Enhanced HRAM anomalies correlate faults between 2D seismic lines

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Summary

Correlation of faults between 2D seismic lines using enhanced magnetic anomalies is illustrated by this example from a High-Resolution AeroMagnetic (HRAM) survey near the Weyburn oil field in S.E. Saskatchewan, Canada, as part of the IEA Weyburn CO2 Storage and Monitoring Project. Advanced HRAM data processing revealed linear short-wavelength anomalies that closely correlate with a number of faults interpreted on 2D seismic sections. These fault-associated magnetic anomalies were used to correlate interpreted faults within 2D seismic coverage area and beyond its limits.

Introduction

Correlation of faults between widely spaced 2D seismic lines is always ambiguous, especially when seismic sections are of different vintages and processing quality. The ambiguity of this "undersampled" correlation can be significantly reduced by integration with the HRAM data. Closely spaced (500m or less) HRAM acquisition lines provide dense and even data sampling over the regional-scale areas.

Structural discontinuities such as faults, subcrops, lithological contacts and depositional edges can create lateral contrasts in magnetization of rocks. Lateral magnetization contrasts often generate detectable magnetic anomalies (Glenn and Badgery; 1998, Grauch et al., 2001; Goussev et al., 2003), many of which are sourced in the sedimentary section. Data processing techniques, like band-pass filtering, can enhance these subtle magnetic anomalies to make them coherent and correlatable over large areas. Magnetic inversion methods, like Euler deconvolution and Werner deconvolution, provide clusters of magnetic depth solutions that can be correlated laterally over HRAM lines and indicate a presence of structural discontinuities.

The study was focused on the Souris River Fault, named after the river that bends sharply along the strike of the dominant intra-sedimentary magnetic anomaly. Magnetic inversion (2D Euler deconvolution) was used to assess the shallow penetration of this deep-rooted fault.

HRAM Data Acquisition and Enhancement

The S.E. Saskatchewan HRAM survey was flown at about 140m above the ground along the orthogonal flight lines with 500m spacing between east-west oriented traverse lines and 1500m between north-south oriented control lines. Pre-processing of the acquired data included standard corrections (diurnals and IGRF), cultural editing, leveling and gridding with a 150m grid cell size. Gridded data were reduced to the pole to compensate for local inclination and declination of the Earth's magnetic field.

Filtering is a conventional method of enhancing magnetic anomalies associated with structural discontinuities. Extended testing of various filtering techniques was conducted for this study. Fig. 1 shows the response of a 1.6-3.2km band-pass filter applied after 1.2-2.4km depth separation (Jacobsen, 1987) of the total magnetic field overlain with the Souris River Fault.

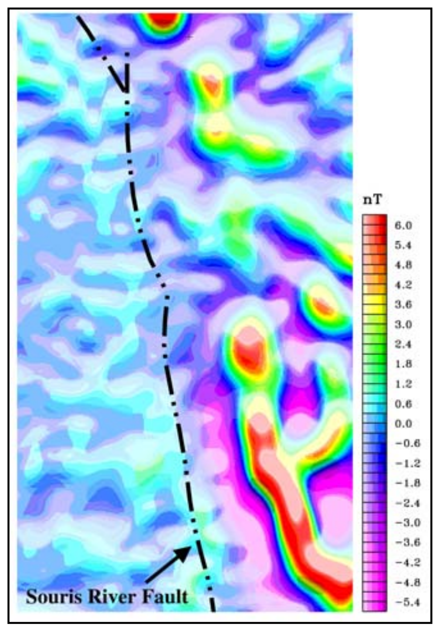

Figure 1: 1.6-3.2km band-pass filter after 1.2-2.4km depth separation of total magnetic field with the Souris River Fault.

Apparently, the fault under consideration has no distinct magnetic signature here and follows a weak trend of truncations of subtle anomalies. Fig. 2 shows the response of the cascaded Goussev filter (Goussev et al., 1998, 2003) overlain with Souris River Fault. This filter was designed with the same pass and separation parameters as Fig. 1 plus the calculation of a difference between the total and horizontal gradients. Comparing responses of the conventional filter (Fig. 1) and cascaded Goussev filter (Fig. 2), the latter has a superior suppression of noise and lateral resolution. Moreover, it enhances the anomalies transparent for conventional filtering.

