CULTURAL EDITING OF HRAM DATA COMPARISON OF TECHNIQUES

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ABSTRACT

High resolution aeromagnetic (HRAM) surveys are typically flown at altitudes less than 150 m above the ground using sensitive magnetometers. Contamination from man-made magnetic objects (cultural noise) such as oil wells, pipelines, power lines and metal buildings can be significant since the magnetometer is close to them. Cultural anomalies, being near the ground surface, generally have short wavelengths (high frequencies) that overlap wavelengths of magnetic anomalies associated with shallow geological features. These shallow features are of particular interest to explorationists. For example, they may be used to determine potential fluid pathways within a sedimentary basin and to identify shallow faults, dikes and mineral deposits. Cultural effects must be removed from the data and the data relevelled before the geology, and in particular the geology associated with the shallow sedimentary section, can be properly interpreted. There are several methods available for identifying and suppressing cultural noise from aeromagnetic data. This paper describes three of these methods (ranging from a manual method to an automated method of picking cultural events) and compares their ability to locate and remove cultural noise. All three techniques apply some method of surgical removal and/or smoothing to remove the noise from the data. The main conclusions from this study are: 1) no method works under all conditions; 2) manual methods are the most reliable when the geological targets of interest are shallow; and 3) cost and time may be the determining factors for choosing a method. Automatic methods are less costly and faster; manual methods are more expensive and time consuming.

INTRODUCTION

The high frequency (short wavelength) content of high resolution aeromagnetic (HRAM) data consists of several components: cultural noise generated by near surface man-made objects, aircraft noise and signal generated by geology. These components overlap, distorting the geological signal, and in some cases, noise completely dominates the high frequency components of the spectrum. The high frequency geological signal can be a very important component of HRAM data, particularly when interpreting data from sedimentary basins or data associated with shallow mineral targets such as kimberlites. The short wavelength geological signal in a sedimentary basin is often associated with intra-sedimentary faults that can provide conduits for fluid movement within the basin and hence hydrocarbon migration pathways.

Noise generated from culture is randomly distributed within the HRAM data and often has the same magnetic characteristics (high frequency, short wavelength and often low amplitude) as signals generated from subtle geological features. Therefore, it is difficult to separate these two components using conventional digital filters. Furthermore, sharp anomalies related to wellheads or other culture are actually broad band in their frequency content, even though they appear to be high frequency. If such spikes are not culturally edited, the low frequency component of each spike will appear as a subtle low frequency feature in filtered versions of the data which are designed to image deep targets.

The effect of cultural noise is also illustrated on the power spectrum plots of the total magnetic field for the HRAM data prior to cultural editing (Figure 1a). It is evident in Figure 1a that the noise dominates the high frequency components of the spectrum. Also note the high frequency spikes in the radial power spectrum of Figure 1 and how they have clearly disappeared after manual cultural editing (Figure 1b). Any effort to remove or suppress cultural noise from HRAM data should attempt to keep the geological signal intact. The overlap between these signals often prevents this from happening, particularly when an automatic method is used to locate and remove the noise. In regions where the objectives of the HRAM survey are deep targets, the removal of short wavelength geological features may not be detrimental to the interpretation. However, removal of short wavelength geological features in areas where the objectives are shallow targets could be very detrimental for the interpretation.

