Mapping HRAM lineaments using 2-D wavelet transform in the Sundre area, West Central Alberta, Canada

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Summary:

This paper describes a robust technique to map HRAM lineaments using wavelet transform analysis and skeletonization. This technique is completely automated and therefore much faster, more cost-effective, and less subjective than traditional approaches to mapping lineaments. Preliminary results are very encouraging and reveal lineament that are likely to be missed using traditional lineament mapping techniques.

Introduction:

As a result of pervasive tectonic activities in the crystalline basement rocks of the Western Canada Sedimentary Basin (WCSB) a series of fractures and faults were generated. Some of these fractures and faults have propagated into the intra-sedimentary rocks of the basin and often appear as linear to curvilinear features on **H**igh-**R**esolution **A**ero**M**agnetic (HRAM) data. These lineaments play a major role in oil, gas, mineral and groundwater exploration because they control structure in the intra-sedimentary as well as in the crystalline basement rocks. For this reason, we consider mapping of lineaments in HRAM data to be one of the most important stages in geological interpretation of an area.

Traditionally, lineament detection and mapping in HRAM data is carried out by visual inspection of a set of enhanced and filtered images of the total magnetic intensity. These filters (for example the horizontal gradient and the analytic signal) are carefully designed to pick lineaments that are associated with faults, fractures, and geological contacts. Going through this process thoroughly over a full range of wavelengths can be a very tedious operation. For this reason we have experimented with an alternative technique based on wavelet analysis to detect lineaments. This alternative technique is much faster, cost-effective and less biased by the interpreter's pre-conceived ideas.

Methodology:

We normally use Fourier (FFT) based analytical techniques to produce enhanced filtered maps to interpret lineaments in HRAM data. By doing this we assume that signals in the HRAM data are of stationary type. The FFT uses cosines and sines to represent a signal and is most useful for representing stationary signals. However, HRAM data contains non-stationary components: for example, discontinuities and abrupt changes in the signal that are attributed to geology that are often not evenly distributed. Hence, FFT is not entirely suitable for analyzing such signals. In this case, wavelet analysis is more suitable to represent non-stationary signals. Wavelet transforms (Daubechies, 1990) decompose an input signal into coefficient matrices which maps all the spatial relationships at multiple scales.

We used 2-D wavelet transform provided in the MATLAB wavelet toolbox to map lineaments in an HRAM data from the Sundre area in Alberta (Figure 1). The area is located at the eastern edge of the Canadian Cordillera deformed belt and contains numerous economic deposits of oil and gas. Prominent faults in the area trend in the northwestern direction with less obvious, but equally important faults trending in the northeastern direction.

Results:

The results of 2-D wavelet analysis of the selected HRAM data are shown in Figure 2, which reveals lineament information in four directions; E-W, N-S, NE-SW and NW-SE**.** We believe that most of the E-W lineations are related to residual acquisition footprints. There are few N-S trends, but those seen are significant geologically. The NW-SE trends are related to Laramide structures. The NE-SW trends are related to wrench faulting originating in the basement and reactivated periodically through the Phanerozoic.

It is also of interest to note that many lineaments could be easily missed if only traditional mapping techniques are used. In order to enhance and refine these lineaments further, we have applied the skeletonization technique on the data (Eaton and Vasudevan, 2004). Skeletonization is a process for thinning the lineaments in a binary image to a skeletal remnant that largely preserves the extent and connectivity of the original lineaments. The results of skeletonization are shown in Figure 3.

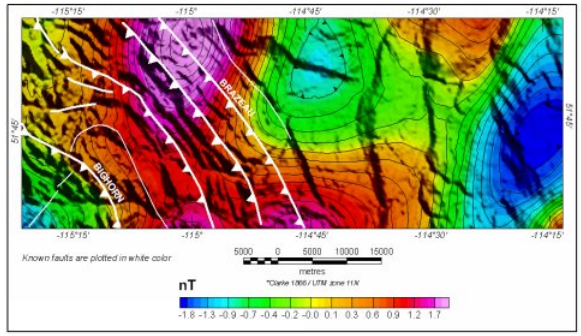

Figure 1. The total magnetic intensity map of the selected area draped on topography. Known faults in the area are plotted in white color

Concluding remarks

This study demonstrates that wavelet transform analysis can be a very powerful tool in detecting and mapping lineaments in HRAM data, especially if this technique is augmented with skeletonization process. Furthermore, this technique is fast, cost-effective and less subjective than traditional mapping of HRAM data.

