Kahil Air-FTG® (Full Tensor Gradiometry) Survey, Case Study of Non-Seismic Advances*

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Abstract

Potential field technologies have witnessed significant advances in terms of resolving power and usability in recent years. One of those is Full Tensor Gradiometry (FTG). FTG is a multi-component, multi-accelerometer technology that measures variation in accelerations due to the Earth’s Gravity Field. The measurements form a 3D depiction of the gravity field as sourced by sub-surface density contrasts. Such density contrasts present themselves in the form of complex geological structures as exhibited by faults, contacts, folds and variable lithologies. The resultant FTG anomaly field is ideally suited to identifying and mapping such geological complexity.

We present a case study describing the Kahil Air-FTG® and Magnetic survey data acquired over Block-55 (Kahil) in the Sultanate of Oman by Bell Geospace. As part of Petrogas Kahil effort to explore Block 55 for hydrocarbons, 8000 Line KM of Air FTG and magnetic survey was acquired in December 2014. The FTG unit used on this project is one of three owned by Bell Geospace. They have a history of performing well during several years of marine survey work and in airborne surveys since being upgraded in 2003. The multi-component data was processed with the latest processing techniques to enhance S/N ratios for better representation of subsurface geology and include Full Tensor Noise Reduction (FTNR) and contact lineament processing (CLP) exploiting the 3D nature of the data. Tensor Axis Realignment and Invariant Analysis techniques, uniquely suited to evaluating 3D data, were used to map potential targets and structural contact information. The FTG data was used for basement depth estimation. The results are presented in Petrel which allows mapping of potential targets and structural and stratigraphic boundaries. Correlation with existing 2D seismic data facilitates a more comprehensive interpretation. The acquisition data and the subsequent analysis have been used for better understanding of the block’s prospectivity and used to locate the newly planned seismic acquisition program.
Abstract

Potential field technologies have witnessed significant advances in terms of resolving power and usability in recent years. One of those is Full Tensor Gravity Gradiometry (FTG). FTG is a multi-component, multi-accelerometer technology that measures variations in accelerations due to the Earth’s Gravity Field. The measurements form a 3D depiction of the Gravity field as sourced by surface density contrasts. Such density contrasts present themselves in the form of complex geological structures as exhibited by faults, contacts, folds and variable lithologies. The resultant FTG anomaly field is ideally suited to identifying and mapping such geological complexity.

This paper presents a case study describing the Kahil Air-FTG® and Magnetic survey data acquired over Block-55 (Kahil) in the Sultanate of Oman by Bell Geospace. As part of Petrogas Kahil effort to explore Block 55 for hydrocarbons 8,000 Line KM of Air FTG and magnetic survey was acquired in December 2014. The FTG unit used on this project is one of three owned by Bell Geospace. They have a history of performing well during several years of marine survey work and in airborne surveys since being upgraded in 2003.

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Background & Objectives

Kahil block 55 is located in the Al Wusta Governorate of Oman on the eastern flank of the prolific South Oman Salt Basin (Fig. 1a). Petrogas Kahil holds the right of 100 per cent interest of exploring hydrocarbons in Kahil Block. As an extra complimentary scope agreed with the Ministry of Oil & Gas (MOG), is to acquire high quality gravity and magnetic data over the entire vicinity to determine potential areas. The total areal coverage is around 7,564 sq km representing nearly 8000 line Kilometers flown across the flying time covering the entire scope of work was three weeks (i.e. day time). Fig. 1b)

The main objective of the Air-FTG® gravity data is to define a number of interesting areas presenting high and low density responses within the surveyed block. After processing and modelling of all anomalies then a clear picture of the basin can be generated and any potential related to mapping mini basins or sags within the block are made.

Survey Specs & Parameters

The survey plan includes how many lines to be flown in order to cover the area of interest based on nominal clearance for desired FTG detectability, line spacing, orientation, cost & time. Figure 2 explains some of these parameters. Now these parameters were put together to meet the specification that Petrogas Kahil required ensuring data across the block were acquired, subsurface anomalies revealing some if not most of the potential areas were.

