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

Elias Al Kharusi[1], Colm Murphy[2], Christopher Bellamy[2], and Saada Al-Rawahi[1]

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[1]Petrogas E & P, Muscat, Oman (elias.kharusi@petrogas.com.om)
[2]Bell Geospace Limited, Edinburgh, United Kingdom

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.

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Geo2016

Elias Al-Kharusi[1], Colm Murphy[2], Christopher Bellamy[2], & Saada Al-Rawahi[1]

1. Petrogas Kahil L.L.C, Muscat , Oman

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This poster 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 main potentials. The total areal coverage is around 7,564 sq km represents nearly 8000 line Kilometers flown across the block. The flying time covering the entire scope of work was three weeks (i.e. day time). Fig. 1b).

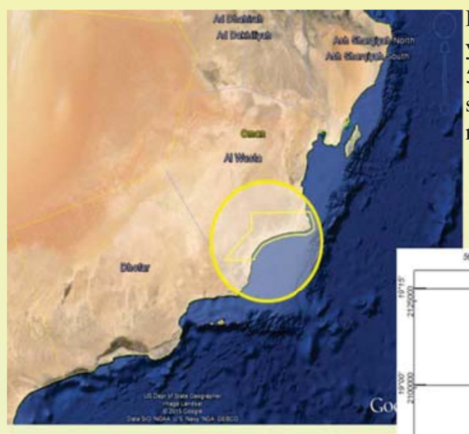

Figure. 1a. A map of Oman locating in yellow the outline concession of Block 55. Kahil (i.e. block 55) is located far south-East side of Oman in Al Wusta region.

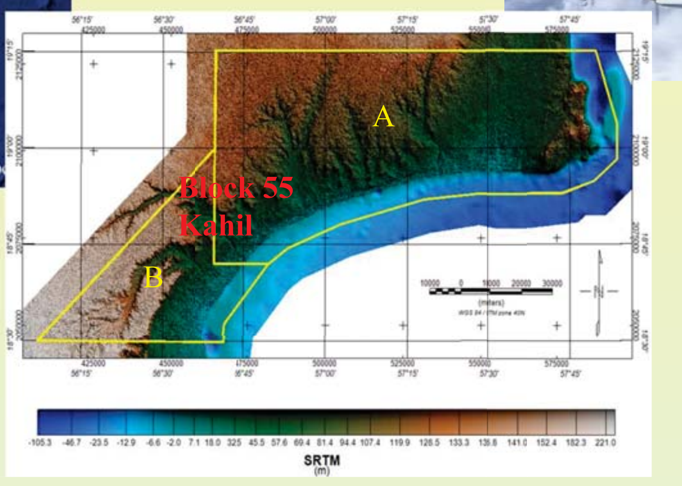

Figure. 1b. Two sectors (A & B) segmenting block 55 with different strategic drive.

Basler Aircraft used. Courtesy: Bell Geospace

The FTG data will aid resolving the sensitivity to key geological targets like top basement, structural complexity, & depth to basement.

The main objective of the Air-FTG® gravity data is to define a number of interesting areas possessing high and low density responses within the surveyed block. After processing and modelling of all anomalies then a clear picture of the basement 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 may 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 to ensure valuable data across the block were acquired, subsurface anomalies revealing some if not most of the potentials were obtained.

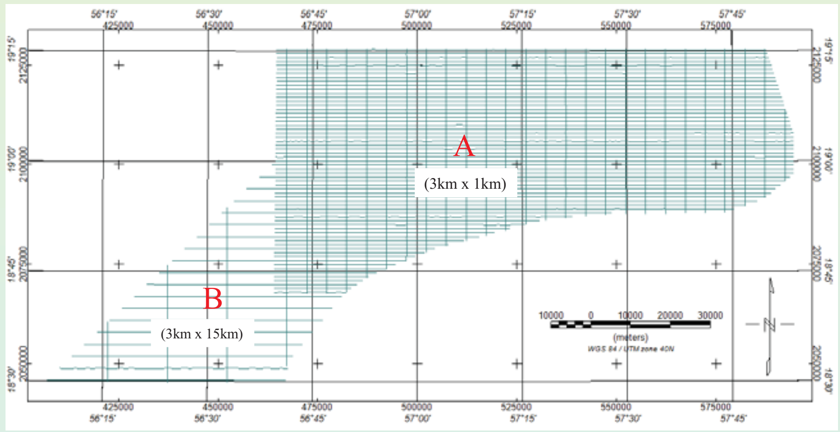

Figure. 2a. Survey plan showing A & B segmenting block 55 with different strategic drive.

