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Exploring prospects with FTG Gravity

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Summary

Prospective geology in the form of salt bodies and fault bound structural closures are particularly suited to exploration using gravity technology. This paper describes usage of the Full Tensor Gradiometry (FTG gravity) method to resolving complex shape patterns associated with these features. Intuitive data enhancement techniques will be used to show character, shape and form of causative anomalies and how the technology is ideal for exploring such prospects in a myriad of geological environments.

Keywords*: Gravity, FTG, exploration, play models*

Introduction

FTG gravity is a technology deployed on both marine and airborne platforms worldwide and has been used on both hydrocarbon and mineral exploration projects. Murphy (2010) describes the workings of the instrument and Murphy and Brewster (2007) discuss methods to extract detailed geological information from FTG Gravity data. Their ideas exploit the tensor nature of the data to create new representations that best identify sub-surface geological complexity in terms of shape, size and orientation of target structures. The impact from such detailed imagery serves to enhance definition of prospective geology.

Modern exploration involves deployment of geological and geophysical surveying and assessment techniques to identify and delineate a pre-conceived geological model that locates targeted resources. Such models are then refined with the addition of new insightful information and used to establish the prospectivity of a region.

Furthermore, once a geological model is defined with a geophysical signature pattern, the same techniques are often used to seek out similar signature patterns across a survey area. This has become particularly important as exploration moves to detect deeper and / or more remote occurrences of economic resources. One of the more successful tools of choice to assist with this endeavour has been the usage of Full Tensor Gravity data.

This paper attempts to use those methods by Murphy and Brewster (2007) to demonstrate how FTG gravity has been instrumental in affirming the existence of sub-surface exploration play models such as salt models and fault block / structural closures for hydrocarbon exploration.

The examples used for this paper include a structural fault block model and a salt body that will testify to the direct usefulness of FTG Gravity.

FTG Gravity

FTG gravity is a multi-accelerometer gravity measuring instrument (Murphy, 2010) that measures changes in the gravity field in 5 independent directions. These directions correlate to different components of what is described as a gravity tensor field. Measuring 5 of the 9 Tensor components, Txx, Txy, Txz, Tyy and Tyz, FTG gravity offers information in terms of shape, size and orientation of subsurface geology. Anomaly amplitudes and wavelengths predict density / thickness and depth information of the same geological feature.

FTG gravity data are measured onboard airborne and marine platforms and have been demonstrated to achieve Tzz detectability thresholds of 2 to 3 E over 200 to 300m (Murphy et al, 2007) for airborne applications.

The different Tensor component data allow a detailed assessment of sub-surface geology. The horizontal Tensor component data (Txx, Tyy, Txy, Txz and Tyz) are used to

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identify and map geological contact information, be it edges of source targets or structural / lithological contact information. Tzz, on the other hand, helps define isopach / density relationships of a body mass in relation to its geological setting. Combined together as Invariant Tensor representations (Murphy and Brewster, 2007), it is possible to utilise all components to directly image subsurface geology.

FTG Gravity and Structural Closures

The term 'structural closure' is used in hydrocarbon exploration to define a hydrocarbon resource entrapped between cross cutting fault structures and overlain by impermeable rock units. Hydrocarbons generated at depth will migrate along fault pathways until sealed by impermeable rock on all sides. These tend to be located above raised fault blocks defined by cross-cutting fault structures. The sealing rock may either be shale, salt or some highly compacted sands, or as in the example presented in this paper, a basalt lava flow. Figure 1 shows a schematic representation of such a structure.

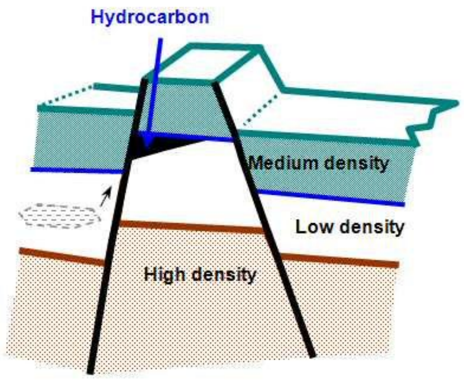

Figure 1: Cartoon schematic depicting the 3D shape of a fault controlled structural closure.

Marine-FTG® data were acquired in the basaltic province of the prospective Faroe-Shetland region offshore NW Europe with a view to image beneath a thick basalt pile and locate a series of structural highs. Previous workers (e.g. Cawley et al, 2005, and Goodwin et al, 2009) document the significance of such highs as focal points for the accumulation of upward migrating hydrocarbons. The overlying volcanics act as a seal.