How it works

Magnetic fields generated in the Earth’s Outer Core induce the field on susceptible geology. The inner core has the highest density that decreases toward the crust and surface. What FTG surveying does is simply measuring variations in density caused by Earth’s gravity. These variations are caused by subsurface geology that can be expressed as series of point masses per unit volume or density; such variations tend to be much smaller than 9.8ms-2. Gravity is measured in units of milli-gals ( i.e. 1Gal=1cm/s2). The value of gravity will vary depending on the number of point masses directly beneath the surface (subsurface geology). Where the magnetic field is measured from the Earth and also object to be detected (i.e. if object is susceptible, then it’s electrons are re-arranged as dipoles and becomes magnetized). In practice, the gravity and magnetic anomalies are expressed in wavelength and amplitude Figure 3.

Steps of Interpretation and Modelling:

1. Start with a basement layer
   a. Define a long-wavelength gravity signal (i.e. Moho layer defines a very long-wavelength gravity and magnetic signal).
2. Describe the observed magnetic field
3. Meta sediment layer
4. Refines modelling for complex structural geology above basement using the observed gradient data
5. Facilitate investigation of density distribution within shallower layers
6. Seismic constraint means we have a guide to the modelling.
7. Layer geometries are fixed in the model to converted pseudo-depth horizons
8. Adjustments made to produce final model

Results & Discussions

FTG gravity data defines areas that possess high and low density responses which mark possible potential areas. Extensive work has been done to integrate all recognised anomalies using regional understanding (i.e. forward modelling) linking geology with aid from some regional poor quality legacy seismic lines. Some dominant immediately to long wave density responses associated with basement or deep rock succession have been mapped. Based on this data new basins have been identified including the already known Tertiary Basin towards the eastern side of the block and other mini basin in the SW direction (Figure 4). Also, major fault zones can be mapped clearly with confidence when compared to legacy seismic data. Both profile modelling and migration results reveal to some extent an approximation of the depth estimate that varies considerably from 1 to 5km referenced to mean sea level.

High amplitude FTG responses are typically related to complex basement topography. This is evident in the centre of the block (relative colour anomaly patterns). Also, the extreme high amplitude anomaly (i.e. pink) located to the cast is associated with high density ophiolite material.

Low amplitude and negative FTG anomalies are associated with basins or locally thickened and deep sediments. Figure 5 shows such a response associated with a mini basin. Attribute analysis of the Tensor data facilitates lineament mapping by delineating contacts separating areas of high and low densities. Figures 6a and 6b show lineament anomalies mapping boundaries and possibly major structuring reaching the surface (i.e. faults) like that evident on the Eastern side of the block trending SW-NE direction. This correlates well with a trough and a normal fault pre mapped by seismic.

Summary

Air-FTG data allowed extracting Depth-Density cube through full tensor migration for Kahil, Block 55.

Enhanced subsurface anomalies have been identified and structural geophysical trend has been mapped. This aided allocating the possible potentials with good definition (i.e. mini basins).

FTG gravity helped estimating depths of possible potential anomalies utilizing density maps resulted from the comparison of FTG & magnetics.

Generated lineament maps provided insights of major faults and mapping the trends of troughs by allocating the edges of shallow basement geology.

High amplitude gravity anomaly bounded by NE-SW trending anomaly pattern is observed in the eastern side of the block. This is associated with the Mayurbhah Outliers.

Acknowledgement

I would like to thank Petrogas Kahil and Sultanate of Oman Ministry of Oil and Gas for permission to present this work. Extended thanks goes to Bell Geospace Limited, Edinburgh, United Kingdom for acquiring and interpreting the data.

Bibliography


Figure 1. Kahil Air-FTG® (Full Tensor Gradiometry) Survey, Case study of non-seismic advances.

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Figure 2. Kahil Air-FTG Gravity data covered Block-55 (Kahil) in the Sultanate of Oman by Bell Geospace. A part of Petrogas Kahil effort to explore Block 55 for hydrocarbons 8,000 Line KM of Air FTG and magnetic survey was acquired in December 2014.