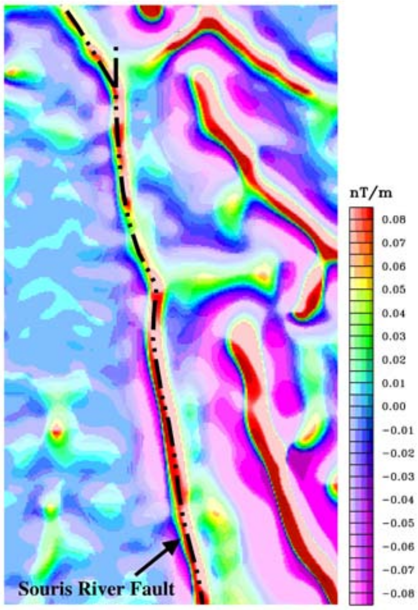

Figure 2: 1.6-3.2km band-pass of Goussev filter after 1.2-2.4km depth separation of total magnetic field with the Souris River Fault.

Modeling shows that in the case of a fault vertically offsetting magnetized layers (Grauch et al., 2001), the response of these filters will be opposite: trough after applying any conventional filter (band-pass, matched or separation) and peak after the cascaded Goussev filter (Goussev et al., 2003).

Magnetic inversion is a complementary method of obtaining structural information from the HRAM data. We use MaFIC (Magnetic Fault Interpretation Cube) for 3D visualization of 2D Euler deconvolution and 2D Werner deconvolution magnetic depths solutions (Rhodes and Peirce, 1999). Fig. 3 shows the MaFIC Euler deconvolution depth slice at 150m below the surface overlain with the Souris River Fault. Surface drainage is shown in black. The north-south trend of shallow magnetic depth solutions closely follows the Souris River Fault indicating that this fault extends up to the shallow depths.

2D Seismic Data and Fault Interpretation

Three nearly parallel SW-NE oriented 2D seismic lines (#1, #2, #3) have been chosen in and close to the IEA Weyburn CO_2 Storage and Monitoring Project area. Spacing between lines #1 and #2 is 12km and 14km between lines #2 and #3. All interpreted faults (black) have roots in the Precambrian basement (Fig. 4). "A" is the Souris River Fault and "B", "C", "D" are faults that closely correlate with corresponding magnetic anomalies on Fig. 2. Two faults on lines #2 and #3 have apparent seismic signatures of a strike-slip faulting and marked "PFS"- Positive Flower Structure and "NFS" - Negative Flower Structure (Fig. 4).

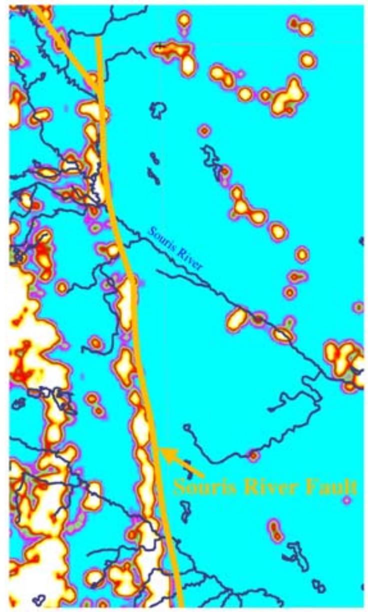

Figure 3: Euler deconvolution depth slice in MaFIC at 150m subsurface with the Souris River Fault.

Correlation of Faults

In the absence of complementary information, the correlation of interpreted faults using only 2D seismic data is very ambiguous, especially for the apparent strike-slip faults. Fig. 5 shows the enhanced HRAM anomalies overlain with 2D seismic lines, seismic fault picks and correlated faults. Note how closely the enhanced magnetic anomalies correlate with fault picks A, B, C, D and the strike-slip fault picks PFS and NFS.

Assuming that a coherent magnetic anomaly is associated with the same type of structural discontinuity over the area of its correlation, we can correlate the fault "A" (Souris River Fault) between and beyond all three seismic lines and faults "B" and "C" between lines #1 and #2. Correlation of fault picks PFS and NFS without reference to the HRAM anomalies is hardly possible at all. Separated by just 14 km, these faults seem to represent the opposite deformation styles: extensional NFS and compressional PFS. Both fault picks are in perfect correlation with enhanced HRAM anomalies which clearly show that these fault picks represent orthogonally trending strike-slip faults: fault PFS trends WSW-ENE and fault NFS trends SSE-NNW (Fig. 5).

Conclusions

(1) Application of the advanced data processing enhances HRAM anomalies that can be used to correlate faults between and beyond 2D seismic lines and, potentially, 3D seismic program areas; (2) integration of 2D seismic and HRAM data provides reliable identification and correlation of strike-slip faults; (3) HRAM data complements seismic programs, both regionally and locally.

