Microlevelling of Aeromagnetic Data using the Naudy-Fuller Space Domain Filter

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Abstract

Microlevelling or decorrugation methods used to remove line-to-line levelling errors of aeromagnetic data which are visible as linear anomalies parallel to the flight lines are explained in this study showing the advantages of using the Naudy-Fuller space domain filter. In this study three methods of microlevelling were tested, the first is microlevelling using Bi-directional line gridding, the second using FFT frequency domain procedures which is based on a directional cosine filter and Butterworth filters, and the third, and most preferable by the authors, is a combination of Naudy non-linear filter and the Fuller Hanned band pass convolution filter, that works in the space domain.

Introduction

Corrugation is a low amplitude element of flight line noise still remaining in the aeromagnetic survey data after tie line levelling. These residual errors show significant streaking or corrugations when the grid is visualized using shaded relief methods. If uncorrected then the computation of derivatives becomes dominated by these line-orientated noise effects.

Therefore the gridded dataset should be filtered to reduce or remove non-geological effects caused by long-wavelength noise along survey lines. Some sources of corrugations are not very clear, however, in this case study the most important source of errors in the aeromagnetic data is due to line to line differences in flying heights. Another source of error arises from; inaccuracy in the measured positions of crossover points of acquisition and tie lines. If an error arises here, it may introduce an error covering a region that extends one line spacing in each direction. The dimensions of this region would therefore be twice the tie line separation by twice the acquisition line separation. A further error could arise from inadequate compensation for the magnetic field resulting from the aircraft.
Corrugation also occurs if the (time-varying) diurnal fluctuations are not accurately measured at the base station, thus affecting part of the measurements along an acquisition line. Finally, corrugation can occur when adjacent flight lines are in opposite flight directions.

Although the contractor performed standard compensation and diurnal corrections and levelling, the rugged terrain and widely spaced tie lines prevented complete removal of flight line noise as seen in (Figure 2).

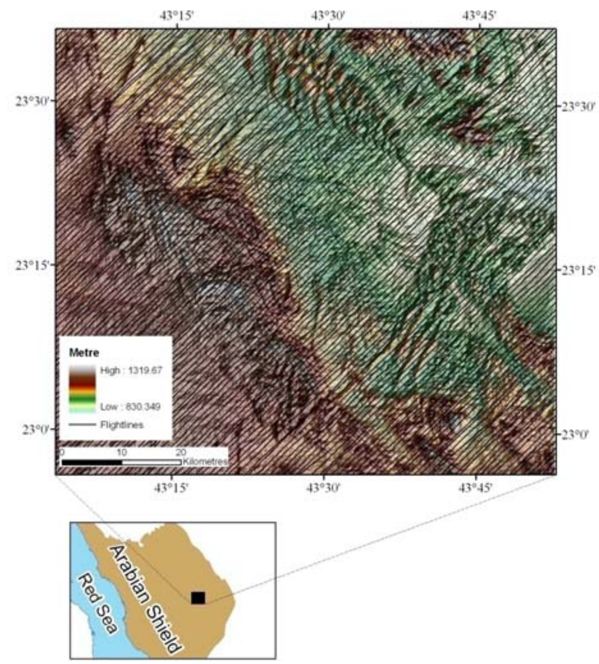

Figure 1: Topography of the test area, Arabian Shield, superimposed by the aeromagnetic flight-lines.

Tested Microlevelling Methods

In this study three methods of microlevelling were tested, the first is microlevelling using Bi-directional line gridding, the second using FFT frequency domain procedures which is based on a directional cosine filter and Butterworth filters, and the third, and most preferable by the author, is a combination of Naudy non-linear filter and the Fuller hanned band pass convolution filter, that works in the space domain and is implemented by the Intrepid™ software (Intrepid manual, 2002). These three methods of decorrugation are described briefly in the following sections.

Microlevelling using Bi-directional line Gridding

There are many methods for microlevelling of dataset collected along survey lines, and the success of any method is largely data-dependant. Microlevelling using the Oasis Montaj™ Bi-directional line Gridding, can be applied to gridded dataset alone, however for optimum results it should be applied to the original line data. In brief, the procedure involves a grid of levelling errors derived from a magnetic grid. These data are then subtracted from the original line data if available, or from the grid. The Bi-directional microlevelling method obtains the error grid by assuming that the gridded data consist of geology, a regional field, and levelling errors, these are separated out at various stages by low pass filtering during the gridding process.

