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Constraining Seismic Interpretation with AeroMag

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Traditionally, magnetic data have been used to map basement faulting, allowing geoscientists to have a better understanding of the structure of the overlying sedimentary section. In the recent past, advances in acquisition, processing and interpretation techniques have made it possible to map intra-sedimentary faulting and fractures as well.

HRAM data are acquired by flying a plane with a magnetometer approximately 100-150 meters from ground surface over an area of exploration interest on a grid with line spacing of 200-800 meters. When flying close to the ground, the magnetometer senses magnetic variations caused by basement crystalline rocks as well as the subtle variations from the sedimentary section, near surface geological signals, and cultural noise from wells, pipelines and other ferrous structures.

The processing and interpretation of HRAM data becomes a task of integration with all available data. The magnetic data at this point show a general distribution of magnetic properties demonstrating broad regional trends. It is important to highlight as much structure as possible through interpretive processing. This is accomplished through various filters, creating a montage of several maps. The processing geophysicist uses the power spectrum of the data and available regional geological control to choose different filters to highlight signals of interest. The result is a set of enhanced magnetic anomaly maps that highlight lineaments. These are due to geological features in the basement and in the sedimentary section, separated by wavelength (longer wavelengths mean deeper sources; shorter wavelengths mean shallower sources). Further perspective can be added by calculating magnetic depth solutions to see faults and structural grain and by displaying these in a 3-D visualization cube with the seismic data.

There is strength in numbers; the ambiguity of separate interpretations drops dramatically with each constraint from a different type of data interpretation that we include. HRAM data continually prove useful in mapping basement faulting as well as understanding the structural grain of the sedimentary section. When interpreting scattered 2D seismic lines, there can be many choices for fault correlation. By combining the available geology and the HRAM data with the seismic fault picks, often one particular correlation becomes compelling. When interpreting small 3-D surveys, it is often hard to make a rational fault map without the regional structural perspective that HRAM can provide. Identifying wrench faults on seismic can be especially challenging because the vertical offset can be small and variable, but the fault can be of a major scale.

In the IEA Weyburn CO_2 Sequestration Project, a large amount of 2-D seismic data was made available to the project for mapping regional scale faults in the area. The purpose of the mapping was to assess the security of the Geosphere as a container for the injected CO_2 gas. The concern about leakage relates to some impurities in the injected gas which would be detrimental to the environment if they leaked to the surface.

Because the faulting patterns were somewhat complicated and the seismic data were relatively widely spaced (Figure 1), we used GEDCO's proprietary HRAM data as an additional constraint to resolve the spatial aliasing of the fault correlations. Figure 2 shows three seismic lines and one filtered version of the magnetic data. There are at least six faults imaged on these three lines and there is no straight forward correlation of the faults between the lines. The situation is made more complicated because the seismic expressions of the individual faults vary from line to line. Using the HRAM data, as enhanced by filtering to emphasize shallow signal, the preferred correlation is shown in Figure 2, with Fault A being the same on all three seismic images and following the distinct magnetic signature of the fault. This previously unknown fault is now called the Souris River Fault because it offsets the flow of the Souris River from its southeasterly regional flow into a short southerly leg for about 10 km. The fault is clearly present at the basement level on depth migrated seismic processing, and it penetrates through the entire section to the surface, as evidenced by the course of the Souris River.
In addition to demonstrating the utility of using HRAM data to constrain ambiguous seismic interpretations, this project also demonstrates clearly that some basement faults penetrate throughout the section in southeastern Saskatchewan. This is an important finding for the IEA CO_2 Sequestration Project. Although there is no evidence that this fault is a leakage path from the reservoir to the surface, the possibility of other basement to surface faults exists, and each must be tested for gas leakage to insure the integrity of the reservoir as a long term storage container.