Survey Designation	Line-km: In-lines	Line-km: Tie-lines	Line-km: Total	Line Spacing (m)
Kahil A	6051.120	1199.640	7250.760	1000/5000
Kahil B	2581.752	533.532	3115.284	3000/15000

Figure. 2b. Survey design specifications showing the line spacing for both segments A & B.

Determine sensitivity to key geological targets:

Top Basement structural complexity

Depth to Basement

Base Tertiary

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 towards 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 $9.8ms^{-1}$. Gravity is measured in units of milliGals (i.e. $1Gal=1cms^{-2}$). 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.

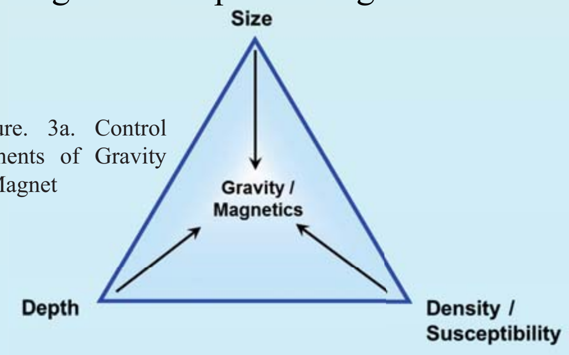

Figure. 3a. Control elements of Gravity & Magnet

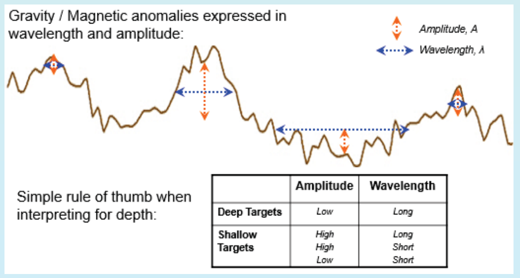

Figure. 3b. Gravity & Magnet anomaly expression.

'Full Tensor Gradiometry (FTG) is a multicomponent gravity surveying technology that measures different components of the Gravity Gradient Tensor' (Murphy, 2004). The information from a tensor can each be related to some geological expressions to some extent defining edges of a geological body or aid mapping geological contacts (horizontal component information) or defining depth/ isopach/density relationships of a body mass in relation to its geological setting (with the vertical component, Tzz). The impact of working with tensor information can be significant in that it facilitates a mechanism to not only identify target geology.

Full tensor gravity gradiometry (FTG) measures simultaneously changes in the gravity field in all directions of the field (i.e. vertical and horizontal components). This is a fundamental difference to conventional gravity that measures only the vertical component of the gravity field vector.

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.
   b. Describe the observed magnetic field
2. Meta sediment Layer
   a. Refines modelling for complex structural geology above basement using the observed gradient data
   b. Facilitate investigation of density distribution within shallower layers
3. Seismic constraint means we have a guide to the modelling.
   a. layer geometries are fixed in the model to converted pseudo-depth horizons
4. Adjustments made to produce final model

Results & Discussions

FTG gravity data defines areas that possess high and low density responses which mark possible potentials across the block. Comprehensive 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 intermediate to long wavelength responses associated with basement or deep rocks 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 (red coloured anomaly patterns). Also, the extreme high amplitude (i.e. pinkish) located to the east is associated with high density ophiolite material.

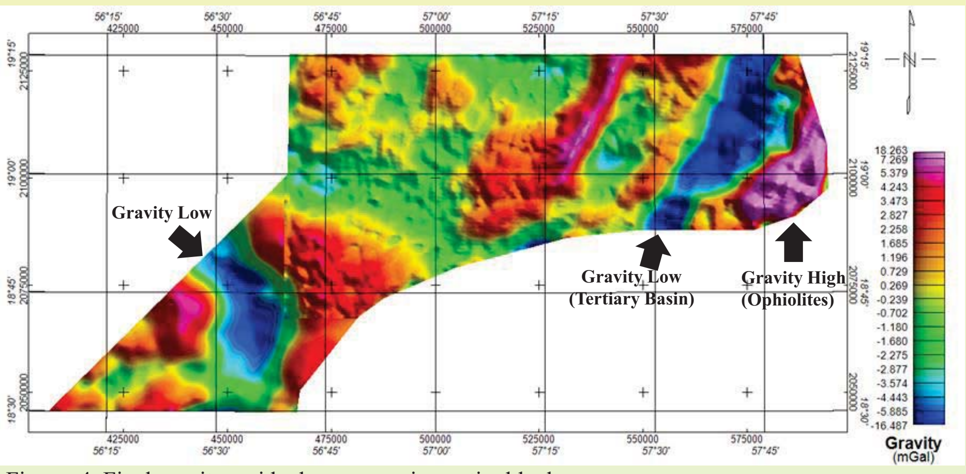

Figure. 4. Final gravity residual map covering entire block.

