

Modeling and Interpretation of HRAM Anomalies from South-Central Alberta Foothills

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HRAM data from the south-central Alberta Foothills were processed to enhance near-surface sources of magnetic anomalies and suppress regional gradients. The processed HRAM anomalies are not related to the topography and are induced by the magnetic properties of the rock units underlying the survey area. Siliciclastic strata dominate the surface geology; they have low magnetic susceptibility ($10^{-6} - 10^{-2}$ SI), and therefore have small magnetic anomalies (ranging between 9.8 and -10.8 nT). A remarkable correlation can be observed between certain lithostratigraphical units and the HRAM anomalies.

The magnetization model constructed to reproduce the HRAM data generates anomalies that closely matches the observed values, and reflects the structural and lithological complexity of the study area. HRAM data show the different magnetic signatures of the Uppermost Cretaceous sedimentary rocks and can be used to effectively map near-surface lithology and structure.

Introduction

Aeromagnetic data have long been used by the petroleum industry to map structures and to estimate depth to magnetic basement. Until recently there has been little interest in studying magnetization within the sedimentary section and consequently in many sedimentary basins very little is known about the presence or nature of magnetic minerals in the sedimentary strata. Where the magnetic susceptibility of different sedimentary horizons was known, the susceptibility information showed that the magnetic layers determined from analysis of the magnetic anomalies correspond to magnetic sedimentary layers (Kivior and Boyd, 1998).

The objective of this study was threefold: (i) to identify magnetic anomalies within the sedimentary section and to correlate them with surface and subsurface geology; (ii) to investigate the magnetic properties of the rocks from the study area, and (iii) to construct a numerical magnetization model across the Foothills based on an existing geological model that was constrained with well data, the interpretation of seismic data and mapped surface geology.

The HRAM data used was acquired in the Rocky Mountain Foothills by Fugro in 1997 from an average height of 120 meters, and cover an area of approximately 4030 sq. km; flight lines were flown in an azimuthal direction of $90^{\circ}/270^{\circ}$ with line separation of 600 m; tie lines were flown in a $0^{\circ}/180^{\circ}$ direction with 1800 m spacing. The magnetic data were recorded with a resolution of 0.01 nT; the cycle rate was 0.1 second and the sample interval 7.0 meters.

Methods

The surface geology, topographic and well data were compiled using MapInfo GIS software. To determine the magnetic properties of the sedimentary strata from the area, field and laboratory magnetic susceptibility measurements were carried out.

The HRAM data (Figure 1) were loaded and displayed in Geosoft's Oasis Montaj. To enhance the shallow, high frequency features, and to suppress the regional gradients, the magnetic data were processed using different filtering techniques. The best results were obtained using a spatial band-pass filter $0.3125-1.25 \text{ km}^{-1}$ (800-3200 m wavelength) shown in Figure 2. The filtered magnetic anomalies were contoured, imported into MapInfo and displayed over the surface geology data. The information obtained was utilized to constrain a 55.35 km long cross-section that was used to model the magnetic anomalies.

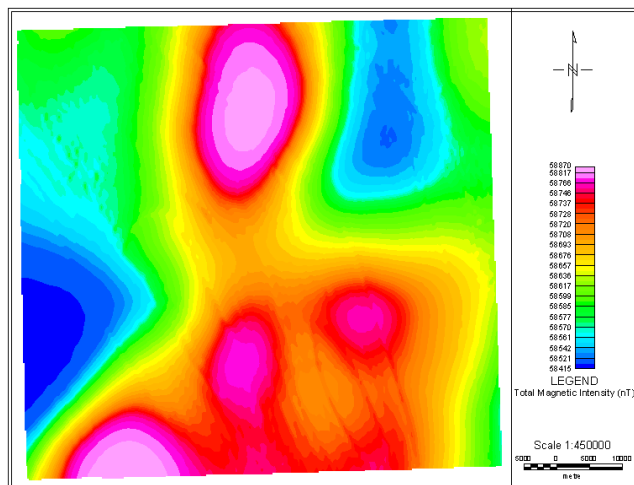


Figure 1. Culture-suppressed total magnetic intensity reduced to pole.

