Interpreting HRAM data for structural grain – A Canadian example with implications for Brazilian interior basins

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Abstract

High Resolution Aeromagnetic (HRAM) data have been used by the petroleum industry in Canada for more than a decade, primarily in the Western Canada Sedimentary Basin (WCSB) and more recently in the offshore basins of Nova Scotia. HRAM data over the Peace River Arch (PRA), which is a long-lived structurally complex area of the WCSB, has been particularly important for hydrocarbon prospecting. The objective of the HRAM surveys was to map basement and intra-sedimentary fault patterns on a regional scale and to thereby provide a framework for geological interpretation and follow-up seismic exploration.

Agencia Nacional de Petróleo (ANP) is planning several airborne geophysical programs over the prospective interior basins of Brazil in the next several years. The results from this Canadian example show the level of detail that can be interpreted from modern HRAM data when combined with a thorough interpretation using a seismic work station. HRAM interpretation allows us to interpret faults across widely spaced 2D seismic lines in complexly faulted areas. This is a necessary first step in order to properly plan 3D seismic surveys with which to define drillable prospects.

Method

GEDCO uses a two-pronged approach to the interpretation of HRAM data. First, the gridded data are filtered. Second a depth analysis process is completed and the data are examined in a proprietary 3D volume visualization cube. Band-pass and gradient filtering is used to highlight magnetic features of interest. The choice of filters is guided by spectral analysis. However, to produce the most useful images for structural interpretation, final filter selections are based on experience and judgment as well as empirical data.

A numerical depth to magnetic source analysis is performed on the gridded data and the results are transformed into a three-dimensional depth cube, via the Magnetic Fault Identification Cube (MaFIC) technique, Rhodes and Peirce (1999). MaFIC permits fault interpretation using seismic workstation tools such as SeisX™, IESX™., and KINGDOMSUITE™. The MaFIC data and magnetic filtered and derivative data are interpreted together to obtain a consistent structural interpretation. The magnetic fault interpretations are integrated with available public and proprietary data to facilitate further analysis and to develop possible hydrocarbon exploration trends.

The structural trends interpreted from the HRAM data may be associated with lithologic changes, faults, differential deposition, and erosion of beds containing magnetic minerals. They may also be caused by geochemical alteration of the rock (i.e., hydrothermal alteration and deposition of magnetic minerals along fault and fracture planes). Locally, high temperature hydrothermal alteration may add or remove magnetic minerals and create areas of low or high magnetic signal. The distribution of these magnetized bodies is important since many of them are associated with basement faulting which, when reactivated, may control faulting within the sedimentary section.

Example

The PRA spans a large region of west central Alberta and southern Northeastern British Columbia (NEBC), an area of approximately 71,449 square kilometers. The PRA Area covers the Peace River Arch and the Dawson Creek Graben System. It also overlies the southwestern extent of the Great Slave Lake Shear Zone (GSLSZ), and reaches the eastern limits of the Laramide thrust and fold belt in the southwestern corner of the area.

Consequently, the PRA area HRAM data indicate a complex fault fabric that can be associated with these several tectonic domains. The predominant fault trends are NE-SW, NNE-SSW, NNW-SSE, NW-SE. Two less developed fault trends are approximately NS and EW. Other fault orientations are present but are represented by only a few short fault segments. All trends are important in developing structural traps and controlling migration of hydrocarbons, focusing dolomitizing fluids, and controlling sediment deposition or reef growth. It is likely that the tectonic processes that elevated the PRA, for example, influenced development of surrounding basins, such as the Hotchkiss embayment.

In Figure 1 lineaments have been interpreted for both the Precambrian and intra-sedimentary sections. This was accomplished using a 3D MaFIC volume. All interpreted lineaments are shown without differentiating between those in the basement and sedimentary sections. To facilitate determination of possible relationships between a particular lineament trend and geological features, the lineaments have been re-interpreted into several strike direction classes: NNW-SSE, NW-SE, NS, EW, and NE-SW. The separate lineament classes permit interpretation of trends and determination of which trends are important to a specific time period or a given geologic feature.

Since the PRA is a mature exploration area, we can compare these interpreted trends with Carboniferous faulting defined from well and seismic data (Richards, et al., 1994 in the Atlas of the Western Canada Sedimentary Basin). Figure 2 demonstrates how well three of these trends compare with current interpretation. Clearly, had HRAM interpretation been available 50 years ago when exploration was just beginning in this area, the exploration effort would have been far more efficient!

Summary

The HRAM data interpretation provides an excellent basis for selecting areas with potential for fault control of deposition, dolomitization and formation of traps. Figure 3 shows how many of the Devonian Leduc reef reservoirs are fault controlled. Figure 4 shows how many of the Triassic pools are fault controlled in terms of where the reservoir sands were deposited.

