Abstract

The resolution of aeromagnetic surveys with line spacings ranging from 200m to 2km was investigated using the energy spectral analysis, multi-window test (MWT) technique. A set of located data from the San Luis basin was sub-sampled to simulate the effect of different survey parameters, in particular line spacing, on the resolution obtainable using MWT.

Widely spaced surveys were found to poorly delineate intersedimentary magnetic horizons and were unable to detect shallow magnetic features while surveys with line spacings of 200 and 400m produced the best results.

Introduction

The resolution of magnetic survey data is determined by the line spacing, flight altitude and other factors such as instrumentation. In this paper a high resolution dataset with 200m line spacing is sub-sampled to simulate the effect of wider line spacing on results derived from energy spectral analysis. The Multi-Window Test (MWT) technique (Yates, et al., 2008) was applied to seven sub-sampled sets of data to determine the depth to magnetic horizons or interfaces in the San Luis basin, Colorado, U.S.A.

Methodology

Energy spectral analysis can be applied to study geological trends and signatures based on gridded magnetic and gravity data. The energy spectrum of a grid is computed using standard FFT procedures and the logarithm of the radial (spatial) average of the energy spectrum is plotted versus the radial frequency (Spector and Grant, 1970). The slopes of linear segments of the decay of the spectrum correspond to separate depth ensembles. The higher frequency end of the spectrum is dominated by the anomalies derived from shallow bodies and noise, while at the low frequency end the main contributors to the energy spectrum are deep-seated bodies (Kivior, 1993). The Moving Window procedure involves computing a spectrum from a window of grid points then moving the window by one grid cell. In this way the study area can be covered by many overlapping windows and their spectra.

In the Multi Window Test (MWT) or technique, energy decay spectra are calculated with a window size increment of two grid cells at every grid point along a chosen profile, resulting in a. large number of spectra for each grid point. Spectra calculation is performed with a range of dynamically varying window functions to allow for a very fine control of noise and other artifacts. Energy spectra are then automatically analysed to obtain estimates of the decay function, and hence, depth estimates (Yates et al., 2008). A range of filters are applied to the decay spectra, so as to obtain the most stable depth estimates. These depth estimates are further processed for visualization.

Visualization is primarily performed using a density outlining method, where the relative density of depth estimates from different window sizes is displayed. A density plateau is a depth at which the depth estimates remain approximately the same when the window size is incremented and have often been found to coincide with susceptibility contrasts when using magnetic data or density contrasts when using gravity data. These susceptibility contrasts usually correspond to magnetic horizons or interfaces. The profiles shown below are colour coded with red representing depths with the largest density plateaus (and thus, strongest interfaces) while blue represent the smallest plateaus.

Procedure

The degree of detail that can be resolved from a survey depends on the spacing of acquisition lines along with other parameters such as acquisition height, sample spacing, instrumentation etc. This paper attempts to quantify the line spacing required to resolve geological structures when using energy spectral analysis. Located data acquired on behalf of the USGS in the San Luis Basin, Colorado, U.S.A. in 2004 was used to test the resolution of the method (Bankey et al., 2005). The survey was flown along east-west traverses that were spaced 200m apart at approximately 150m altitude. This survey was chosen because the located data is freely available and the 200m line spacing is around half the more common line spacing used over sedimentary basins (400-500m). A 30x30km area in the northern part of the survey was chosen as a test area because there are relatively deep sediments and this part of the survey is closest to a seismic traverse across the northern part of the basin (Figure 1).

After the tie lies were removed from the dataset, the data was gridded at 40x40m which is one fifth of the line spacing. The resulting TMI grid was reduced to the pole using the inclination and declination that the USGS researchers applied with their analysis (64deg and 10deg respectively) (Figure 2). In order to simulate a 400m line spacing survey, every second line was removed from the line data and an 80x80m grid was produced which was then reduced to the pole in the same manner as the 40x40m grid. This procedure was followed to produce 600m, 800m, 1000m, 1600m and 2000m line spacing datasets which were gridded at 120x120m, 160x160m, 200x200m, 320x320m and 400x400m respectively. These grids were all reduced to the pole and the resulting data prepared for spectra computation.

An east-west profile along 4135000mN was chosen (Figure 2) and MWT spectra were computed at every grid point along the profile. The number of window sizes used and the smallest and largest window sizes depend on the grid cell size and the expected geometry of the basin. The minimum depth that could be detected is determined by the grid cell size. The smallest window used was 20 grid cells for all datasets while the maximum window size varied depending on the grid cell, for example, the maximum window size for the 40x40m grid was 500 grid cells or 20km. The minimum window size was set at 20 because of the requirement for sufficient points for the spectra to be interpretable but this means that shallower horizons cannot be detected with wide grid spacing. This 20 grid cell restriction means that the minimum window size with the 400x400m grid is 8000m.