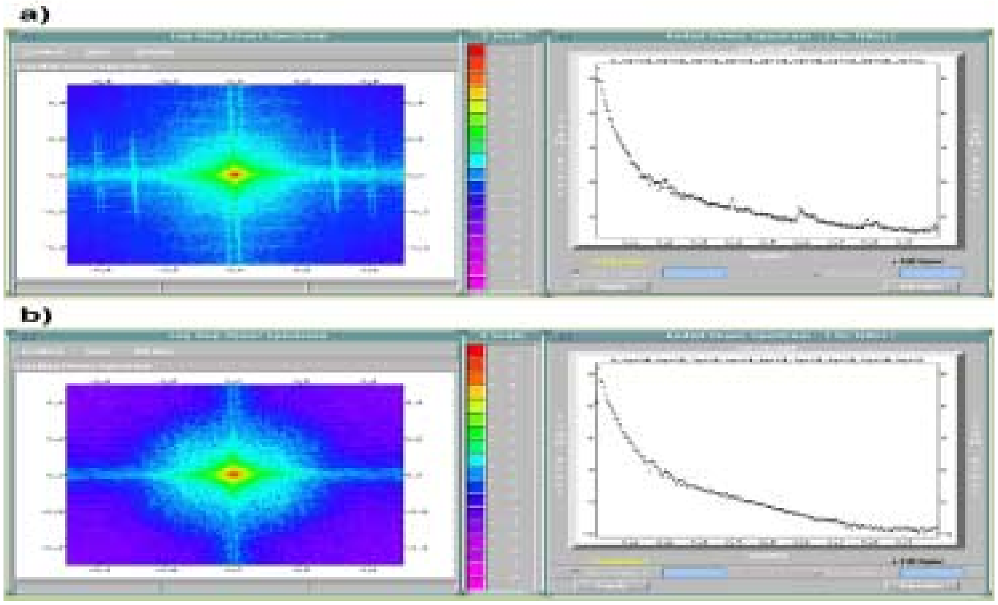

Figure 1. Map and radial spectral plots of total magnetic field for data from the Peace River area in northeast British Columbia: a) before cultural editing; and b) after manual cultural editing. The map spectrum plots DC power at the center out to 0.5 Nyquist at the edges. The radial spectrum is a sweep of the map spectrum and is plotted out to the Nyquist frequency.

METHODOLOGY

Several techniques for locating and removing or suppressing cultural noise are now discussed. The three methods considered in this paper are: 1) manual; 2) semi-automatic; and 3) automatic. In all three cases the data should be relevelled after cultural editing.

Manual Technique

The manual technique involves surgical removal of cultural noise and in-filling with a smooth curve on a line by line basis. The HRAM data are plotted as profiles at a scale suitable for identifying high frequency (short wavelength) features (spikes) on the magnetic profiles. The locations of these spikes are picked manually by an experienced technician or geophysicist and marked on the profiles. The marked spikes are checked against ground-track videotapes of the survey by a technician to determine if a feature is caused by surface culture. Spikes identified as culture during video checking are plotted on a map along with the flight lines, known culture (e.g., wells and pipelines) and rivers. An experienced geophysicist inspects the profiles on a workstation and interactively edits the data.

The process consists of three stages:

a. visually inspecting paper profiles to flag magnetic features that could be potential cultural noise;

b. checking these flagged features on in-flight video recordings and plotting those associated with visible culture onto a map; and

c. interactively editing the cultural noise profile by profile using a workstation.

The interactive editing procedure consists of replacing the noisy data with a best-fitting polynomial curve that uses the original sampled data points, thereby maintaining continuity of the data and retaining as much geological signal as possible in the area affected by the cultural noise. The characteristics of the polynomial as well as the length of the replacement gate are determined by the editing geophysicist. This is an intensive hands-on approach and, as such, is the slowest and most expensive of the three techniques described in this paper. It works best in areas where there are good digital databases of well locations and pipelines.

Semi-Automatic

The semi-automatic technique, briefly described here (Pearson, 1996), involves computing the theoretical magnetic responses of different forms of cultural noise and then matching these responses to the HRAM data on a profile-by-profile basis to identify potential cultural noise using a pattern recognition technique. The noisy region is removed from the profile and refilled using a function based on an upward continuation filter of the removed portion of the data. The amount of upward continuation is determined by the processor on an anomaly-by-anomaly basis.

The process consists of three stages:

a. developing theoretical magnetic responses of the different cultural noise sources;

b. using neural network based pattern recognition techniques to locate regions of potential cultural noise on the HRAM profiles; and

c. surgically removing the noisy data and replacing it with an upward continued function. The amount of upward continuation depends on the individual anomalies.