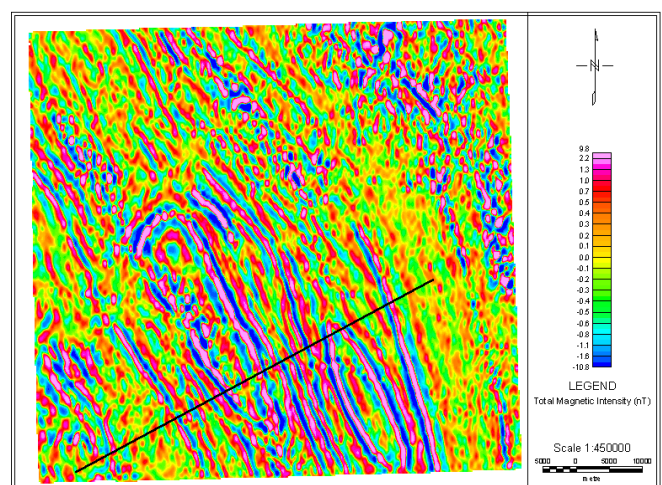


Figure 2. Bandpass filtered (0.8-3.2 km) total magnetic field

Interpretation

Siliciclastic strata dominate the surface geology of the study area; they have low magnetic susceptibility and therefore low magnetic anomaly values (ranging between 9.8 and -10.8 nT) were recorded over the area. The field and laboratory magnetic susceptibility measurements show a good correlation between the observed HRAM anomalies and the magnetic properties of the underlying rocks (Figure 4).

The processed HRAM data highlight the structural complexity of the area as variations in magnetic intensity, irregular patterns, and as offsets or changes in strike direction (Figures 2 and 3). Most of the magnetic anomalies originate in Upper Cretaceous post-Wapiabi strata (Lower and Upper Brazeau and Lower Coalspur), and appear to increase in intensity at the contact with the Tertiary Upper Coalspur Formation and with the underlying Alberta Group strata. The Tertiary, Lower Cretaceous and Jurassic strata and the Paleozoic carbonates exhibit low magnetic anomalies (-1.0 nT) with rare higher values probably due to cultural responses (Figure 3).

The occurrence of HRAM anomalies related to Brazeau and Lower Coalspur strata may be related to their depositional history and petrographic compositional stages in the post-Wapiabi sandstones of the southern and central Alberta Foothills (Mack and Jerzykiewicz, 1989). Sedimentological studies show that post-Wapiabi sandstones are composed of significant amounts of opaque minerals (magnetite and ilmenite) (Teifke, 1972; Rahmani and Lerbekmo, 1975).

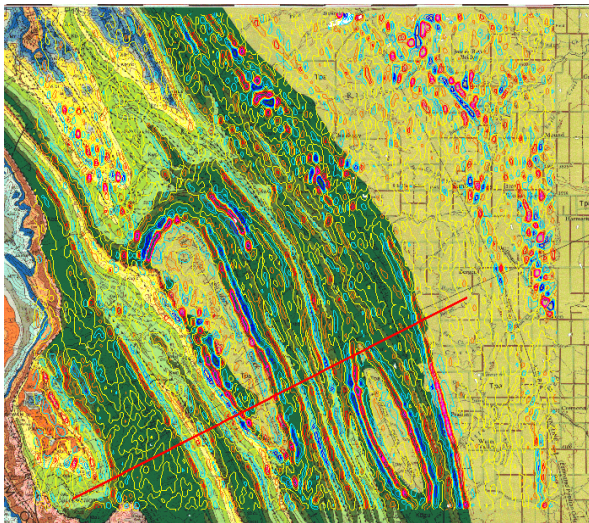


Figure 3. Geology and HRAM anomalies map. The red line shows the location of the geological model used for the forward modeling of the HRAM data.

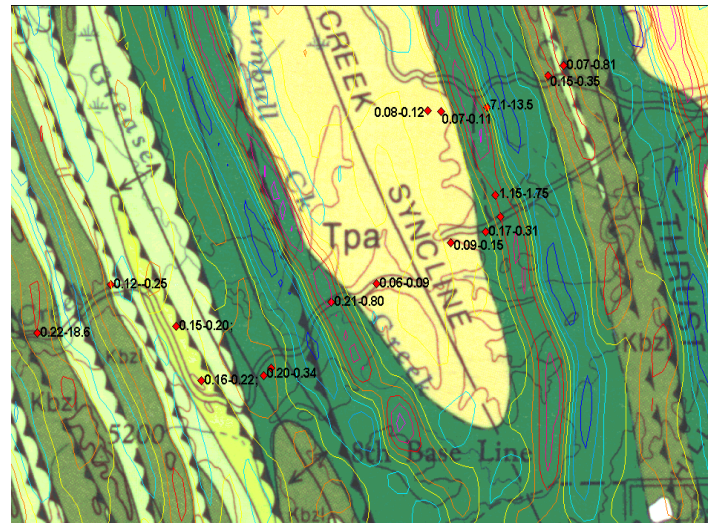


Figure 4. Field magnetic susceptibility measurements (10^{-3} SI) and HRAM anomalies.