References

Daubechies, I., 1990, The wavelet transform, time-frequency localization and signal analysis: IEEE Trans. Inf. Theory, **36**, 961-1005

Eaton, D., and Vasudevan, K., 2004, Skeletonization of aeromagnetic data: Geophysics, 69, 478-488.

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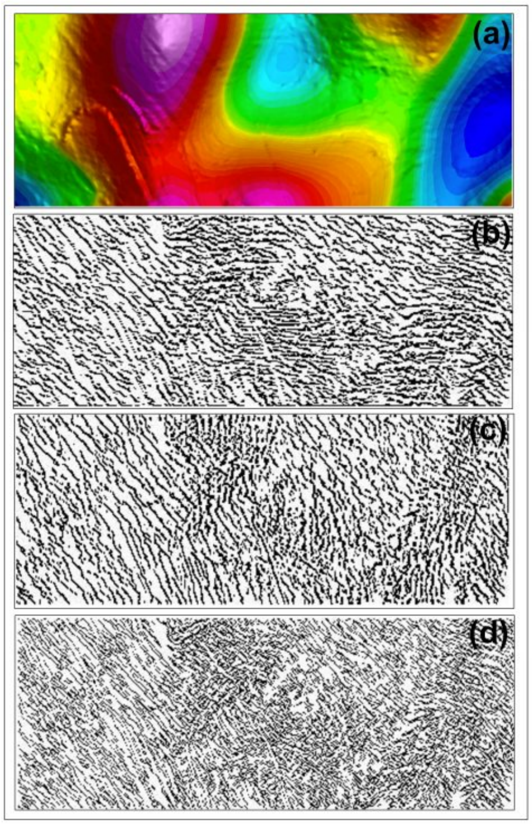

Figure 2. The results of 2-D wavelet transforms; (a) the original image, (b) E-W lineaments in the image, (c) N-S lineaments in the image, and (d) NE-SW and NW-SE lineaments in the image

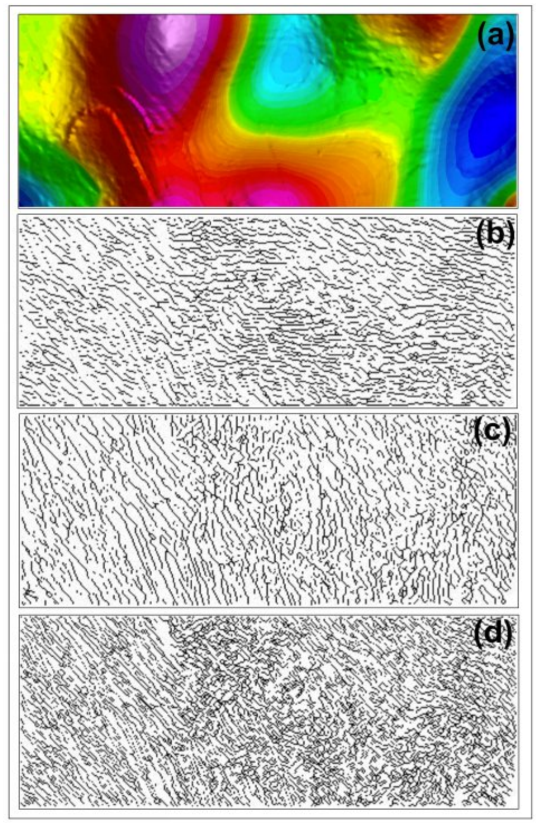

Figure 3. The results of skeletonization on 2-D wavelet transforms; (a) the original image, (b) E-W lineaments in the image, (c) N-S lineaments in the image, and (d) NE-SW and NW-SE lineaments in the image