This approach is not fast, because each cultural event must be evaluated by an experienced technician or geophysicist. It is approximately twice as fast as the manual technique.

Automatic Technique

The automatic technique, commonly referred to as cultural suppression, is based on using the analytic signal of the total magnetic field to identify cultural events. A low pass filter designed for the specific area is applied to the analytic signal to retain all longer wavelength features. The original and filtered analytic signals are then compared in order to identify the large amplitude, short wavelength magnetic anomalies typical of most forms of cultural noise. The method involves several passes of the data using higher frequency cutoffs that endeavor to identify progressively lower amplitude cultural noise. The cultural responses are then suppressed using a mathematical function that removes noise to a chosen maximum amplitude (typically 1 nT) specified by the operator. The number of passes and the detection parameter are adjusted until the technician or geophysicist is satisfied that the maximum amount of cultural noise is suppressed without adversely affecting the geological responses.

The process consists of three stages:

a. computing the analytic signal;

b. applying low pass filter on the analytic signal to identify cultural noise - use several passes with different high frequency cutoffs to progressively identify lower amplitude cultural noise; and

c. suppressing the cultural noise to a selected maximum amplitude using a mathematical function.

There is flexibility for an experienced technician or geophysicist to spend as much or as little time as desired evaluating particular cultural anomalies. This approach is the fastest of the three methods because there is limited manual intervention.

This approach can also be implemented as a semi-automatic process in which zones of cultural noise are selected manually, rather than automatically. The mathematical function used to correct the data is the same as in the automatic technique.

The final edited magnetic data for all three of these techniques often must be relevelled prior to further processing.

Comparison Of Techniques

The purpose of cultural editing is to remove as much of the cultural noise as possible from the HRAM data while retaining as much of the geological signal as possible. This is quite a challenge. In areas with significant development of facilities, cultural editing may be very difficult to carry out. Cultural noise generally produces short wavelength (high frequency) and low amplitude responses. There are certain types of cultural noise however that can have short wavelengths, but large amplitudes. There are even some longer wavelength (low frequency) cultural responses caused from interference of a number of closely spaced noise sources or from flight lines sub-parallel to linear noise, such as power lines and pipelines. Cultural responses can even vary from profile to profile for the same man-made noise (e.g., pipelines).

The task of removing such a variety of noise sources from the HRAM data while retaining the shallow geological signal, whose frequency content significantly overlaps the frequency content of the noise, is indeed difficult. Automatic methods of removing or suppressing cultural noise have more difficulty than manual methods in distinguishing shallow geological signals from noise since the visual verification of the correlation of the noise with culture is not done. A certain amount of the shallow signal may be removed during cultural editing using these methods. On the other hand, manual methods sometimes have difficulty determining whether a particular feature is noise or signal when no culture is visible at surface. There is a chance therefore that some noise will remain and some signal will be removed during manual cultural editing. We shall now use a few examples to illustrate these points.

The profiles in Figure 2 compare the semi-automatic technique with the manual technique. The profile along the bottom is the total magnetic field before cultural editing. The location of cultural features (two pipelines and two cased wells) and two rivers are shown on this profile. The upper profile is the unedited (bottom) profile minus the edited profile (semi-automatic), and the middle profile is the unedited profile minus the edited profile (manual). Both these techniques did a good job in removing the cultural events. Note in this case that the semi-automatic method also removed the magnetic response associated with both rivers. In this example the semi-automatic method removed signal as well as noise. Given that the courses of both rivers are fault-controlled, the removal of these river responses is undesirable.