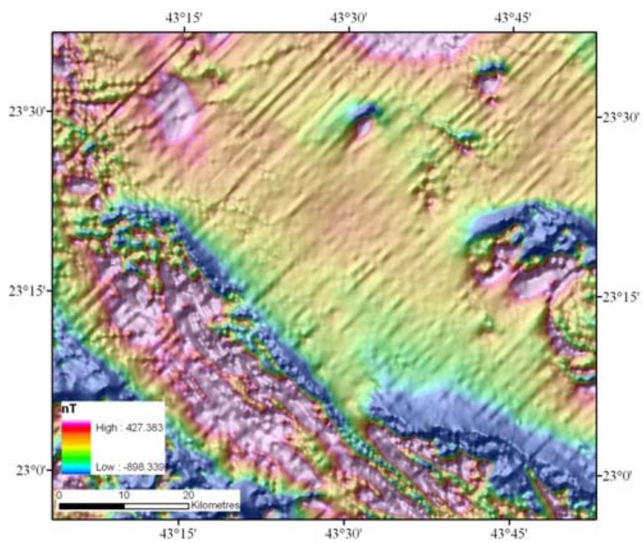

Figure 2: Corrugation appeared clearly in the aeromagnetic data.

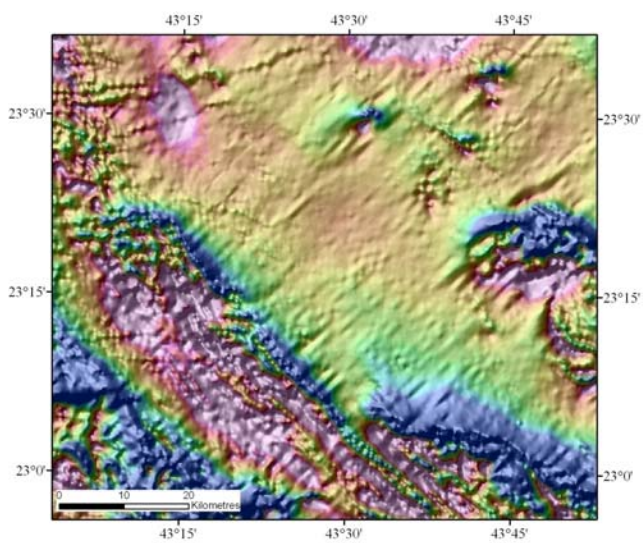

Figure 3: Aeromagnetic data decorrugated using Bi-Directional Gridding.

Levelling using Bi-directional line gridding involves rotating the aeromagnetic survey lines to E-W or N-S directions. For aeromagnetic data of this study, decorrugation by Bi-directional line gridding did not show perfect results (Figure 3) probably due to the specification of aeromagnetic surveys as it was mentioned previously that decorrugation is largely data dependent, see Geosoft Technical notes (2003a) for more details.

FFT Decorrugation

Basically this method is a Fast Fourier Transform technique employing a high-pass Butterworth filter in conjunction with a directional cosine filter in the frequency domain. The technique can retain anomalies, from gridded data, in the flight line direction only. These anomalies are further filtered to remove geologically significant signal and to generate a correction grid. The corrections are subtracted from the original data. However, in this method it is difficult to distinguish between levelling errors and true geological anomalies of similar wavelength parallel to the flight lines. Therefore, the amount of corrugations removed were kept to a minimum by setting the Butterworth filter to four times the line spacing so that only frequencies on the order of the flight line spacing can be passed, and the directional cosine filter to pass wavelength only in the direction of the flight lines.