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Acknowledgements

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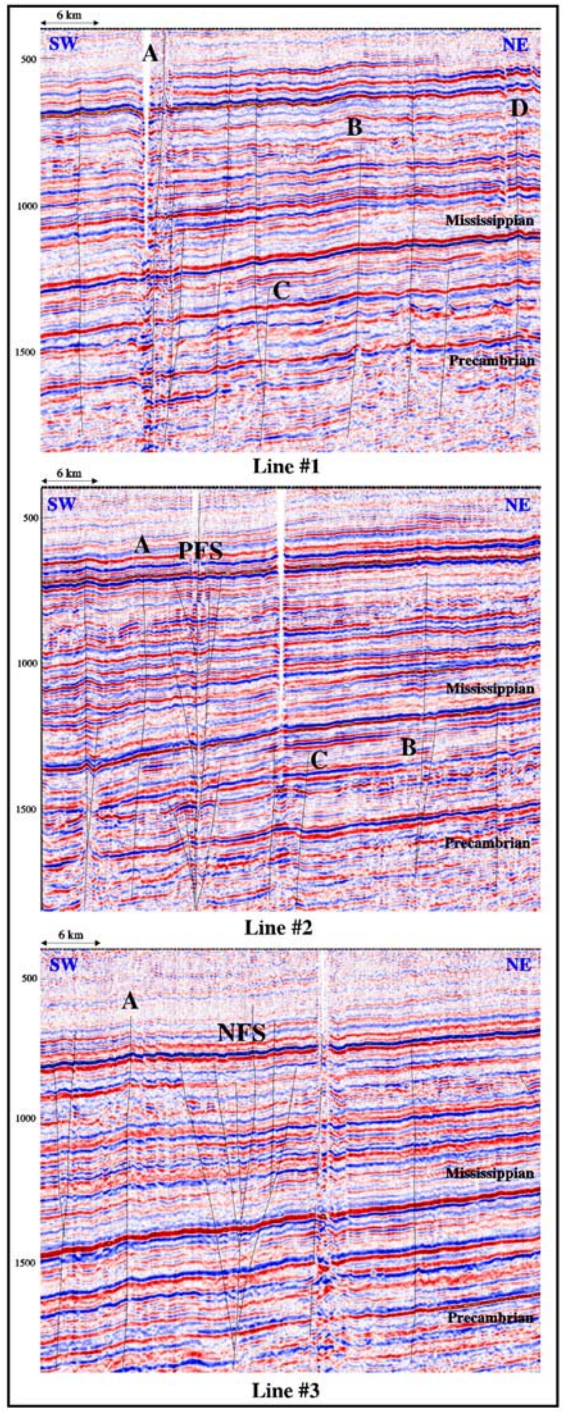

Figure 4: Three 2D seismic sections with interpreted faults. "A" is Souris River Fault.

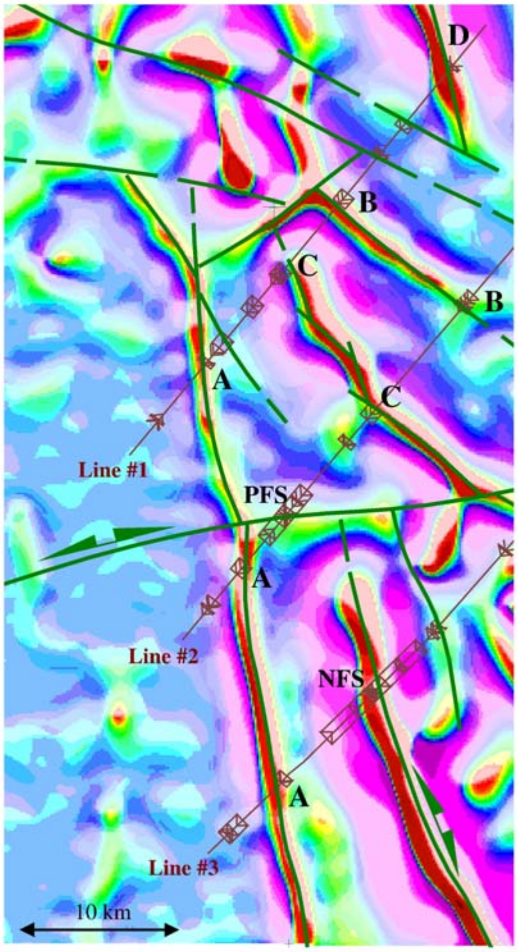

Figure 5: Enhanced HRAM map (cascaded Goussev filter map) with 2D seismic lines, seismic fault picks and interpreted faults. "A" is Souris River Fault.