Geological Trend versus Mathematical Trend: Introducing a High-Resolution Approach to Subsurface Structure Mapping using Well-log Data and Geospatial Analysis

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Summary/Introduction

In general, the conventional approach to structure study uses potential-field data, including aeromagnetic and gravity data, for detecting the basement structures, and geophysical well-log data (combined with seismic data when available) for interpreting the sedimentary cover structures. With respect to well-log data, the main approach is to interpret faults from isopach and structure-top contour maps. For example, descriptions of structures related to the PRA-PRE, as presented by DeMille (1958), Lavoie (1958), Williams (1958), Sikabonyi and Rodgers (1959), Jones (1980), Cant (1988), Barclay et al. (1990), Dix (1990), O'Connell et al. (1990) and O’Connell (1994), are all based on use of well-log and sedimentological data to identify fault locations and trends, as well as magnitudes and types of offset.

The conventional well-log and seismic interpretation techniques have achieved varying success in detecting regional structure and major faults. However, the structure-top contour maps are usually characterized by a regional trend, and this trend can mask local structure and faults that cause only minor offset (e.g., a few metres). Variations at such a metre-scale dimension on the structure-top contour map usually show as subtle irregularities in contour lines or subtle variations in the spacing of contour lines and are therefore difficult to interpret. In addition, the location of faults can only be poorly defined on the contour maps (e.g., cf. Barclay et al., 1990’s Figure 6 with Figure 7). As a result, it is difficult to interpret faults with small offsets by using the conventional structural-top contour approach. These faults are usually beneath the detection resolution of seismic data.

Trend-surface analysis (TSA) has been used by geologists for more than 50 years to separate an observed contour map into two components: a regional trend and a local fluctuation component. (Davis, 2002). However, limited by using a global polinomial method in trend modeling, it does not allow geilogist’s input to achieve an optimal removal of unwanted trend; this leads to a low resolution and sometimes artefacts in highlighting the interested features. This presentation introduces a new approach, developed on the basis of trend-surface analysis, to detecting faults with small, meter-scale offsets (5 to 10 metre).

Method

The new approach goes one step beyond the conventional TSA approach by incorporating advanced geostatistics for modelling the trend and residuals and extracting, from residual surfaces, information on formation-top offset patterns that could be caused by faults. This new approach applies trend surface analysis on formation-top picks, but it is fundamentally different from the conventional trend surface analysis in that it models a geological trend, other than a mathematic trend (Mei, 2006). The conventional trend surface analysis uses the global polynomial method and the power of the polynomial (e.g., first, second or third) is the only parameter for input. It generates only a mathematical polynomial trend surface that is inadequate for extracting meter-scale formation-top offset information. The geological trend is modeled using local polynomial or Kriging techniques, which allow and is constrained by input of geological knowledge into the trend modeling. An ideally modelled geological trend, in this case, contains all the unwanted areal features including the regional and local subsidence and the effects of regional and differential compaction, leaving only fault-related information on linear formation-top offsets in the resulting residual surfaces.

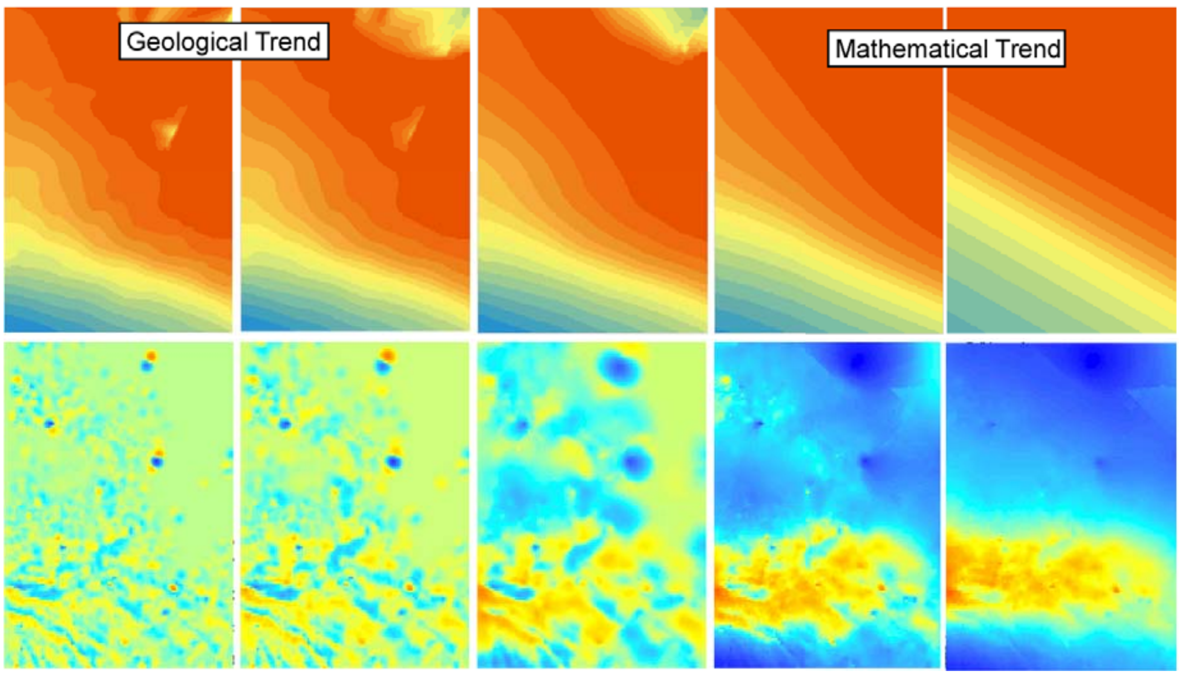

Figure 1: Geological trend vs. mathematical trend. The top row contains trend surfaces and the lower row contains the corresponding residual surfaces, respectively. The residual surfaces from mathematical trend removal only allow recognition of major features (e.g., PRA) and faults with a formation-top offset greater than 100 m; while the residual surfaces from geological trend removal allow recognition of faults associated with meter-scale offsets.

