

Geophysical Structural Patterns of the Crystalline Basement of the Eastern WCSB*

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Introduction

The study area covers the eastern part of the Western Canadian Sedimentary Basin (WCSB), extending from W96 – W110 and N49 – N58 to Alberta boundary ([Figure 1](#)). The aim of this study is to seamlessly map the crystalline basement structure over the entire eastern WCSB. The basement structure is crucial in determining the origin, deformation, and evolution of the basin, as well as the influence of the basement on the overlying Phanerozoic rocks and deposition and migration of hydrocarbons within the basin.

This article discusses the use of gravity and aeromagnetic attributes to the regional-scale basement structure to delineate basement structures within the eastern WCSB.

The gravity and aeromagnetic maps contain a wealth of information about the anomalous bodies within the basement. The information can be divided roughly into two types: (1) magnitude, gradients, and derivatives of anomalies, giving information on the depths and physical-property contrasts of the bodies; and (2) shapes of the contour lines, yielding information on the horizontal positions, sizes, and shapes of the structures. Our analysis is mostly based on the shapes of the interpreted source bodies which are measured from the trends and patterns observed in various attribute maps. The interpretation is derived from automatically extracted geophysical attributes. An assessment of the reliability of the conclusions is based on the self-consistency of the derived geophysical model and the consistency of this model with geologically mapped basement exposures.

The primary structure of the WCSB is considered to be a mosaic of basement blocks, each with its distinctive history and structure. The origin of the primary structure within the study area has been widely discussed by Card et al. (1998), Kreis et al. (2000), Miles et al. (1997), Pilkington and Thomas (2001), and Li and Morozov (2006). On top of this, a secondary structure was also recognized from the dominant lineation or domain structures within each of these blocks. The origin and control on the formation of this secondary structure in western Saskatchewan was discussed by Kreis et al. (2000).

This study focuses on the subtle geophysical features that help characterize the secondary basement structures.

Methodology

The WCSB Precambrian basement deepens from exposure to -2500 m, which also causes a decrease in resolution of its aeromagnetic and gravity imaging ([Figure 2](#)). A series of signal processing techniques was employed to compensate for this loss of resolution. Band-pass filtering was used for revealing the major structures of the basement by removing the regional long wavelength (>100 km) and the shallow short wavelength (< 1 km) anomalies. This filtering enhances the expression of anomalies of the buried basin basement structures.

Processing methods based on gradients may enhance images of the boundaries of source bodies. Modern numerical analysis techniques can help to produce numerous useful attributes. However, no single method leads to a direct and unambiguous structural interpretation at the sub-domain level and multiple attributes need to be correlated.

In this study, we integrated band-pass filtering; reduction to the pole, horizontal and vertical gradients, tilt gradients, analytic signal, pseudo-gravity, and curvature analysis to produce various new attribute data sets. The multi-attribute analysis performed under additional geophysical information constraints results in structural pattern maps not only highlighting the boundaries of the primary structural elements but also revealing the internal patterns within the secondary units.

Geophysical Structural Pattern Map

Maps of aeromagnetic pseudo-gravity gradient maxima help to define the internal characters and boundaries of the geophysical basement domains within the eastern WCSB. By combining the gravity and aeromagnetic datasets and using new processing techniques, a high-resolution geophysical structural trend map was obtained ([Figure 3](#)). Note the structural trends that not only delineate the boundaries of the primary structural element but also show the internal patterns within the secondary units ([Figure 3](#)).

WCSB geophysical structural trend maps clearly show the regional structure of the area including 10 parts: the Rae and Hearne cratons, Great Falls Tectonic Zone, Wyoming Craton, Hearne-Reindeer-Sask BZ, Sask Craton, Sask-Reindeer BZ, Reindeer Zone, Churchill-Superior BZ, and Superior Province. The secondary structural units as well as the internal subtle trends are also expressed by the lineation patterns on this map.