Figure 2 shows an image of the bandpass wavelength filtered Tzz component data. The image shows a series of positive anomalies that appear fault controlled, with the south eastern anomaly associated with the prospective Westray Ridge, a structural closure. The other highs have been mapped, modelled and subsequently drilled (yellow stars). Results demonstrate that prospective sands occur above a Mesozoic aged ridge structure and overlain by volcanic rock (Statoil UK Ltd., pers. comm. 2006)

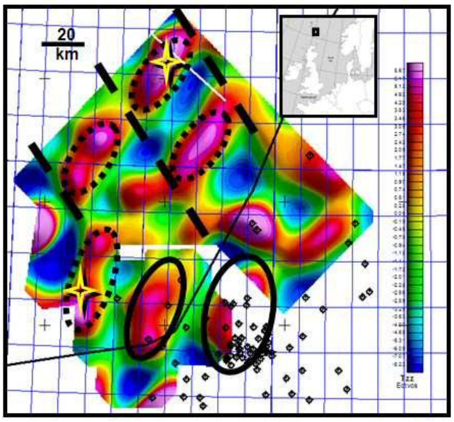

Figure 2: Wavelength filtered bathymetry corrected Tzz data from the Faroe Shetlands offshore Europe.

The example shown is a clear example of how FTG Gravity is suited for mapping the presence of such structures in challenging exploration environments.

FTG Gravity and Salt body definition

Figure 3a shows a bathymetry corrected Tzz image for a known salt body offshore Norway (Murphy et al. 2002). The anomalous low in the centre of the survey data corresponds to the salt feature. Filtering techniques applied to the data permit a detailed investigation into the salt body shape and form. Figures 3b and 3c indicate a complex shape to the salt and a multi-stalk salt body geometry is proposed (Murphy et al. 2002).

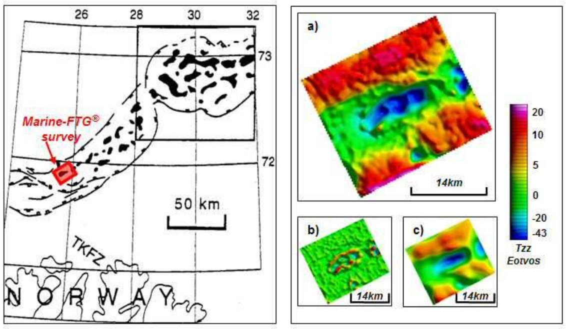

Figure 3: Location Map for the Marine-FTG® survey in the Nordkapp Basin. Inset shows (a) the bathymetry corrected Tzz and wavelength filtered images for (b) less than km and (c) 5 to 30km spatial wavelengths.

Figure 4 shows a plot of lineament contact information identified using the Invariant analysis method described by Murphy and Brewster (2007) grey shaded on an image of the bathymetry corrected Tzz. The interesting observation is the prediction of the edge of salt shown by the shorter wavelength lineaments. The outer rim locates the edge of the salt canopy and encompasses an inner rim. The inner rim suggests it maps the edge of salt at depth beneath the salt canopy. The area between the 2 edges of salt is proposed as outlining potential for overhang development. Supporting evidence for its existence is the presence of similar overhang development on other salt bodies elsewhere in the Nordkapp Basin (Murphy et al. 2002).

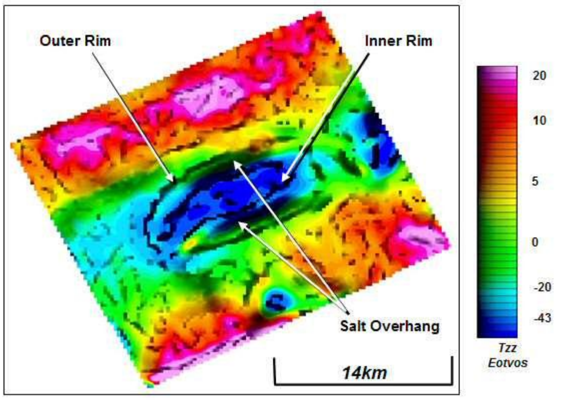

Figure 4: Plots of contact lineaments (grey shade) on bathymetry corrected Tzz (colour).

Conclusions

FTG Gravity data routinely acquired on exploration programmes offers the end user an ability to affirm and refine geological play models. The multi-component tensor field identifies key attribute information of geological bodies that permit identification of not only body shape, size and extent, but also information relating to its geological setting. The impact for exploring prospective geology is profound. The methods presented in this paper are fast and efficient; and facilitate rapid decision making exercises into the viability of a region's prospectivity.

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