Examples

This new approach allows us to recognize the extensions of faults associated with the Dawson Creek graben complex (DCGC) and new faults in the Upper Cretaceous strata; all of these faults are asscoated with meter-scale formation-top offsects (Figure 2). The faults of DCGC found in Carboniferours and Permain strata are usually associated with offsets of over 100 m, and they were not identified in the structure-top contour and isopach maps and conventional seismic profile for the Cretaceous strata.

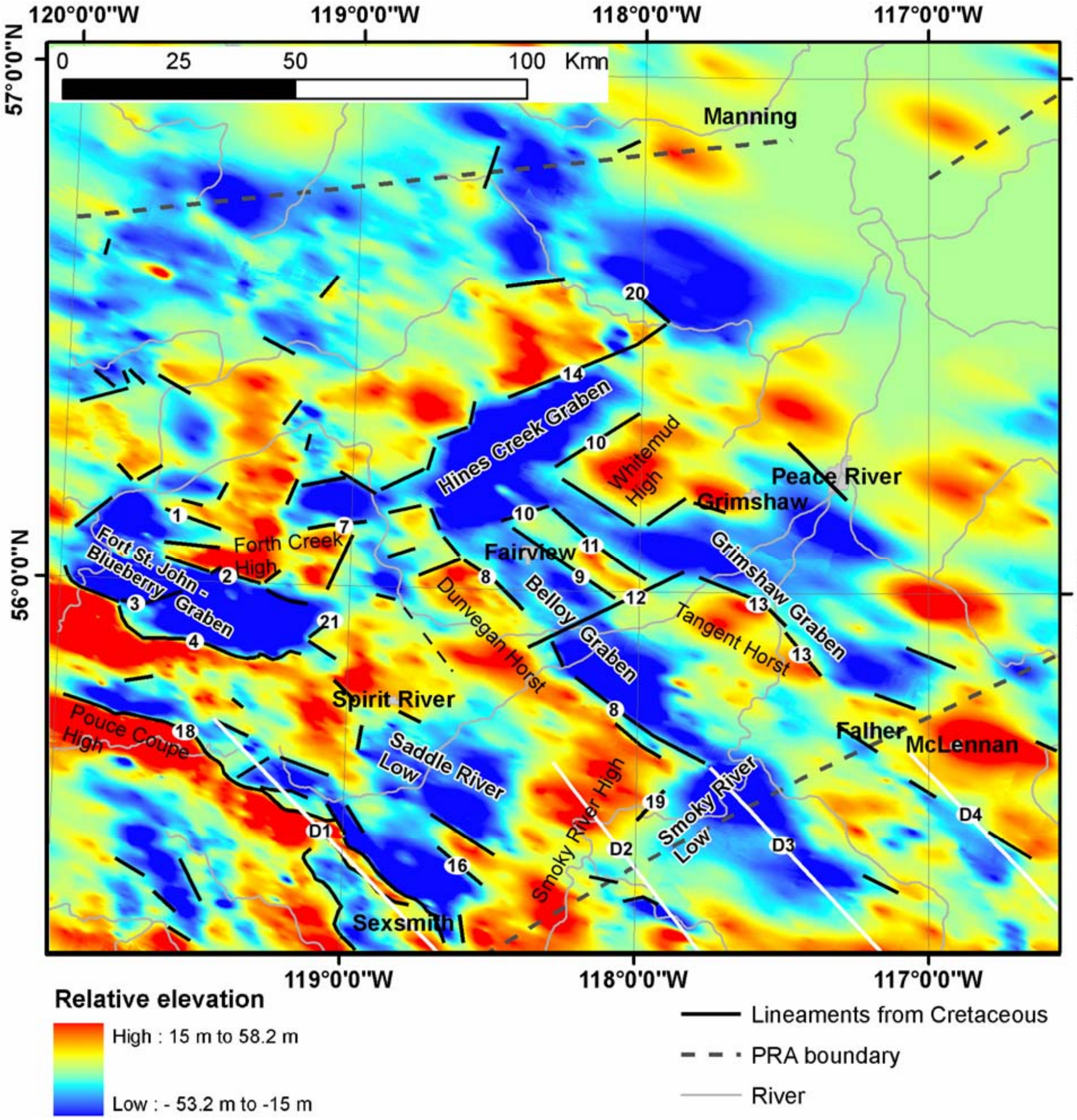

Figure 2: Formation-top offset pattern and interpreted faults of Cretaceous formations, superimposed on the residual map for the Basal Fish Scale Zone (BFSZ). Major faults: 1, Bear Canyon; 2, Josephine Creek; 3, Farmington; 4, Gordondale; 7, George; 8, Belloy (Dunvegan); 9, Fairview; 10, Whitemud; 11, Bluesky; 12, Berwyn; 13, Normandville (Tangent); 14, Hines Creek; 16, Teepee; 18, Pouce Coupe; 19, Smoky River; 20, Beaton Creek; 21, Blueberry. D1–D4, the four faults interpreted by Donaldson et al. (1998).

Conclusions

The new approach has a higher resolution in detecting formation-top offsets and higher accuracy in digitizing fault locations compared to the conventional contour-map, seismic-section and aeromagnetic-data interpretation techniques in structure mapping for the sedimentary cover.

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