In order to maximize the value of the HRAM data, the data should be integrated with seismic data and geological models based on mapping and well data. Full use of the MaFIC cube and various filtered data products makes the integration process easy. The objective is to look for correlations between magnetic and other data trends. Some considerable insight will be gained simply by going through this process.

Any relationships that are established can be used to step out from the existing database of seismic data, as an example, to develop leads. The results may guide selection of seismic data purchases, the shooting of new lines, or planning new 3D surveys so that they properly image critical faults. This framework could refine geologic models and improve the understanding of the petroleum systems of the area.

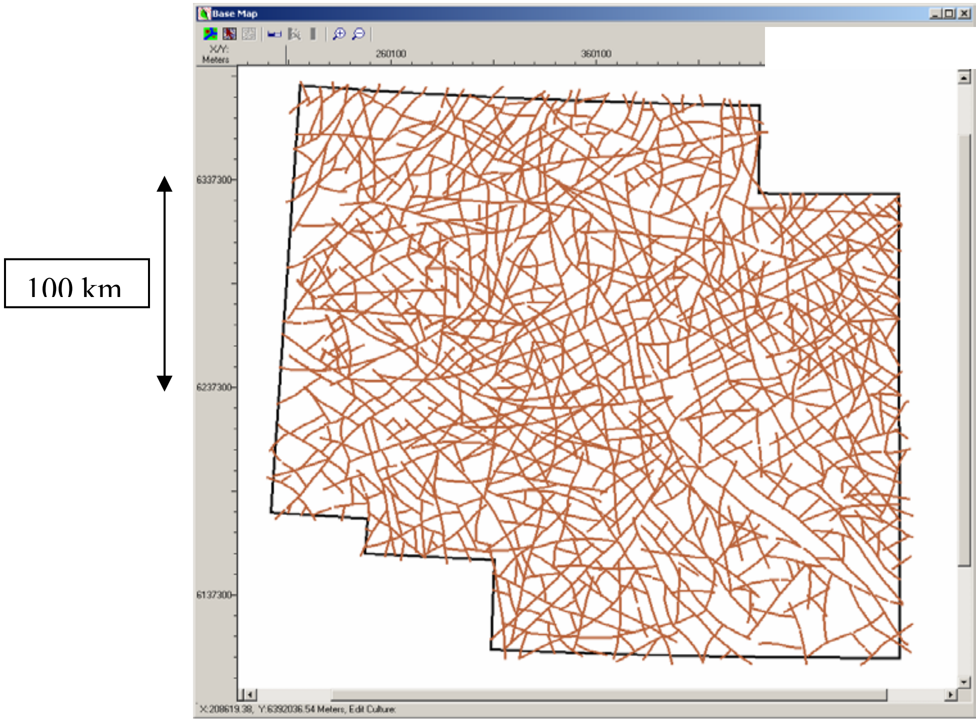

Figure 1 - All lineaments interpreted from HRAM data are shown

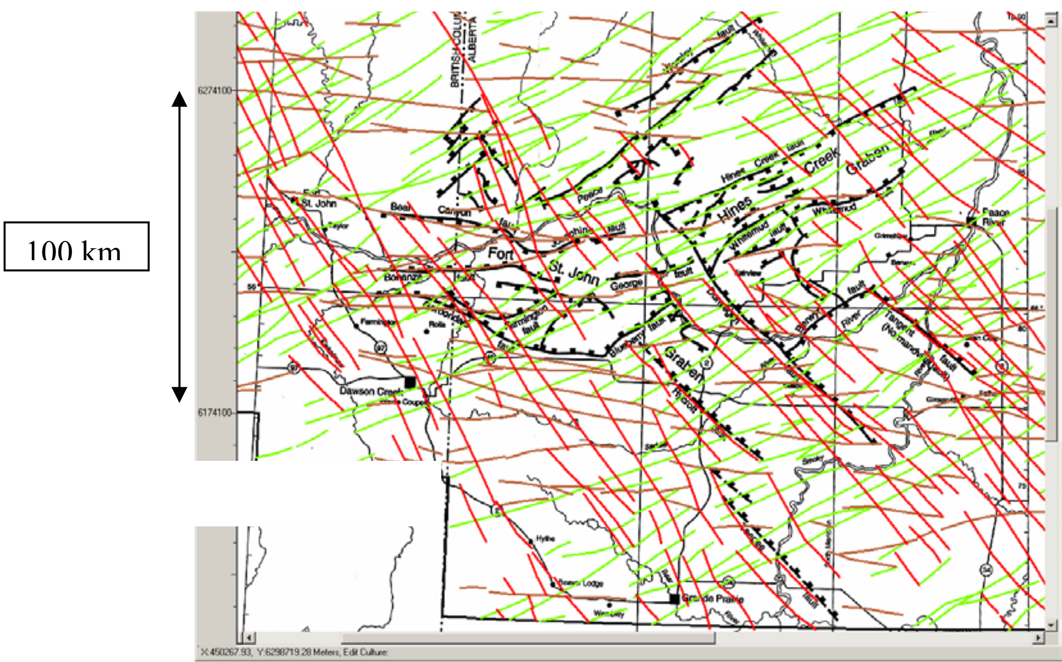

Figure 2 - Overlay of NNW, NE and EW lineaments on published Carboniferous fault system (Richards, et al.., 1994)