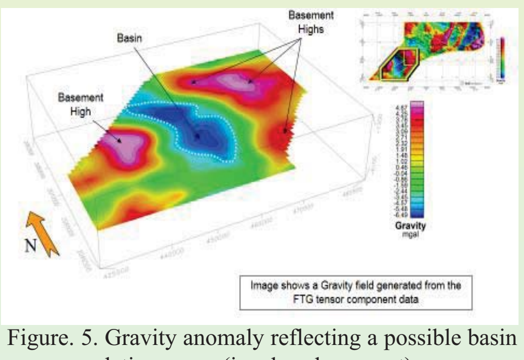

Figure. 5. Gravity anomaly reflecting a possible basin accommodation space (i.e. deep basement).

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.

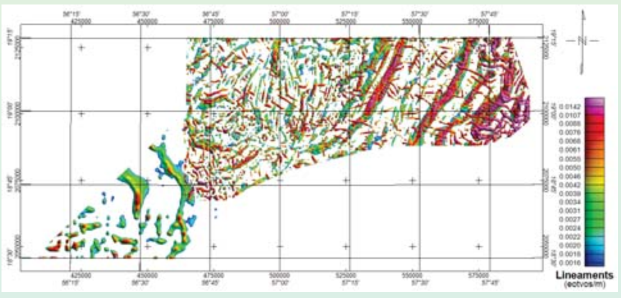

Figure. 6a. Lineament analysis attribute. Lineament anomaly amplitude variation provides insight to depth and / or density contrast of causative geology. It aid allocating edges of shallow r small scale geology (i.e. trough, major faults).

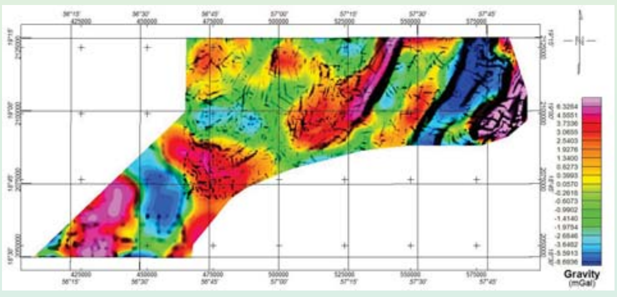

Figure. 6b. Gravity residual map after mapping possible faults and trough anomalies and now mini basins and structurations that reach the surface can be identified.

Figure. 7. shows a simplified depth conversion as well as a 2-density layer model provides some insight to the topography of the top basement. Depth converted seismic and formation density constraints can improve the 2D basement models, highlighting subtle variations in density and structural style of the top basement surface. This subtle density contrast is suspected as well as more complex structures line modelled (line 930403). Aeromagnetic data shows deep magnetic basement. A deep mafic magnetic basement is suspected to fit the aeromagnetic data of this line & other lines used in this study.

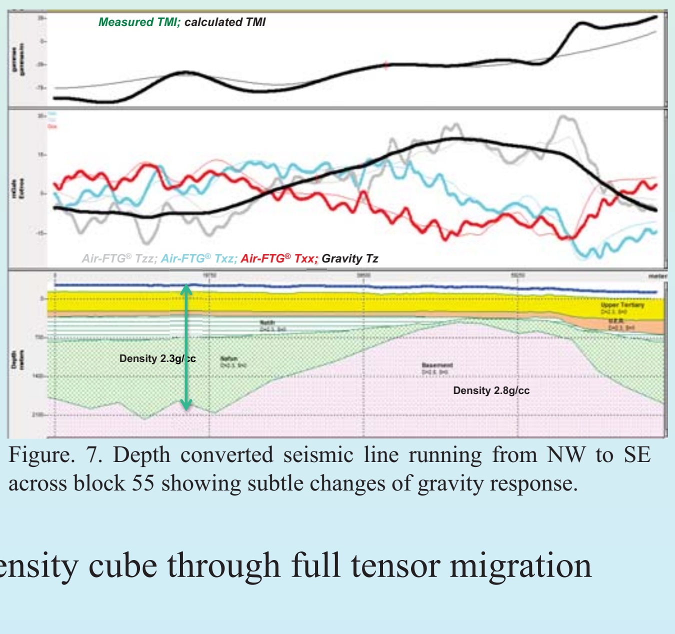

Figure. 7. Depth converted seismic line running from NW to SE across block 55 showing subtle changes of gravity response.

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 geological 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 depth maps resulted from the comparison of FTG & magnetics.
- Generated lineament maps provided insights of mapping 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 Masirah Ophiolite.

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