Integrating Full Tensor Gravity, Magnetic and Seismic in the Pannonian Basin of Croatia: New Methods and Applications in a Proven Hydrocarbon Basin

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Summary

Acquisition and advanced processing of Full Tensor Gravity (FTG) and Magnetic data, in conjunction with the re-interpretation of vintage 2D seismic, has led to a greater understanding of the Croatian portion of the Pannonian basin. New methods for processing and visualizing the Potential Field data and improved integration with seismic data has extended the regional exploration effort.

Theory and Method

The Pannonian Basin is a Back Arc Basin that extends from Central Romania through Serbia, Hungary and Slovakia to Central Croatia. Oil and Gas are produced from lacustrine Miocene sands as well as the earlier Badenian sandstones, marls and limestones. (Saftic, et. al., 2003; Pavelic, 2001). The 'basement' rocks are an extremely complex assemblage of rock types, including highly deformed Mesozoic Carbonates, igneous and metamorphic rocks. (Haas, et. al., 1999). Basement highs are often productive and this an important factor in the usefulness of Gravity and Magnetic methods.

The Croatian portion of the Pannonian basin has long history of development, including the discovery of large structural fields.

The goal of the Full Tensor Gravity and Magnetic survey was multifold:

1) Identify structural features where 2D seismic is not present and, if they are not fully delineated, determine the areal extent of these structures;
2) Map deeper portions of the basins to identify mature source areas and possible migration pathways;
3) Estimate, if possible, the Badenian isopach in order to avoid possible 'bald' highs and distinguish basement highs from other structural features;
4) Identify igneous intrusions as a possible risk factor;
5) Compare and contrast depth estimates from Magnetic and FTG to understand basin development.

A Full Tensor Gravity and a Magnetic survey were acquired by Bell Geospace in early 2017 and integrated with a pre-existing regional Gravity survey supplied by the Croatian Government and updated by GETECH.

Survey planning for the airborne survey involved feasibility modelling to determine the appropriate line spacing and flying height to ensure capture of the required signal bandwidth. A line spacing of 500m and nominal terrain clearance of 100m was determined.

The terrain rugosity across the survey area is largely benign, apart from a NE trending ridge at the northern end of the Block and the presence of a National Park across the middle (Figure 1). The survey was therefore planned as two separate blocks to ensure adequate coverage, meeting the desired specifications.

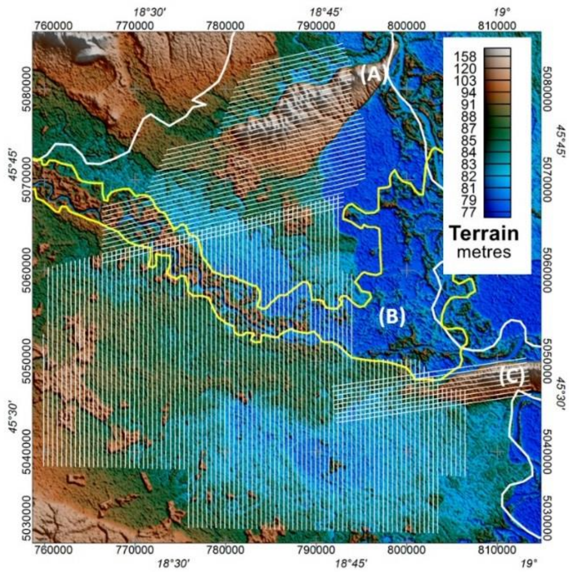

Figure 1. FTG and Magnetic Survey Lines and Topographic Image in NE Croatia. Area (A) is a topographic ridge, Area (B) is a National Park and Area (C) represents an a portion added during the survey.

A key aspect of the acquisition procedure is its flexibility and it was altered to address preliminary anomalies identified as the survey progressed. For example, an area in the east was added (Figure 1, Area (C)) with minimal loss to daily productivity. The available ground gravity and magnetic data were used to assist with line levelling ensuring the newly acquired data is tied fundamentally to the existing coverage. A total of 3,400 line kms were acquired. FTG data processing involved line levelling, tensor noise reduction and conversion to a stable Tensor and Gravity product. The FTG Gravity signal and ground data were spectrally analyzed to identify the common wavelength content. The ground data was low pass filtered and the FTG gravity field high pass filtered using a cut-off wavelength of 30km that is common to both data sets. The filtered outputs are then added together to produce the Full Spectrum Gravity product shown in Figure 2.