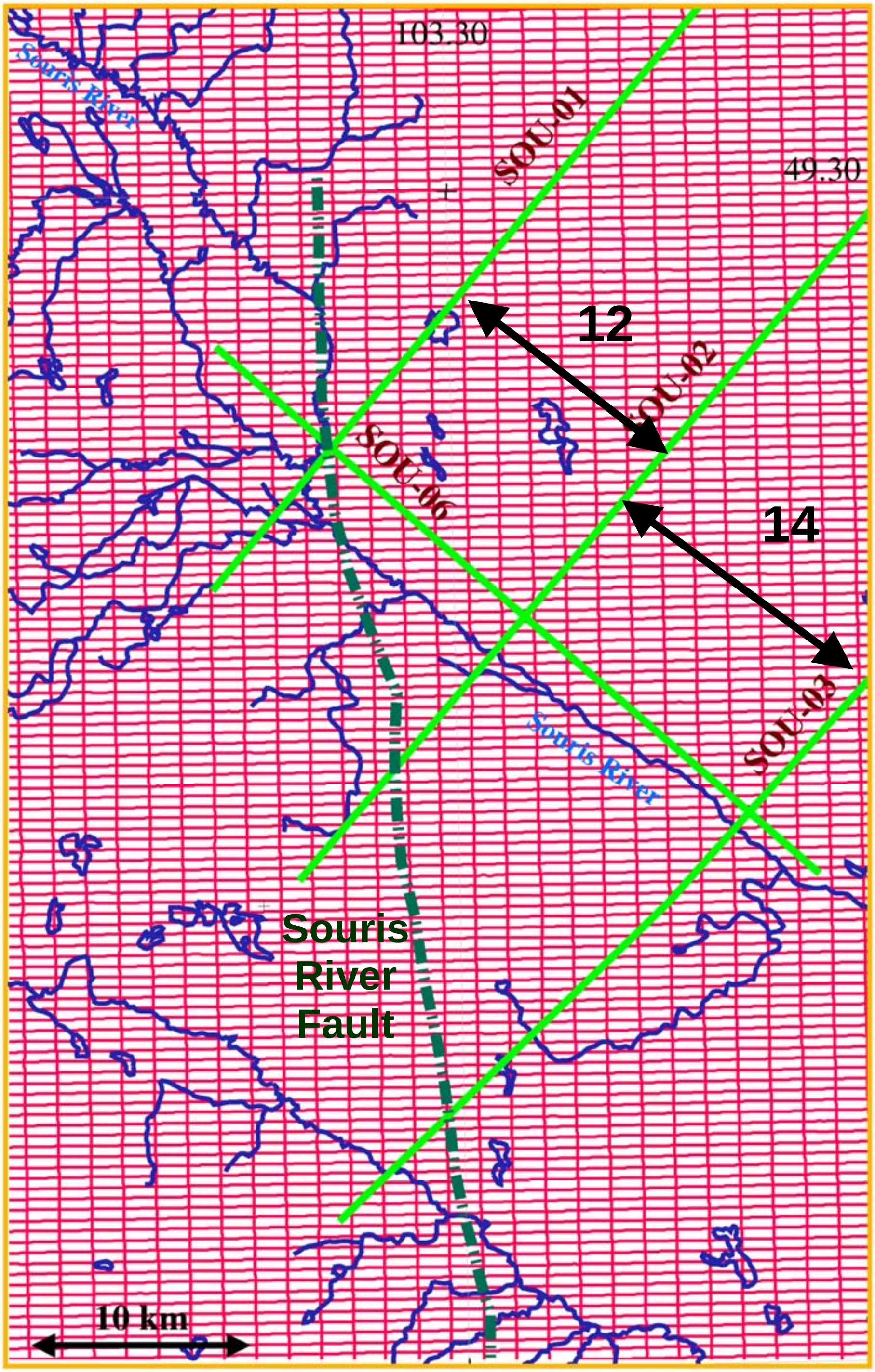

Figure 1: Index map for project showing the use of enhanced HRAM anomalies to correlate faults on 2-D seismic data. This example was completed as part of the IEA Weyburn CO_2 Sequestration Project. The study area is shown in red in the inset. The inner inset shows the distribution of wells in the area, including the Weyburn Field. The red lines show the HRAM data (500×1500m line spacing) and the light green lines show the 2-D seismic data being correlated. The drainage is shown in blue and the interpreted Souris River Fault is shown as a dark green dashed line.