Modeling of the HRAM Data

A 2-D geological model representing a 55.35 km vertical section across the south-central Alberta Foothills was constructed based on an existing model that was constrained with well data, the interpretation of seismic data and mapped surface geology (Soule, 1993). The model comprises three lithostratigraphic successions: Cambrian-Early Campanian, Late Campanian-Late Maastrichtian and Tertiary. Seventeen thrust faults and two backthrusts describe the structural complexity of the study area. Between one and three sandstone layers were assigned within the Brazeau and Coalspur strata. The Cambrian-Early Campanian (pre-Brazeau) succession was amalgamated in one lithostratigraphical unit due to the similarity of their magnetic properties (Figure 5). The magnetic susceptibilities were assigned based on published and measured values.

Oasis Motaj's GM-SYS module was employed for the modeling. GM-SYS methods calculate the magnetic model response based on the algorithms described by Won and Bevis (1987) and Rasmussen and Pedersen (1979). The final model comprises 99 magnetization blocks and is presented in Figures 5 and 6. The magnetic susceptibility values assigned to each block range from 0 to 0.025 SI. Figure 5 displays the 'best fit' geological model and Figure 6 presents the magnetic susceptibility model for the 'best fit'.

The modeled Brazeau and Lower Coalspur strata contain most of the blocks which have higher magnetic susceptibility values (Figure 6). The highest values were assigned to the sandstone layers (up to 2.5×10^{-2} SI) that contain detrital magnetic minerals. It should be noted that the calculated and observed magnetic values are matched well by magnetization models of the Brazeau and Coalspur strata (Figure 5). In modeling the observed HRAM data, the Paleozoic, Triassic, Jurassic, and part of the Cretaceous strata were assigned zero magnetic susceptibility due to their weak magnetic signature observed in the data. However, low magnetic susceptibility values (in the same range as those measured and/or published) for the sedimentary strata situated at or below 1000 m depth will not induce any magnetic anomalies detectable at the surface. Examination of Figure 5 shows that the magnetization model constructed to reproduce the HRAM anomalies closely matches the observed values and reflects the structural and lithological complexity of the study area.

