Detecting Shallow Geological Features in High Resolution Aeromagnetic Data of the Horn River Basin Using Second Derivative in the Gradient Direction (SDGD) and PLUS Filters

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Summary

Detecting shallow geological features such as faults, fractures and buried channels is very important for oil and gas exploration. These shallow geological features also play an important role in geohazards detection. One way to detect shallow geological features is by mapping the short wavelength high frequency components of **H**igh **R**esolution **A**ero**M**agnetic (HRAM) data. The short wavelength high frequency components of HRAM data are normally attributed to shallow geological features. Several spatial and frequency based filters exist to detect shallow geological features in HRAM data. Among these filters are the derivative, gradient and the more recently introduced tilt angle. Although, these filters provide a way to detect shallow geological features, they amplify the level of noise and produce artifacts in the data especially if the data are processed in the frequency domain.

In this poster we introduce a group of filters to process HRAM data. These filters aim at enhancing the high frequency contents of HRAM data and reducing the level of noise and thus revealing shallow geological features related to faults, fractures and buried channels more clearly. These filters are known as the second derivative in the gradient direction (SDGD) and the PLUS. These filters were applied on HRAM data covering the Horn River Basin in Northeast British Columbia. Prior to applying the SDGD and the PLUS filters, the HRAM image was convolved with a Gaussian filter in order to reduce noise in the data.

The aim of this study is therefore to detect shallow geological features using SDGD and PLUS filters. The preliminary results of this study are very encouraging. We were able to detect features that are believed to be related to faults, fractures and buried channels that we were not able to detect on images produced by using traditional filters.

Introduction

Shallow geological features are becoming important in oil and gas exploration as well as in geohazard detection. Several types of digital filters exist to detect shallow geological features. Most of these filters utilize the short wavelength high frequency components of HRAM data that are associated with shallow geological features. Although these filters are good at enhancing shallow geological features, they frequently enhance the level of noise and introduce artifacts in the data.

In this poster we introduce two spatial based filters that might be able to tackle these problems. These filters are known as the SDGD and the PLUS.

The area selected to test these filters is located in the Horn River of NEBC. The HRAM dataset used is owned by Fugro Airborne Surveys (Fig. 1). The HRAM survey was flown with a flight line spacing of 400m oriented NE/SW and a tie line spacing of 1200m oriented EW. The survey was flown with a draped ground clearance of 100m. Fugro performed cultural editing on the survey data in order to remove artifacts related to wells and pipelines in the area.

The Horn River Basin is located at the border of the Foothills thrust belt with the Western Canada Sedimentary Basin (WCSB) and it intersects three main Precambrian litho-tectonic magnetic basement terranes (Fig. 1); Nahanni at the center, Fort Simpson Magmatic Arc to the east, and Fort Nelson Magmatic Arc to the west. The Precambrian basement terranes in the WCSB have been interpreted from the amplitude, texture and trends of the regional aeromagnetic data in conjunction with gravity data and isotopic age dating of Precambrian drill cores (Ross *et al*., 1994; Pilkington *et al*., 2000). The Fort Simpson and Fort Nelson Magmatic Arc Terranes have distinctive NS trending magnetic high (Fig. 1). The Fort Simpson and Fort Nelson Terranes are characterized by the presence of ferrimagnetic minerals, most likely magnetite, which has a sufficiently high susceptibility to produce of the high amplitude anomalies characteristic of this terrane. Such large magnetization is usually indicative of calc-alkaline igneous rocks associated with magmatic-arc environments. The Nahanni terrane which is associated with a magnetic low is interpreted as thinned Fort Simpson basement (Cook *et al*., 1999).

The Precambrian basement is covered by sedimentary rocks of the Horn River Basin. The Horn River Basin contains a sequence of stratigraphic horizons and plays that are considered potential for shale gas exploration. The main formations of interest for shale gas exploration in the Horn River Basin include the Devonian Muskwa shale and Evie shale (Walsh *et al.*, 2009).

Methodology

The gradient based filters, SDGD and PLUS used in this work were developed at the Delft University of Technology by van Vliet and Verbeek (van Vliet and Verbeek, 1994). Prior to applying these filters on the HRAM image of Horn River Basin (Fig. 1), we used a 2D Guassian filter to suppress the level of noise in the data.

Afterward, we have calculated the SDGD and the PLUS filters using the following partial derivatives:

$$A_{xx} = \frac{\partial^2 a}{\partial x^2} \qquad A_{xy} = \frac{\partial^2 a}{\partial x \partial y} \qquad A_x = \frac{\partial a}{\partial x}$$

$$A_{yy} = \frac{\partial^2 a}{\partial y^2} \qquad A_{yx} = \frac{\partial^2 a}{\partial x \partial y} \qquad A_y = \frac{\partial a}{\partial y}$$

Since $\boldsymbol{A_{xy}} = \boldsymbol{A_{yx}}$ only five of these derivatives were used in SDGD calculation as shown in the following formula:

$$SDGD = \left\{ \frac{A_{xx} A_x^2 + 2 A_{xy} A_x A_y + A_{yy} A_y^2}{A_x^2 + A_y^2} \right\}$$