The profiles in Figure 3 compare the automatic method with the manual method for a profile from the Athabasca HRAM survey (Best et al., 1998, this volume). The response from a pipeline is evident on the unedited (bottom) profile. Note in particular the large negative side lobes on each side of the peak. The width of the magnetic anomaly caused by the pipeline is between 600 m and 800 m (10 fiducials = 10 s flying time which is about 700 m), which is a short wavelength (high frequency) anomaly with an amplitude of nearly 100 nT. The other three profiles, going from top to bottom, are the edited magnetic profile (automatic version of cultural suppression method), the edited magnetic progile (semi-automatic version of cultural suppression method) and edited magnetic profile (manual method). The manual method removed the pipeline response, while the cultural suppression method still has an amplitude of approximately 25 nT where the pipeline was located. The small magnetic feature near fiducial 290 was removed by the manual process, but was retained by the cultural suppression process. Figure 4 shows a similar result for a different profile illustrating the difference between edited and unedited profiles. In this case, the semi-automatic method of cultural suppression did not select the large anomaly associated with the pipeline. The manual method removed a small magnetic response near fiducial 1522 that could be a shallow geological feature.

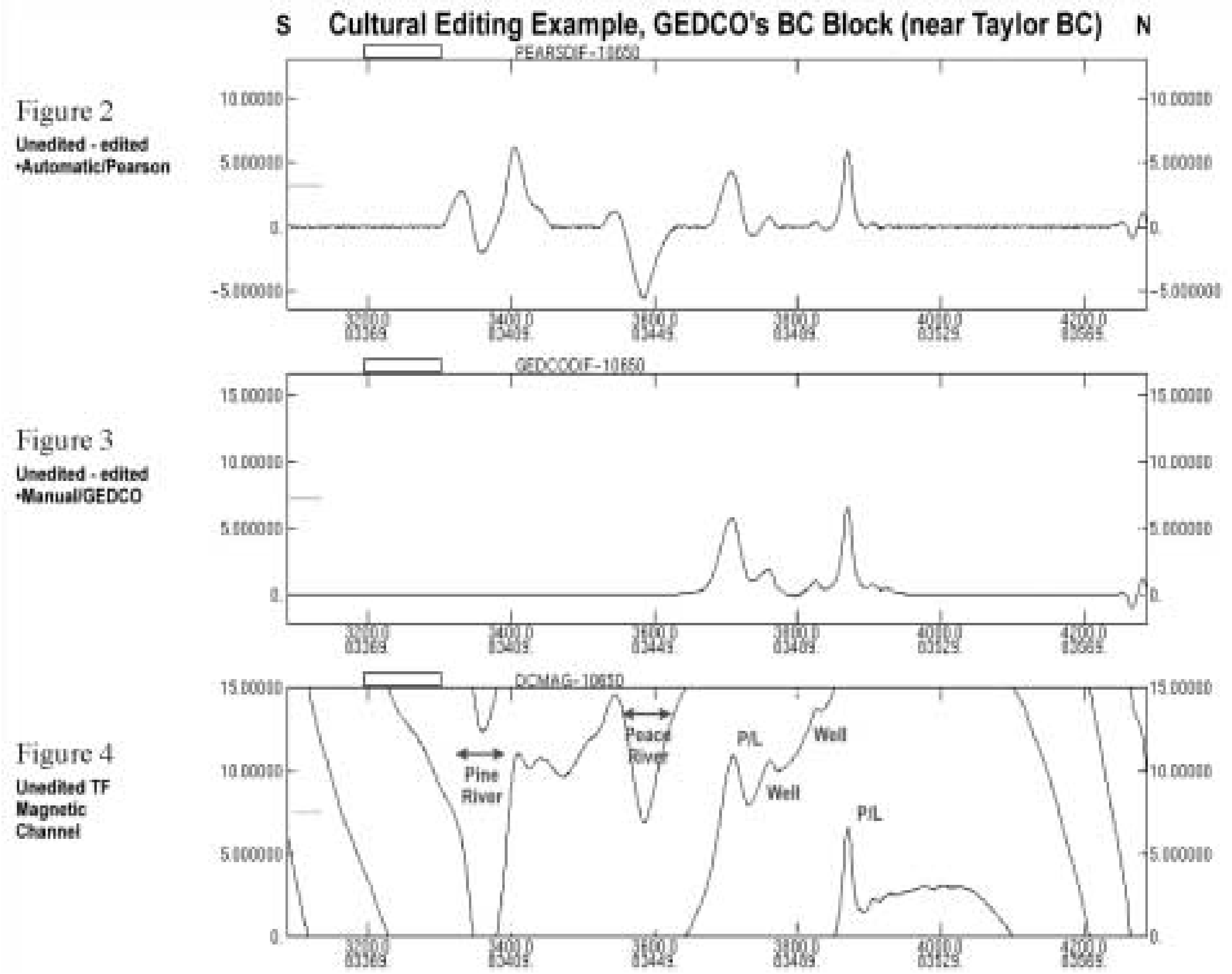

Figure 2. Cultural editing example for a profile in same data set as Figure 1. The vertical scale on all profiles is in nT. The upper annotation is sample number (about one sample every 6-8 m, depending on aircraft speed), and the lower annotation is fiducial (FID) number. The lower profile is the unedited magnetic field, the middle profile is the difference between the unedited data and manual edited data, and the top profile is the difference between the unedited data and semi-automatic edited data. The magnetic response of the Peace and Pine River Valleys reflects both the terrain effect of the river valleys, where iron-rich cretaceous sediments outcrop in the valley walls, and the magnetic signature of deeper fault control, which controls the courses of both rivers.

Figure 3. Cultural editing for a profile in the Athabasca area (Best et al., 1998, this volume). The lower profile is the unedited data, the next profile is manually edited data, the next profile is the semi-automatic version of the culturally suppressed data, and the top profile is the automatic version of the culturally suppressed data.

Figure 4. Cultural editing for a profile in the Athabasca area. The lower profile is the unedited data, the next profile is the difference with manually edited data, the next profile is the difference with the semi-automatic version of the culturally suppressed edited data, and the top profile is the difference with the automatic version of the culturally suppressed data.