The spectra for each window size and at every grid point were interpreted automatically because of the very large number of spectra generated. However, automatic interpretation is not always successful, especially where there is significant noise or the geology changes rapidly. For this reason, a quality control procedure was implemented where depth versus window size plots were prepared for selected points along the profile; these were manually checked for plateaus and the plateau depth was plotted on the MWT cross-section. This QC analysis was repeated on the output from several different grids.

Results

The profiles shown in Figures 3a-g, confirm the expectation that increasing the grid spacing decreases the resolution. As the grid spacing increases the lateral resolution declines and the plateaus become less well defined which makes it more difficult to select the correct window size for manual interpretation and for quality control of the automatically interpreted results. Note that the points on the profiles in Figure 3a-g are smallest on Figure 3a and largest on Figure 3g.

The density plateaus represented by red on the profiles below (Figure 3), become less dense and, therefore, tend towards the blue part of the colour scale on successive profiles. This is because there are less window sizes that the particular depths can be determined from, which is related to the number of points on the spectrum graph. Where there are few points, the automatic interpretation program has difficulty in correctly picking the slope of the decay of the spectrum so that depth estimate is rejected. The parts of each profile that are white are depths where there are no results or where depth estimates have been rejected as unreliable.

There is a strong plateau on Figure 3a, centred at approximately 420000mE and 1200m deep, that becomes more and more difficult to define as the data is progressively sub-sampled. The plateau is poorly defined and the estimates of depth to the interface have a large range on Figure 3f (320x320m grid spacing) and the plateau has disappeared altogether on Figure 3g (400x400m grid spacing).

The MWT profile, shown in Figure 3a, has a series of strong plateaus between the western edge of the profile and 415000mE, with a depth range of approximately 400 to 700m. This series of plateaus can still be seen on Figure 3e (200x200m grid spacing) but there are only a few locations and depths with a high density of results while the plateaus cannot be determined on Figures 3f and 3g because there are insufficient points on the spectra to interpret these depths.

Conclusions

The results from the MWT analysis have shown that the resolution of the survey data has a significant impact on the ability to accurately define depths to magnetic horizons or interfaces using energy spectral analysis. High resolution surveys with line spacings of 200 and 400m are needed to image subtle intersedimentary horizons while energy spectral analysis using widely spaced surveys of 1600m or 2km can not resolve shallow features.

The data used for this study was made available for research purposes by the USGS.

References

Bankey, V., Grauch, V., J., S., Webbers, A. and PRJ, Inc. (2005). 'Digital data and derivative products from a high-resolution aeromagnetic survey of the central San Luis basin, covering parts of Alamosa, Conejos, Costilla, and Rio Grande Counties, Colorado, and Taos County, New Mexico', Open File Report 2005-1200, USGS.

Kivior, I., Boyd, D., Shi, Z., and McClay, K., R., 1993, 'Crustal Studies of South Australia based on Energy Spectra Analysis of regional magnetic data': Exploration Geophysics, 24, 603-608.

Spector, A., and Grant, F., 1970, 'Statistical models for interpreting aeromagnetic data': Geophysics, 35, 293-302.

Yates, S., Kivior, I., Damte, S., Markham, S., L., and Vaughan, F., 2008, 'Imaging multiple horizons with spectra techniques in the Sirt Basin, Libya': in press.