The sum of *SDGD* and the Laplace filter is called the PLUS and it was calculated using the following formula:

$$Laplace = (A_{xx} + A_{yy})$$

$$PLUS = \left\{ \frac{A_{xx} A_x^2 + 2 A_{xy} A_x A_y + A_{yy} A_y^2}{A_x^2 + A_y^2} \right\} + (A_{xx} + A_{yy})$$

Results

The reduced to pole total magnetic intensity image (Fig. 1) was used as an input to calculate the SDGD and the PLUS filters. Figure 2 displays the results of applying the SDGD filter on the HRAM image. The SDGD image (Fig. 2) clearly displays geological patterns that might be indicative of shallow geological features such as faults, fractures and buried channels. These features appear to be enhanced further on the Laplace and the PLUS filters (Figs. 3 and 4, respectively). In order to see the detected geological features on these enhanced images more clearly a portion of Figure 4 was zoomed in and displayed in Figure 5.

Conclusions

The SDGD and the PLUS filters appear to be powerful tools in detecting faults, fractures, buried channels and other shallow geological features in HRAM data. In addition to HRAM data these filters can be applied on other geophysical data such as 3D seismic.

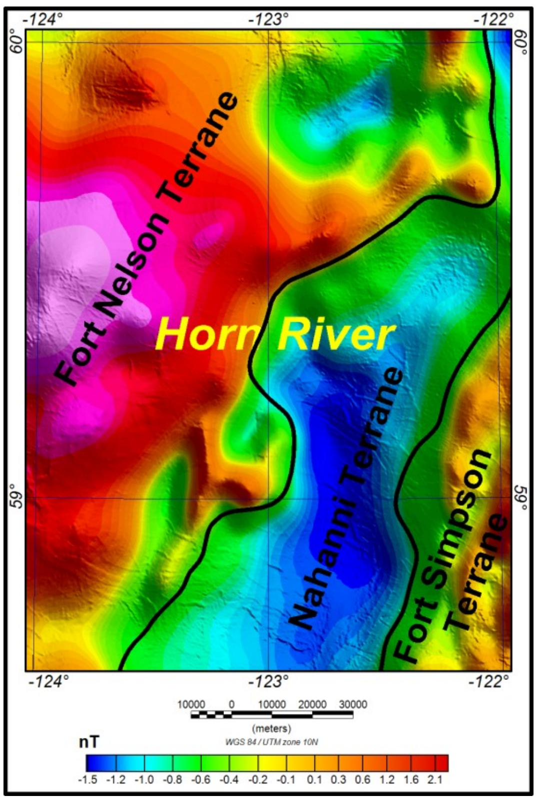

Fig. 1. RTP image of Horn River HRAM data.

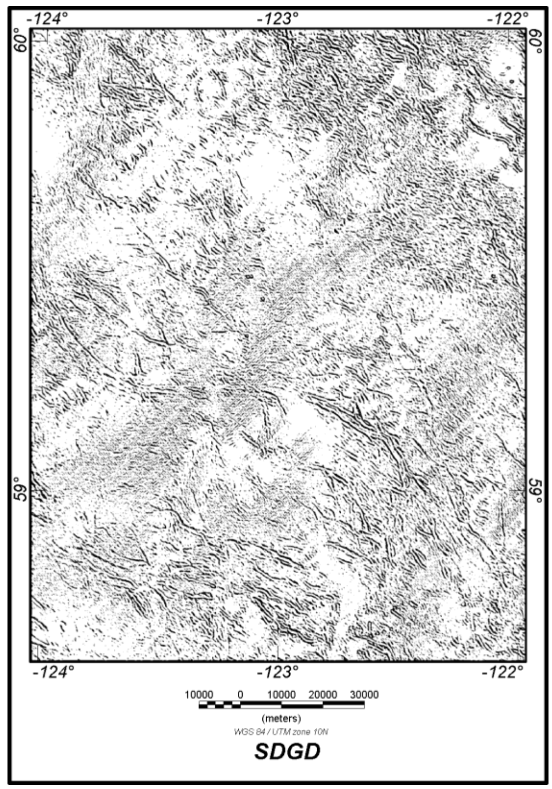

Fig. 2. SDGD image of Figure 1.

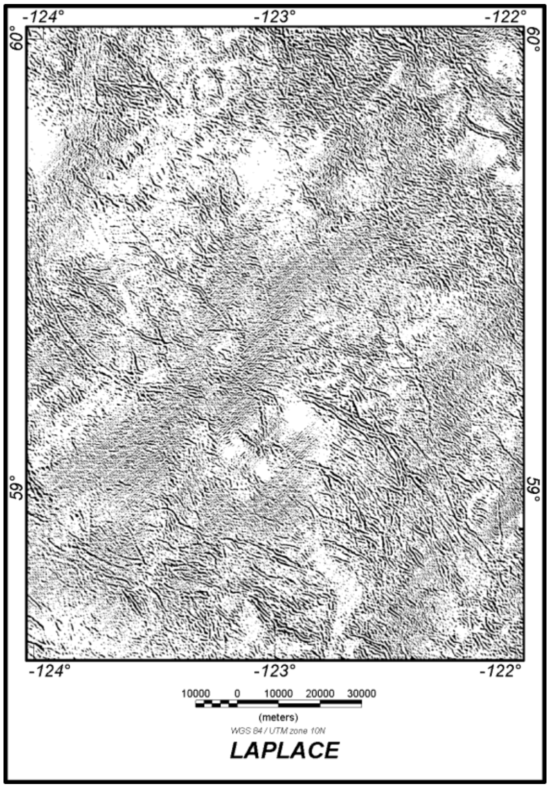

Fig. 3. Laplace image of Figure 1.