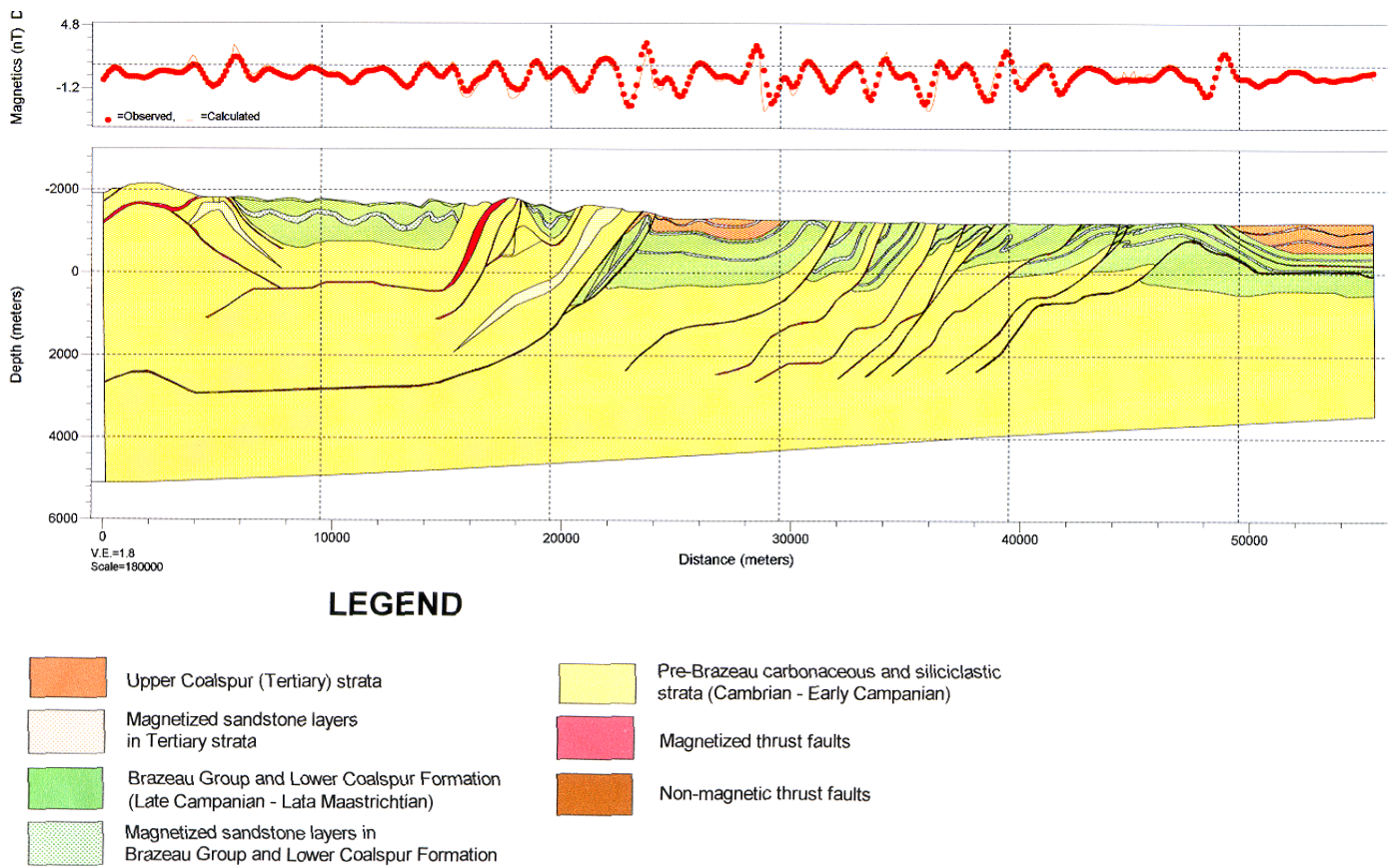
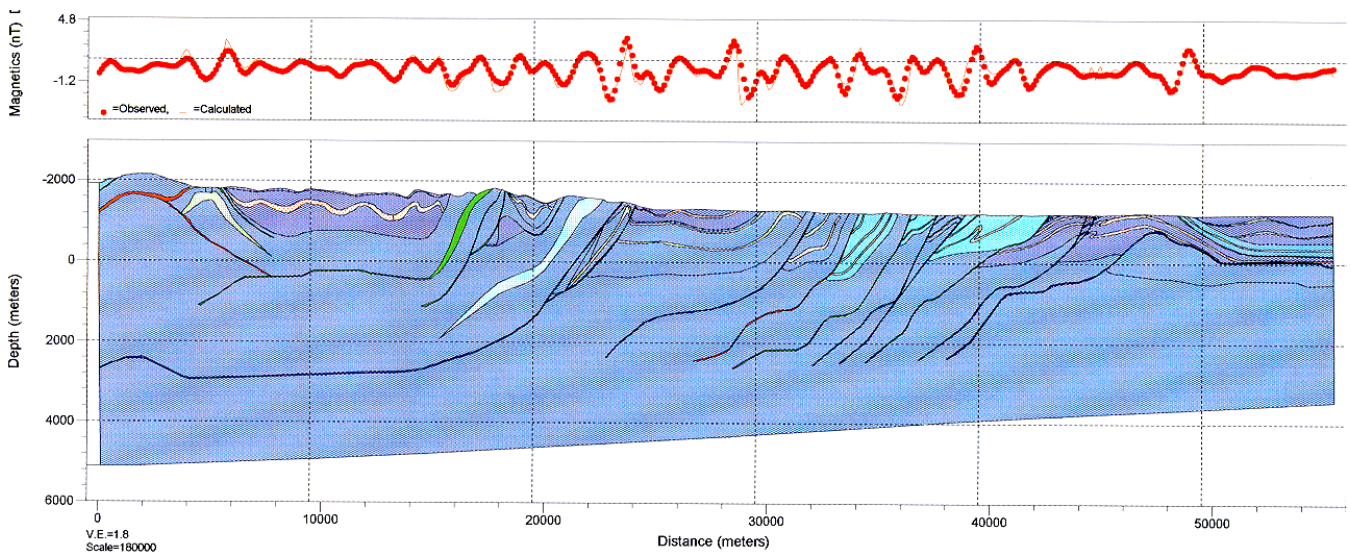


Figure 5. Forward modeling of HRAM data



Magnetic Susceptibility (SI)

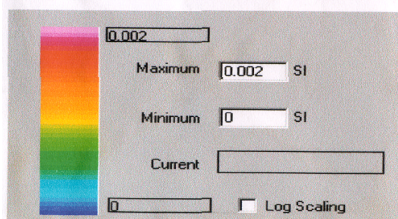


Figure 6. Forward modeling of HRAM anomalies (magnetic susceptibility color scale)

Conclusions

The modeling and interpretation of high resolution aeromagnetic data can help to map lithostatigraphy and structure in structurally complex areas, if the magnetic properties of sedimentary strata are known. In fold and thrust belts HRAM data may be used in early stages of exploration to map the near-surface lithology and structures and to assess the provenance of magnetized rocks.

Acknowledgments

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