SUMMARY AND DISCUSSION

Cultural noise caused by man-made objects can severely distort HRAM data, particularly in areas of heavy infrastructure such as oil and gas producing regions. The removal or suppression of this noise is therefore an essential step in HRAM processing. Relevelling is required after cultural editing.

Each of the cultural editing procedures described in this paper has advantages and disadvantages. Table 1 lists the major advantages and disadvantages of the manual and automatic methods, with semi-automatic methods falling somewhere in the middle. The examples given in Figures 2, 3 and 4 illustrate several of the more technical advantages and disadvantages.

Automatic techniques that remove the high frequency response from HRAM data without detailed checking against known and suspected culture are more likely to remove a portion of high frequency geological signal along with the cultural noise. This may or may not be acceptable, depending on the objective of the survey. Automatic methods are fast and hence less costly than manual methods. In some cases time and cost are of the utmost importance.

Semi-automatic techniques are more hands-on than automatic techniques and therefore avoid some of the pitfalls. They are, of course, somewhat slower and more expensive.

Manual techniques are slower and more expensive because they require considerable hands-on interaction. These methods are more selective of the noise and generally remove less high frequency geological signal than automatic methods. The ability to remove all noise and to leave all the geological signal is directly dependent on the skill of the geophysicist doing the interactive editing and the quality of the databases used to create known man-made features. Manual procedures generally provide a more selective method for removing cultural noise when the geological objectives are shallow (intra-sedimentary faults, shallow mineral targets, etc.) In these cases, better separation of noise and signal is worth the additional cost and time.

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Table 1

	Manual	Automatic
Advantages	cultural noise more easily identified	much less expensive
	high percentage of cultural noise removed	high percentage of cultural noise removed
	less geological signal removed	no processing delays
	more effective in severely contaminated areas	greater potential for loss of geological signal
Disadvantages	expensive	greater potential for loss of geological signal
	time-consuming	less effective in severely contaminated areas
	not all cultural noise is removed	not all cultural noise is removed
Subjective	interpreter must choose which anomalies are culture and how wide a piece of data to edit	processor must choose amplitude cutoff and judge results

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