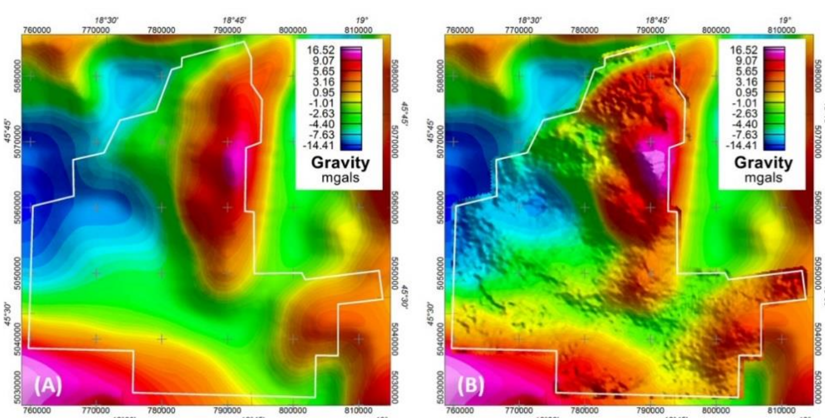

Figure 2. Ground Based Bouguer Data (A) compared to FTG + Ground Bouguer (B) showing increase in spatial frequency.

Magnetic data processing involved diurnal and IGRF corrections before levelling and subsequent reduction to pole transformation. The airborne data were merged with the ground data using the same method as for the Gravity. A wavelength of 15km was selected for the cut-off wavelength. Figure 3 shows a comparison of the ground data with the newly acquired data.

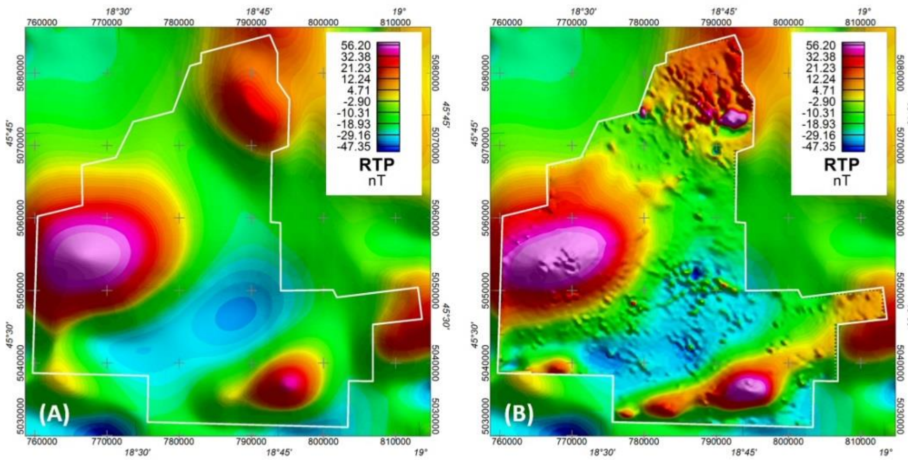

Figure 3. Ground Based Magnetic RTP (A) compared to New Magnetic + Ground (B).

Key steps in the processing and interpreting the resulting data include creating Depth Intervals by Power Spectral Analysis of the FTG and RTP Magnetic data, extracting Horizontal and Vertical Derivatives, and using advanced methods such as Adaptive Tilt Angle Depth estimation (Murphy, et. al, 2012). Figure 4 below shows the estimated depth to contacts assuming horizontal sheets, derived from Depth Interval 2.

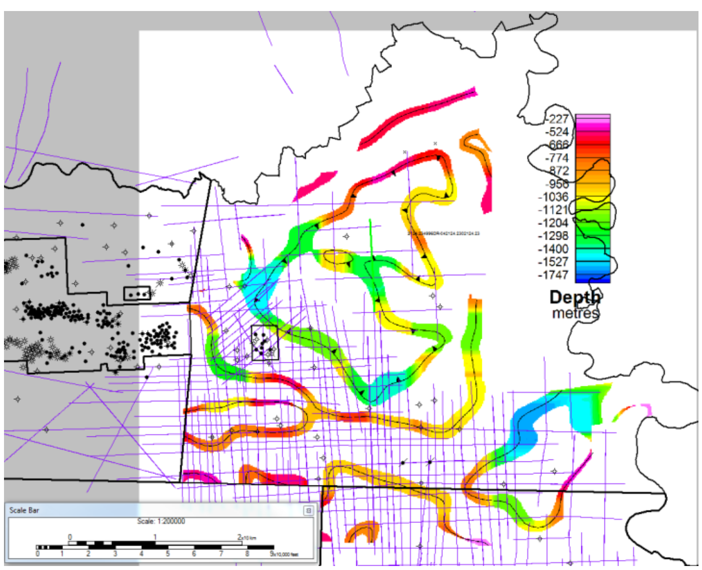

Figure 4. Depth in NE Croatia from Gravity Depth Interval 2 to Contacts, Assuming Horizontal Sheets. Purple lines are existing 2D lines.