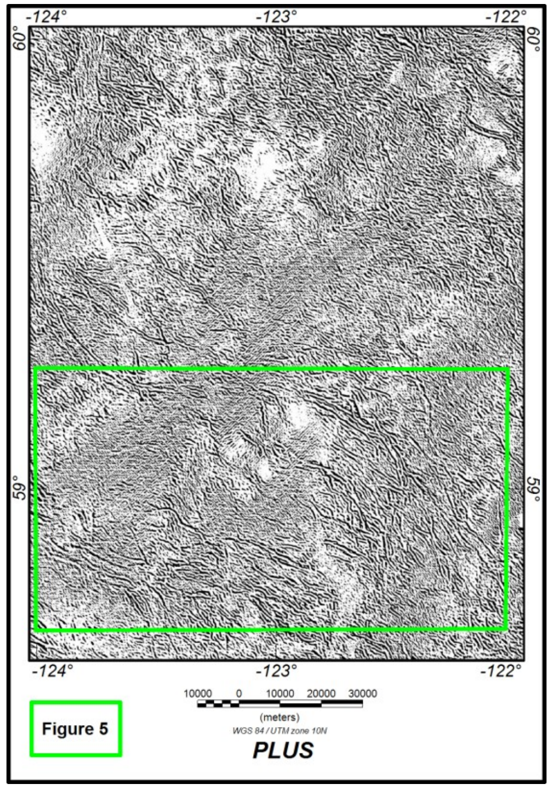

Fig. 4. PLUS image of Figure 1.

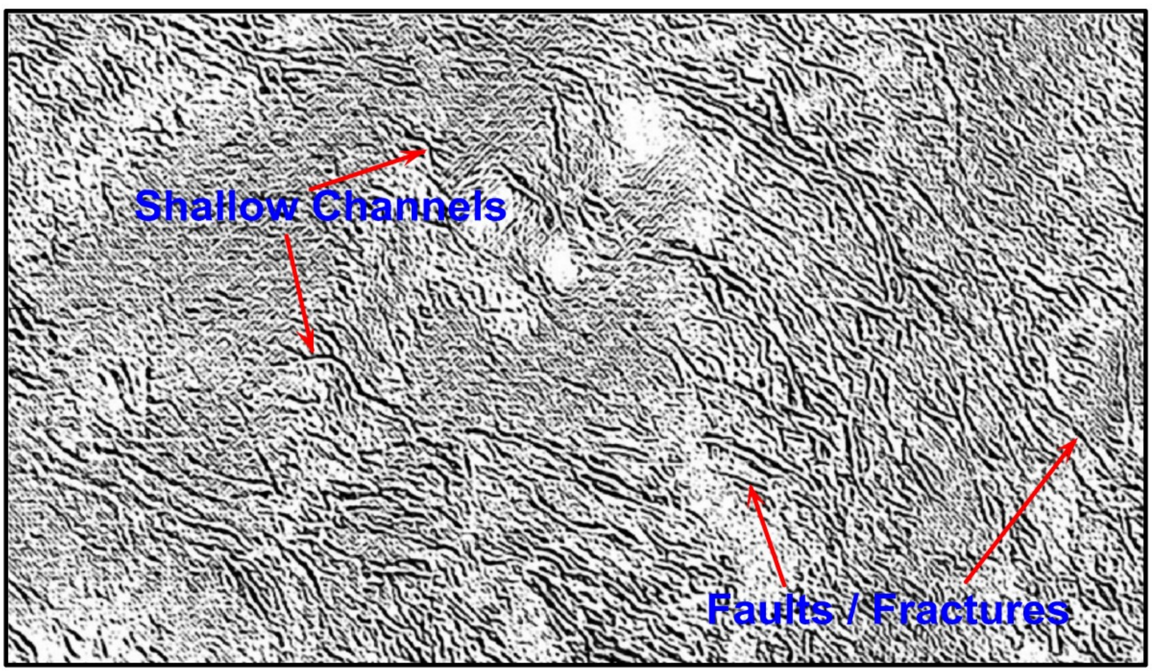

Fig. 5. Zoomed area within the PLUS image (green box on Figure 4) shows examples of Faults, fractures and shallow channels detected by PLUS filter.

References

Van Vliet, L.J and Verbeek, P.W., 1994, Edge Localization by MoG filters: Multiple-of-Gaussians: Pattern Recognition Letters, **15**, 485-496.