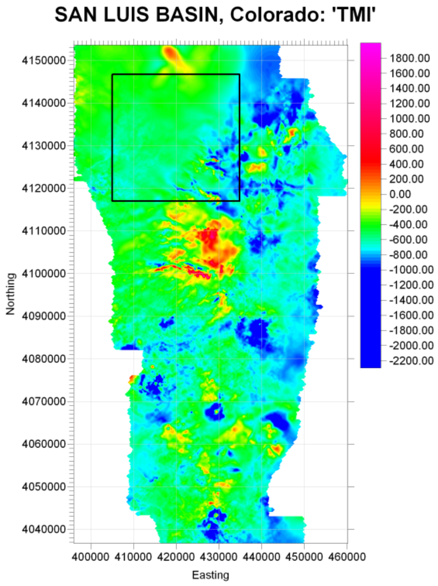

Figure 1. San Luis basin survey. 'TMI'
Square outlines study area

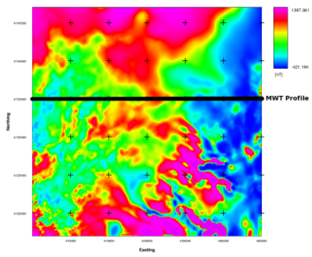

Figure 2. RTP image of study area
Black line indicates MWT profile

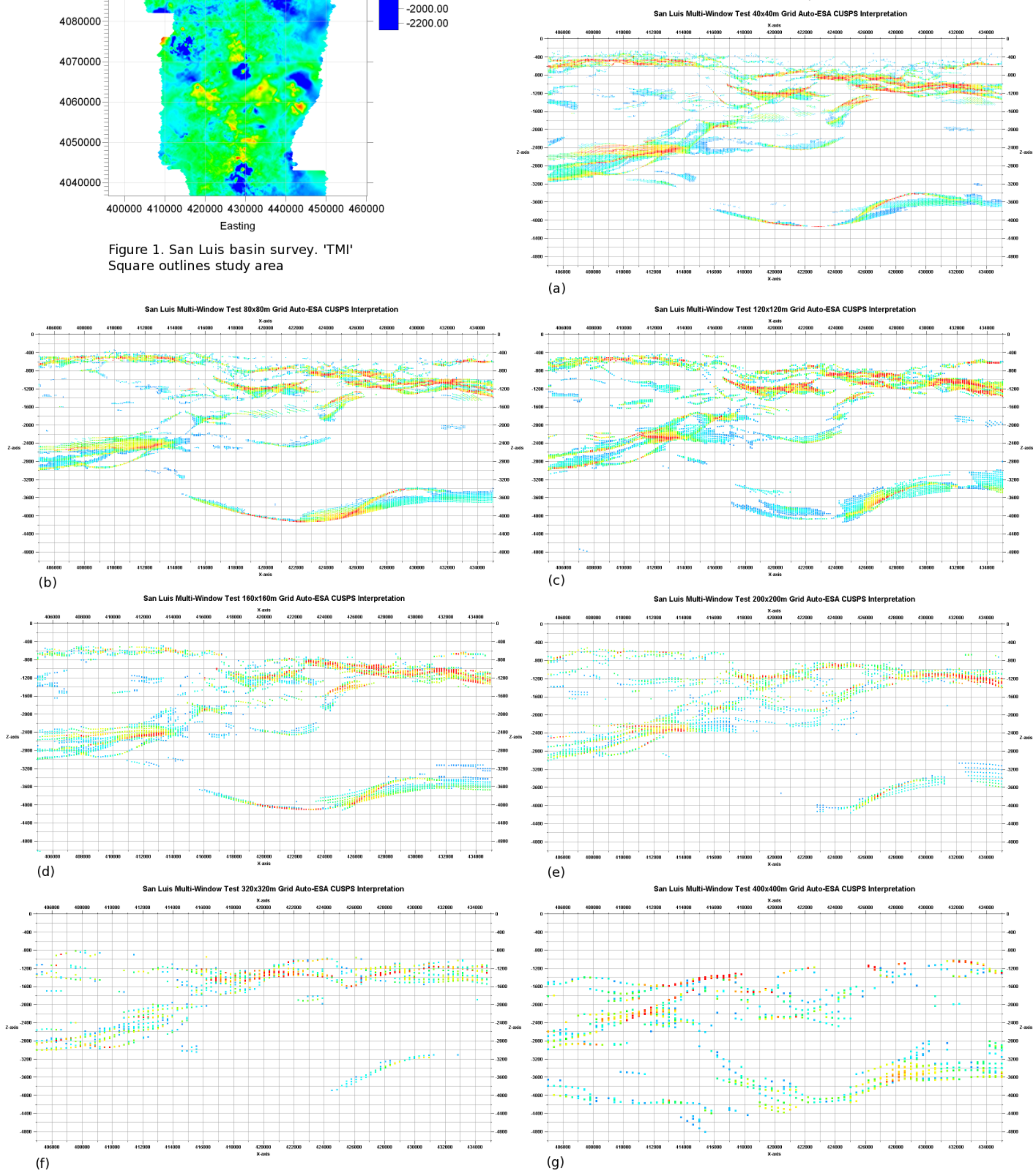

Figure 3. Automatically interpreted MWT profiles along 4135000mN using (a) 40x40m grid, (b) 80x80m grid, (c) 120x120m grid, (d) 160x160m grid, (e) 200x200m grid, (f) 320x320m grid and (g) 400x400m grid