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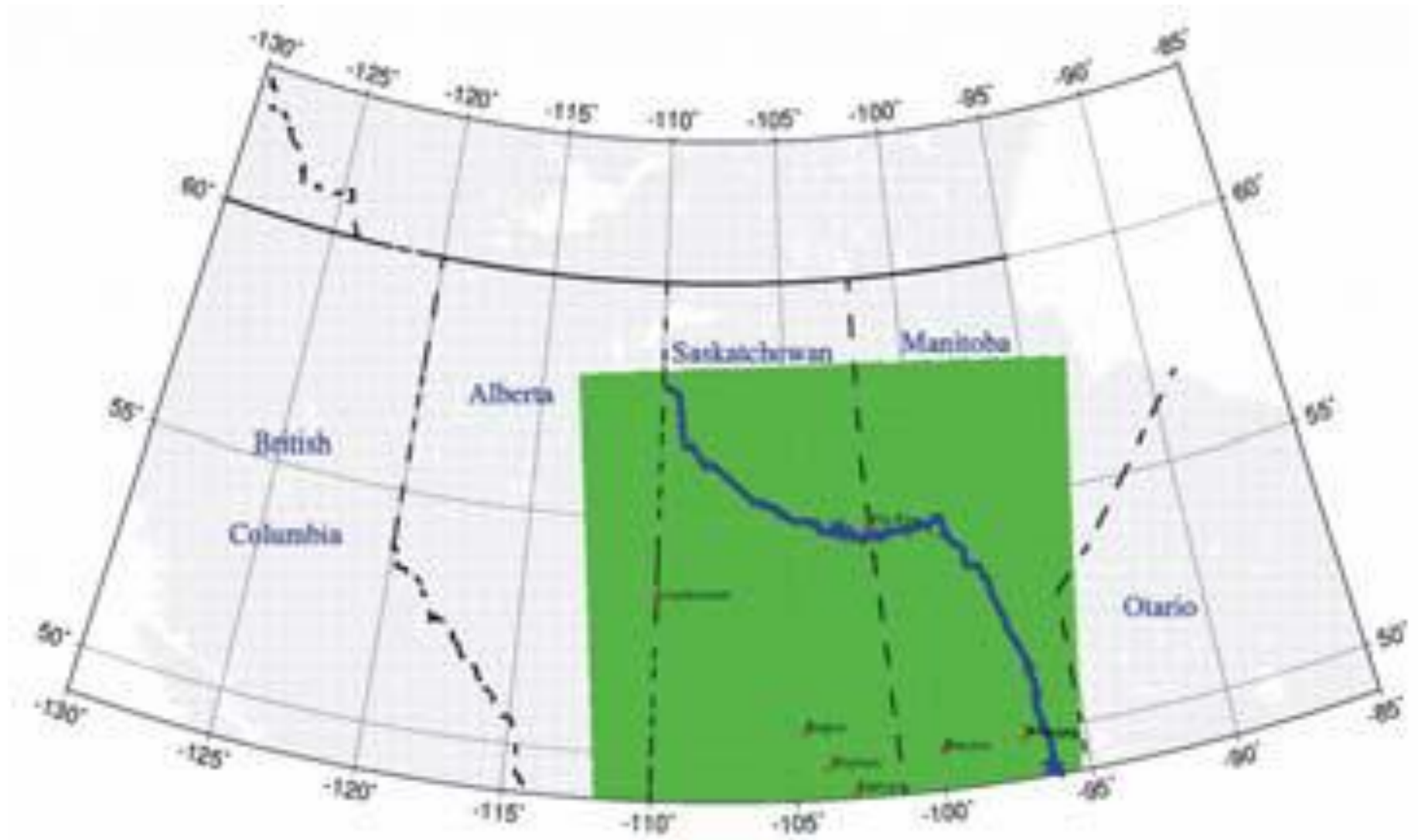


Figure 1. Study area is W96° - 110°, N49°-58°. Blue line is the edge of Canadian Shield.