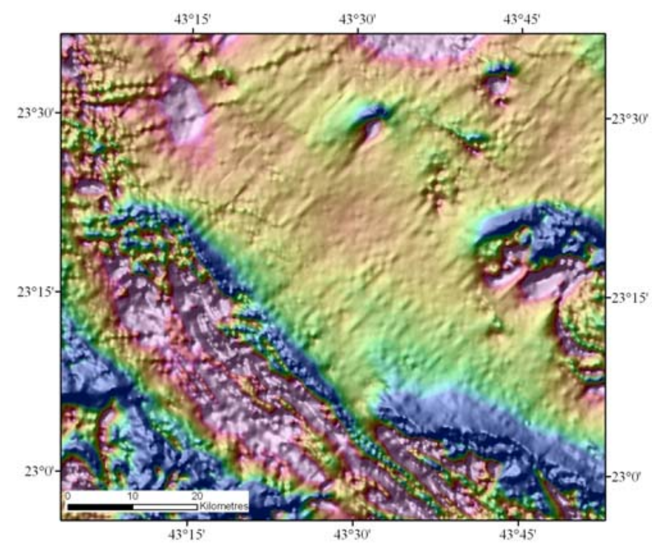

Figure 4: Aeromagnetic data decorrugated By FFT high-pass (Butterworth filter and a directional cosine filter in the frequency domain).

FFT decorrugation can be applied to gridded data but as for any decorrugation method, the best results are achieved by applying the resultant correction on the flight line database after removing any geological anomalies from the errors , see Geosoft Technical notes (2003b) for more details. This method demonstrates a reasonable outcome (Figure 4), although in some areas there were some remaining obvious corrugations.

Decorrugation by Naudy-Fuller filters

After removing the noise and spikes from the flight line data and gridding the test area (with rotating the flight line if they are oblique in direction to E-W or N-S directions), an input grid for the decorrugation tools is produced. Grid were decorrugated using Intrepid™ Decorrugation tools, which were designed to remove anomalies (in these case errors) with precisely defined characteristics, and to specify corrections for corrugation. These corrections do not remove geophysical information related to the geology since they extract residual errors with: the longest possible wavelength along the flight lines, the shortest wavelength perpendicular to the lines and the smallest dynamic range.

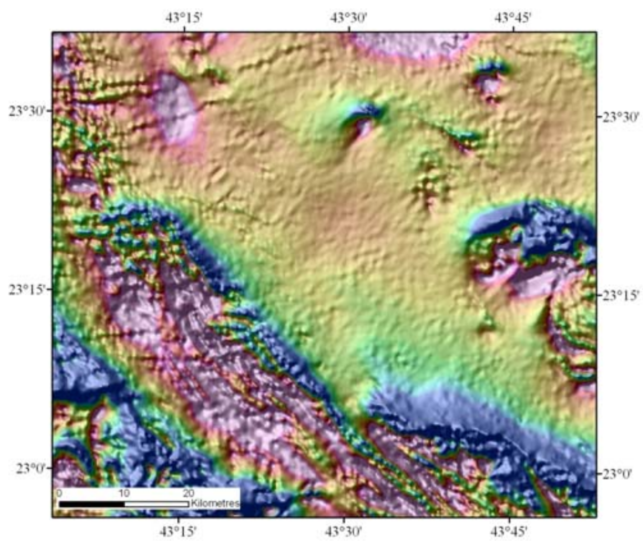

Figure 5: Aeromagnetic data decorrugated by Naudy-Fuller filters

In this study, the filter parameters applied a width twice the flight line spacing and length of at least twice the tie line spacing. However due to the nature of some of the aeromagnetic surveys data sets of this study the width had in some cases to be increased but not to exceed 25 % of the suggested length. The theory behind the above filter parameters is that a corrugation caused by differences between acquisition lines should have a wavelength of twice the acquisition line spacing. Corrugations can also be caused by errors in tie line levelling. If crossover points between tie line and acquisition line have errors then the total extent of the corrugation may extend as far as the next tie line on each side. Thus, the corrugation must have a length (wavelength) of at least twice the tie line spacing.

This decorrugation method utilizes two types of filter: a high pass and low pass filters. The high pass filter is applied perpendicular to the acquisition lines direction, whereas the low pass filter is applied in the acquisition line direction. The aeromagnetic data have been decorrugated by applying the Naudy filter (Dreyer and Naudy, 1968) first followed by a Fuller filter (Fraser et al., 1966) for the high pass filter, and smoothed Fuller for the low pass filter as it will remove any introduced high frequency noise. Decorrugation by this method (Figure 5) removes almost all corrugations and produces well levelled grids.