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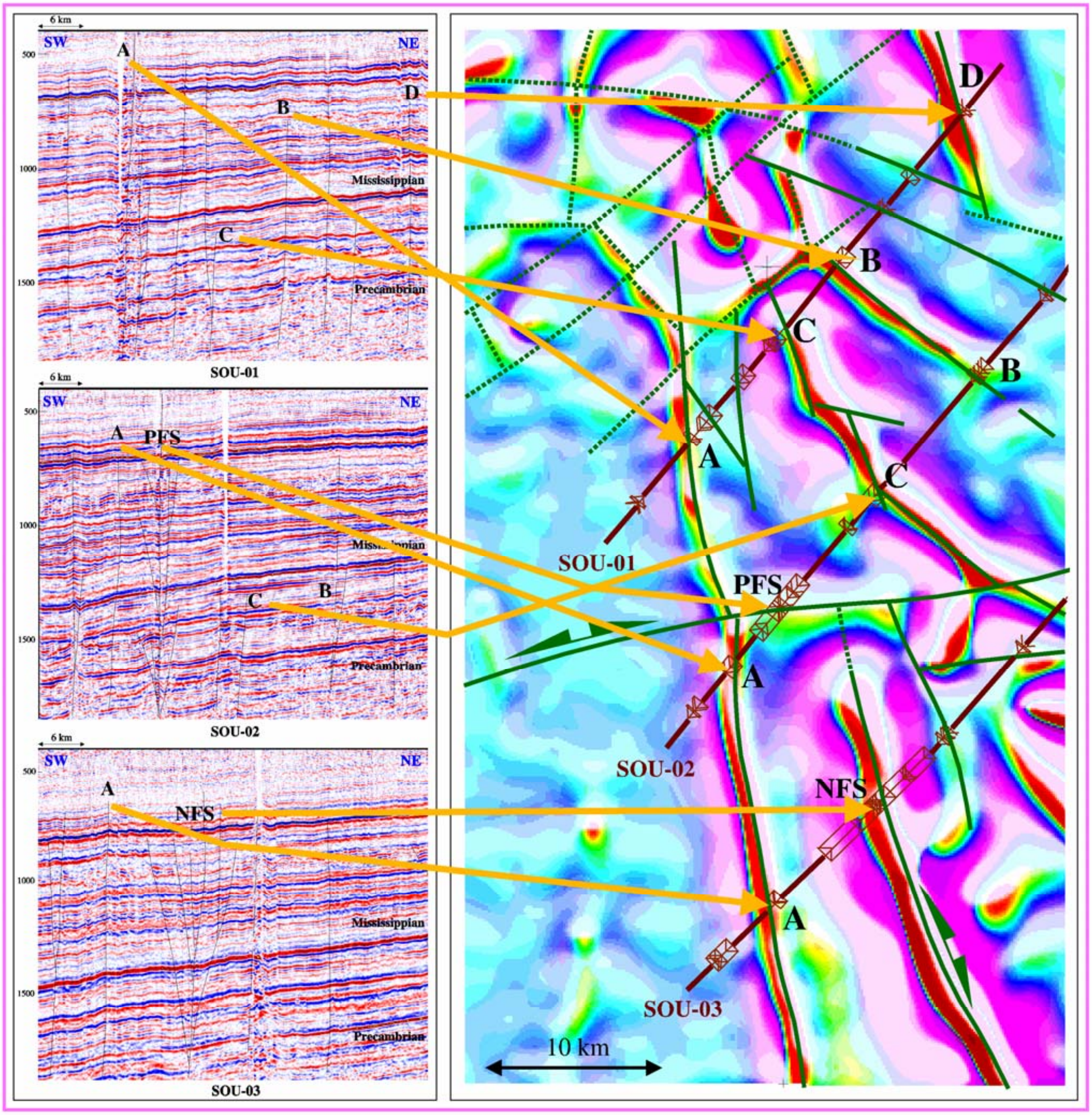

Figure 2: The map on the right shows a shallow filter of the HRAM data (reds are highs and magenta colors are lows). The four seismic lines are shown in dark brown and the fault locations as picked on a seismic work station are indicated. Panels of seismic lines SOU-1, 2 and 3 are shown on the left, with interpreted faults labeled by letters A-D and PFS (positive flower structure) and NFS (negative flower structure). The positions of those faults on the map are connected to the seismic images of the faults by the yellow arrows. Because the seismic character of the faults is so variable, it is unlikely that anyone would correlate fault A across all three lines without the HRAM data as an additional constraint. Goussev et al. (2004) name this fault the Souris River Fault because it offsets the course of the Souris River into a north-south direction for about ten km. This fault offsets basement and penetrates to the surface, so it is an important consideration in the IEA Weyburn CO_2 Sequestration Project.

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Suggested reading

Gibson, R.I., and Millegan, P.S., eds., 1998, Geologic Applications of Gravity and Magnetics: Case Histories; Society of Exploration Geophysicists and American Association of Petroleum Geologists.

Goussev, S.A., Griffith, L., Peirce, J., Cordsen, A., 2004, Enhanced HRAM Anomalies Correlate Faults between 2D Seismic Lines: SEG Extended Abstracts, **23**, 730-733.

Wilson, M. and Monea, M., 2004, IEA GHG Weyburn CO_2 Monitoring & Storage Project Summary Report 2000-2004: from the proceedings of the 7th international conference on greenhouse gas control technologies: Petroleum Technology Research Centre.