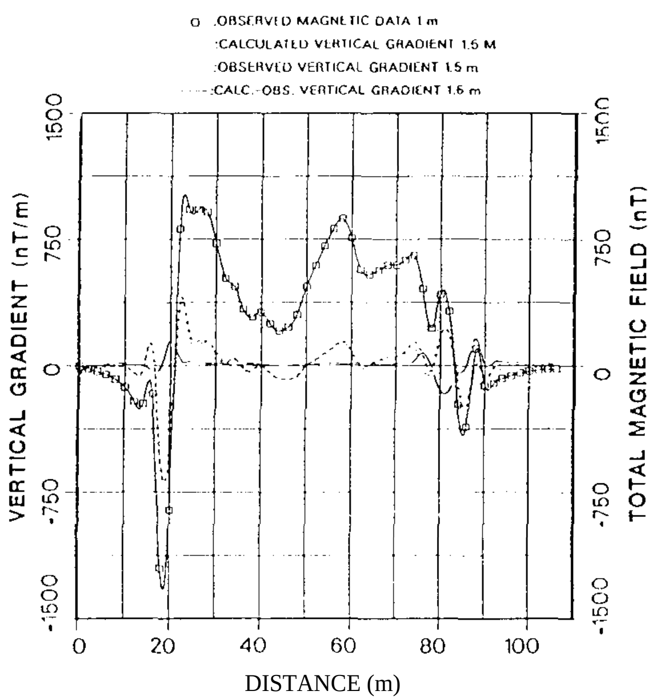

FIG. 10. Observed total-field magnetic data, observed and calculated vertical gradient and difference between observed and calculated gradient data along profile line 124.

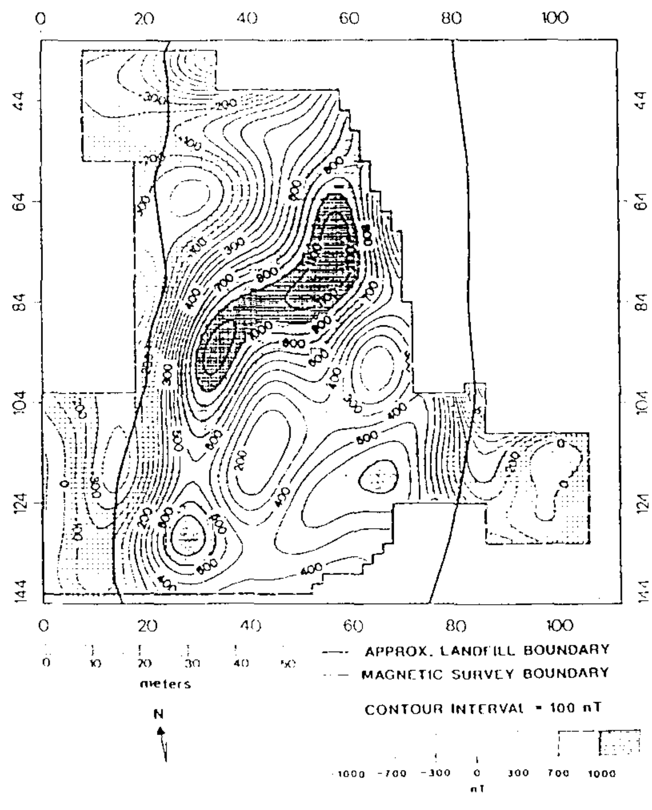

Fig. 12. Contour map of low-pass wavenumber filtered (wavelengths > 20 m) magnetic data from the Thomas Farm landfill site.