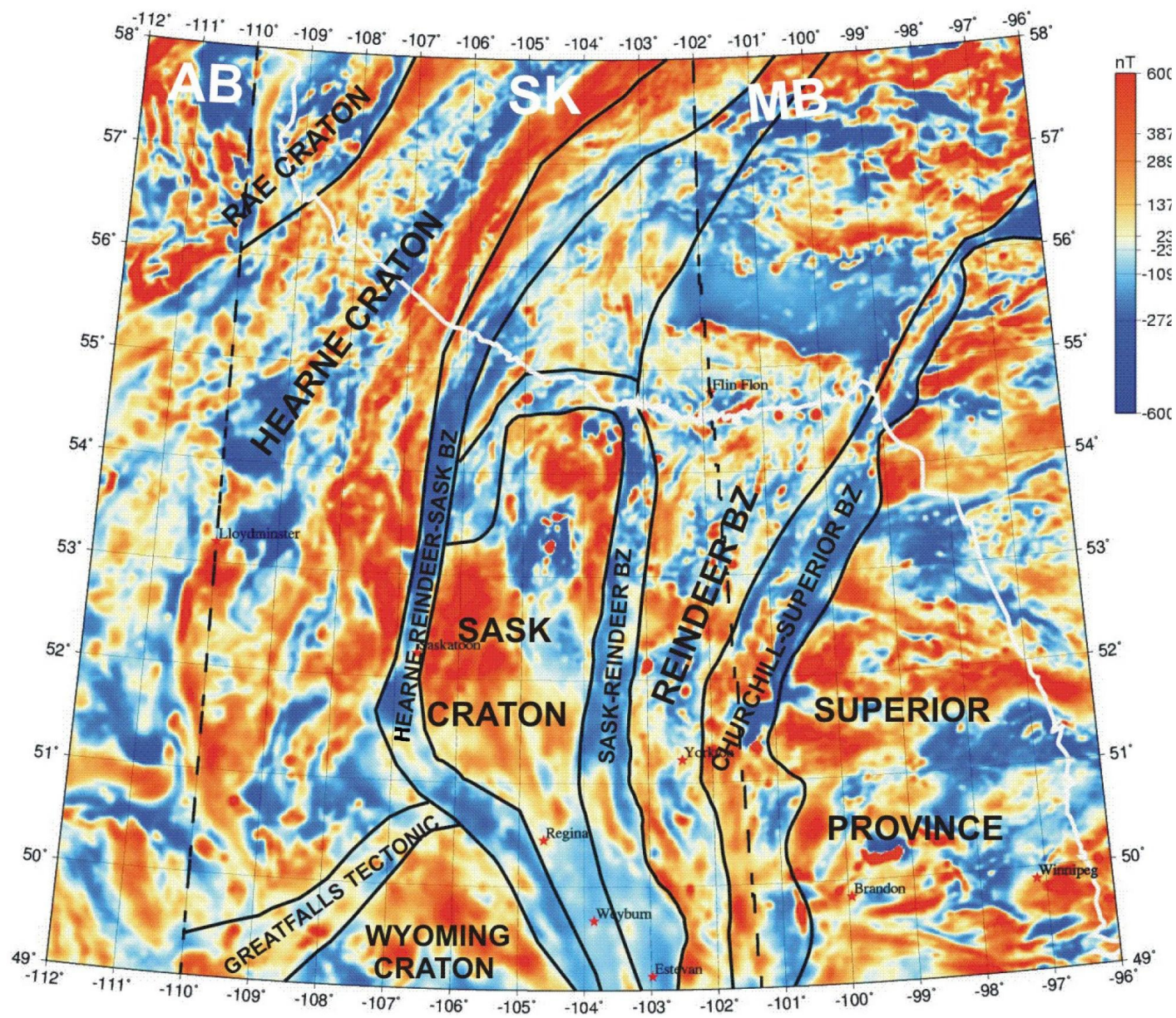


Figure 2. Residual total aeromagnetic anomaly field map. The thick white line is the Canadian Shield edge; black lines are the boundaries of the primary structural units.