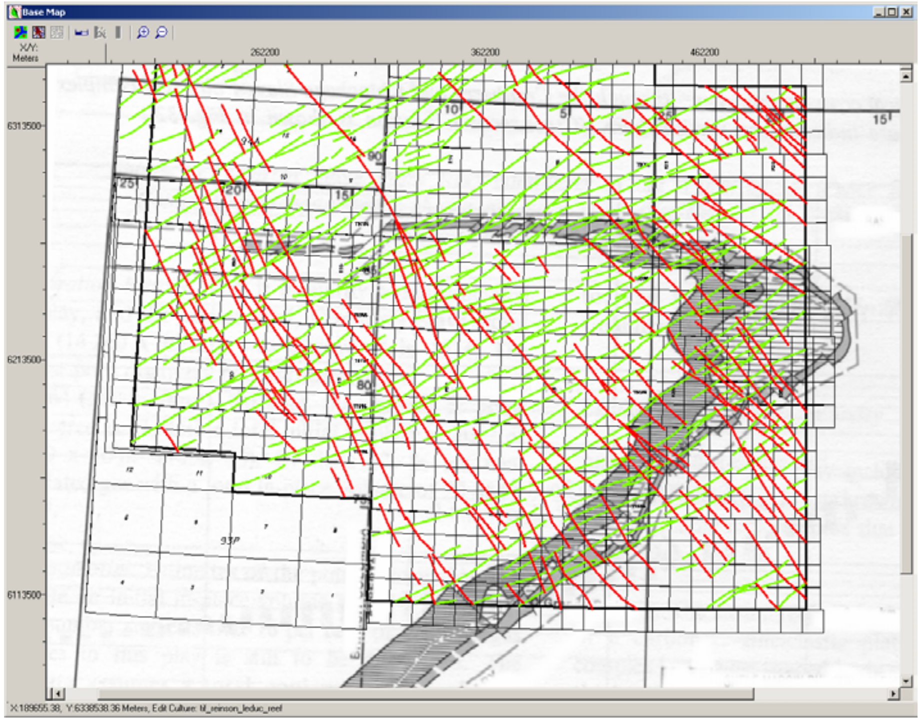

Figure 3: Comparison of HRAM –interpreted faults with Leduc facies map (Dix, 1990).

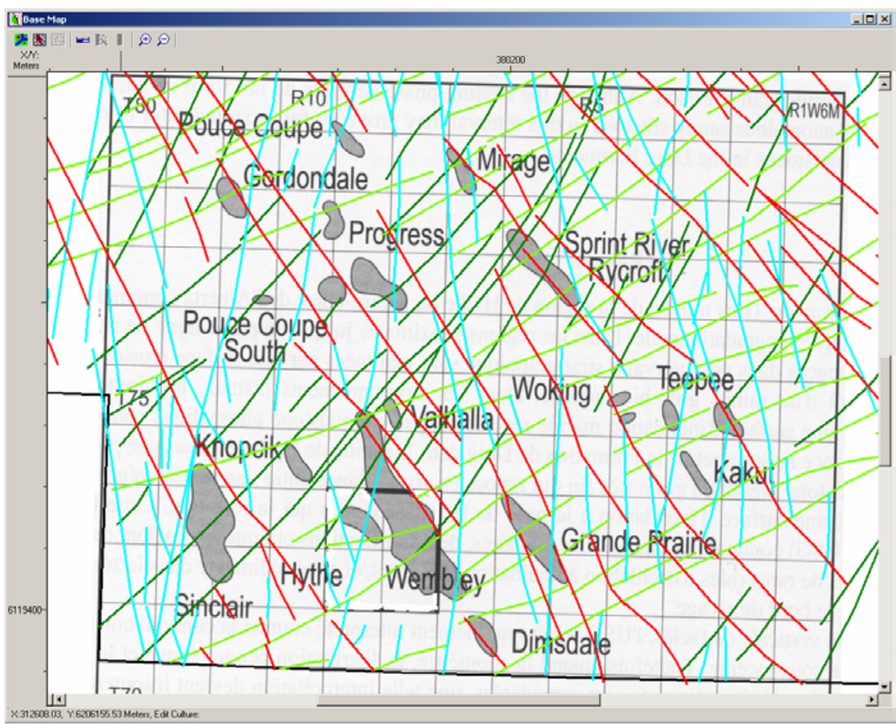

Figure 4: Same as previous figure with the NNE and the NS lineaments overlain. Note how Sinclair pool (SW corner) has a shape that is bounded by the various lineament sets. Movement on any one of these faults could have triggered the turbidity currents in development of many of these reservoir bodies.