Conclusions

First vertical derivative (FVD) was applied on the decorrugated gridded data as seen in Figures 6-8 for closer inspection, which confirms that the best results were obtained by using a combination of Naudy and Fuller filters (Figure 8). This method removed (minimized) almost all the corrugation errors, whilst retaining the geological induced magnetic anomalies allowing the maximum resolution of the data to be retained.

Acknowledgments

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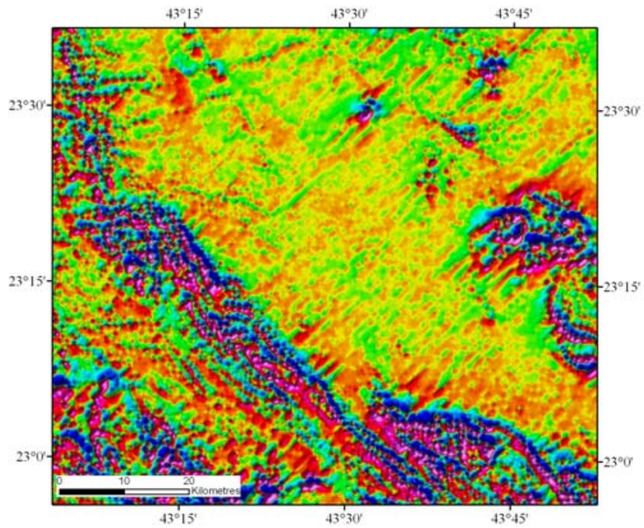

Figure 6: First vertical derivative (FVD) of the aeromagnetic data microlevelled using Bi-directional decorrugation seen in Figure 3.

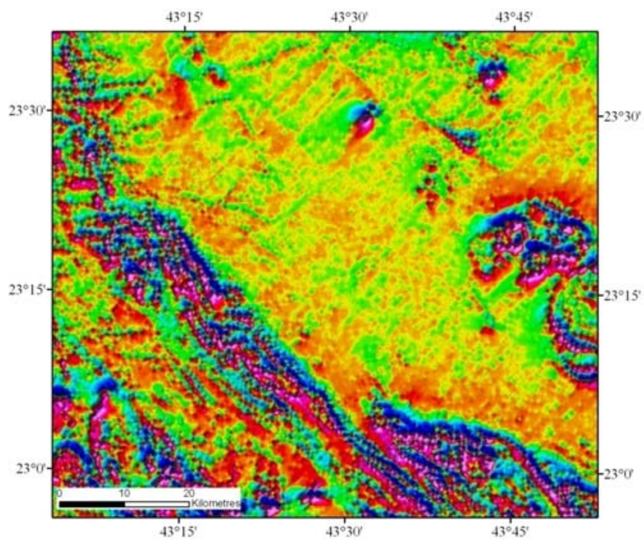

Figure 7: FVD of the aeromagnetic data microlevelled using FFT decorrugation seen in Figure 4.

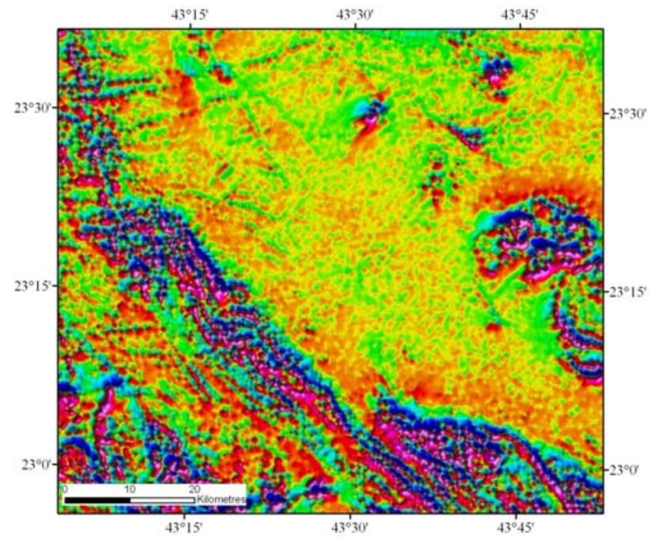

Figure 8: FVD of the aeromagnetic data microlevelled by decorrugation of Naudy-Fuller filters seen in Figure 5.