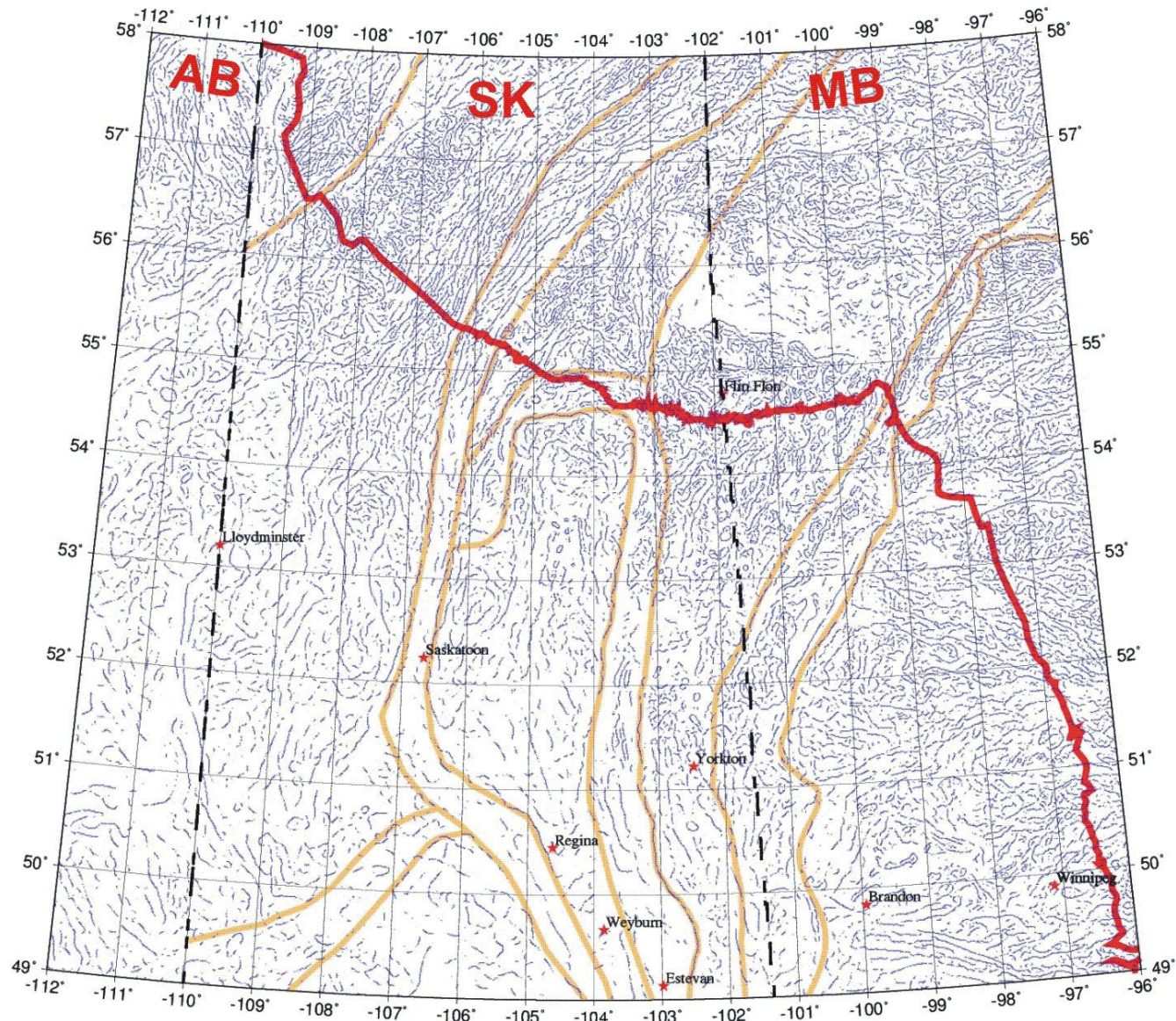


Figure 3. Structure pattern map of the crystalline basement of the Eastern WCSB. The thick red line is the Canadian Shield edge. The yellow lines are the boundaries of the primary structural units. The blue curve lines are the extracted crystalline basement structural features which provide details about the secondary domain structure and internal trends.