Examples

In addition to these methods, two new methods were used in to improve the integration of FTG and Magnetic data with seismic data. Previous work (Salem, et. al., 2007) demonstrated the utility of the Tilt Angle for extracting depth estimates, but in this interpretation the Gradient of the Magnetic Tilt Angle is also used by projecting the Gradient on to the seismic image, without a depth estimate, to aid in the interpretation of changes in the basement or other intervals that strongly affect the Magnetic Field. See Figure 5. This technique was also used by one of the authors in the Patia Subbasin of Colombia (Westlund, et. al, 2014).

Because the Miocene aged sediments of the Pannonian Basin are highly uniform in terms of velocity, the second additional method of visualization and analysis was to convert the Depth Interval Tzz Gravity Anomaly directly to Seismic Time using a linear regression of the Basement Time on 2D seismic vs the Tzz value. This was remarkably successful in the main areas. See Figure 5.

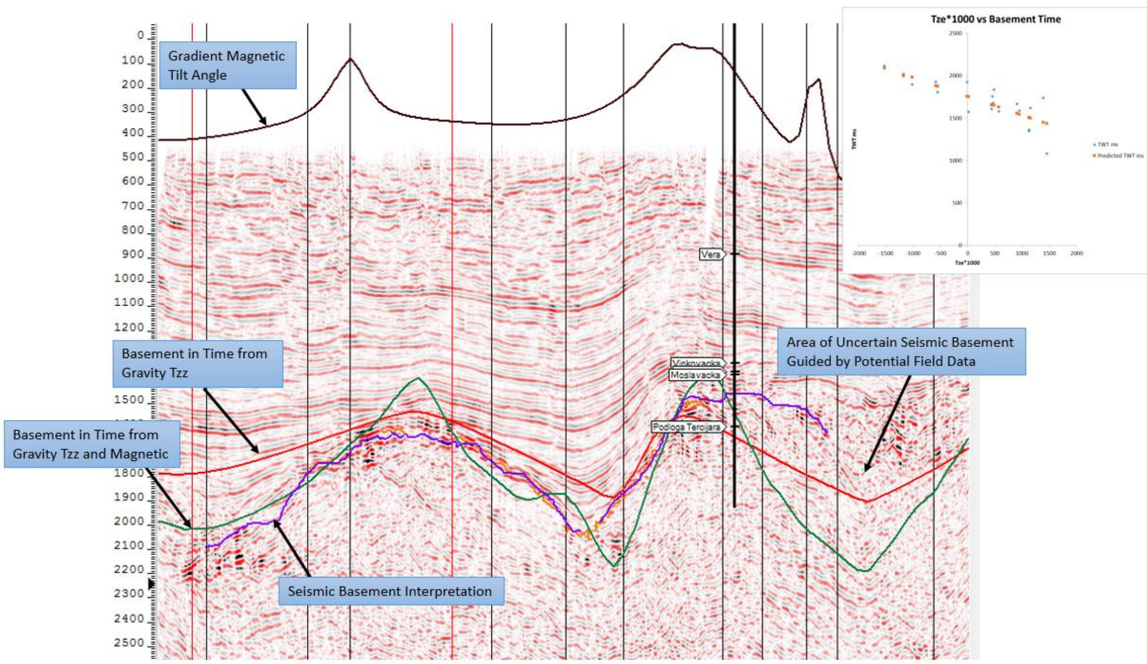

Figure 5. Reprocessed 2D Line with projected derived FTG and Magnetic products. Note close alignment of seismic and derived products.

Conclusions

Modern FTG and Magnetic techniques can be an effective tool in aiding map scale and prospect-seismic scale exploration efforts. Highly flexible acquisition programs which respond to developing exploration concepts and modern processing methods are a highly cost effective method of aiding both seismic interpretation and the screening of exploration prospects.

Acknowledgments

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