Full Tensor Gravity – from marine to airborne solutions for offshore, nearshore and transition zone exploration

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Introduction

Full Tensor Gravity Gradiometry (FTG) data form an integral part in offshore, nearshore and transition zone exploration initiatives and has enjoyed considerable success worldwide. Deployed on both seagoing and airborne platforms, FTG is well suited for identifying and resolving complexities both within basement and above basement within basinal settings, such as those associated with salt, closed structures, carbonates and structural mapping challenges. The technology benefits all stages of the exploration cycle from frontier to advanced play evaluations. Data acquired on both marine and airborne platforms excel at resolving complex geological structure over large areas offshore whereas airborne solutions are adopted for nearshore to transition zone work. Marine acquisition captures a higher frequency content and is better suited for detailed assessment of complex geology at near sea-bed and shallow depths.

What is FTG?

FTG measures the rate of change of gravity in all directions of the field as exhibited by sub-surface geological density contrasts. The measured data are a series of independent components defining a Tensor field (Murphy, 2010). Txx, Tyy and Txy measure the rate of change of the gravity field in the horizontal components whereas Txz and Tyz measure the horizontal rate of change of the downward pull in the horizontal components. Txx and Tyy, when combined provide a unique measurement of the rate of change in gravity in the downward component, Tzz. The individual component information is directly suited for mapping complex geometries on targeted geology that generate a density contrast with host geology. In addition, the directly measured Txz, Tyz and Txy components identify and map geological contact information defining the structural and stratigraphic setting of the target. All data are a measurement of the Gravity Potential that when combined accurately depict a gravity anomaly field.

When to use FTG?

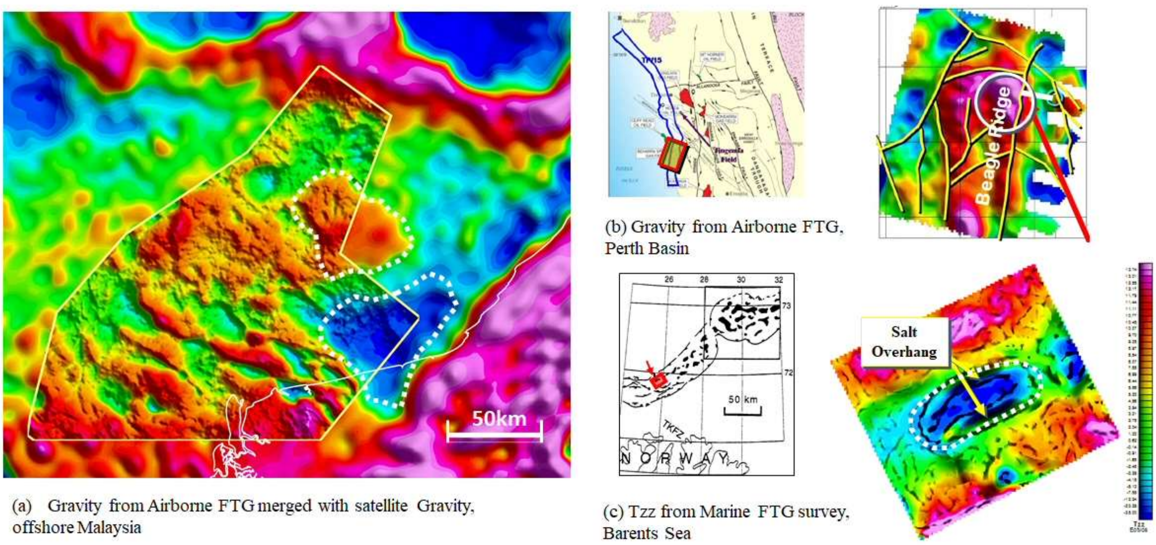
Combining a gravity anomaly field derived from the FTG tensor component data with legacy gravity data in the form of marine and / or satellite data yields an uplift in resolution that serves to expedite exploration risk analysis in frontier settings through its ability to quickly identify prospectivity.

Legacy gravity data often acquired as part of wide line spaced 2D seismic programs over large geographic settings suffer from loss in spatial resolution due to the regional extent of the survey.

When acquired as part of focussed 2D/3D seismic programmes, a similar loss in resolution is encountered, due to operational preferences being shown to the seismic performance. The impact is spatial filtering of signal during processing to produce coherent anomaly maps.

FTG, on the other hand, is acquired on dedicated vessels facilitating capture and retention of high frequency signal associated with subtle geology in shallow intra-basinal settings. The independent tensor component information is used to locate and delineate geological complexity relevant for advanced exploration work programmes such as salt, closed fault block and carbonate body geometry definition or mapping of complex fault frameworks. In addition, the gravity anomaly generated from the tensor information yields a high spatial resolution making FTG ideally suited for mapping complex structural patterns basin wide.

Figure 1 shows examples of how and where FTG data is used from frontier to advanced exploration in offshore settings. Figure 1a displays a combined Gravity field from FTG with satellite gravity data for offshore Malaysia locating primary basins and complex structuring associated with shallowing basement. Figure 1b shows gravity from FTG used to validate a structural fault block interpretation from vintage 2D seismic in transition zone setting of the Perth Basin, Western Australia. Figure 1c shows a Full Tensor anomaly map describing a salt feature in the Barents Sea offshore Norway (Murphy and Brewster, 2007). The colour scale is defined for Tzz; grey shading from an analysis of the horizontal component information for Txz and Tyz and locates overhang geometry on the salt body sides. The Malaysian and Australian examples were data acquired on airborne platforms. The Barents Sea example is from marine acquisition.



(a) Gravity from Airborne FTG merged with satellite Gravity, offshore Malaysia

(b) Gravity from Airborne FTG, Perth Basin

(c) Tzz from Marine FTG survey, Barents Sea

Figure 1. Data examples of FTG. (a) merged gravity from FTG with satellite data mapping regional geology, (b) focussed gravity from FTG defining structural block in Perth Basin and (c) FTG tensor analysis defining salt body shape in the Barents Sea, offshore Norway.

Both marine and airborne acquisition are ideal for large area survey work from offshore to nearshore applications. Airborne survey work is best suited for transition work. Marine acquisition offers best resolution for near-seabed and shallow depth applications.

Marine and Airborne – operational considerations

Acquisition and sampling rate

FTG data acquired on marine platforms offer a higher sampling rate over airborne platforms (Mims et al, 2009) simply by virtue of the slow ship movement. FTG data is sampled at 1 sec intervals that on marine surveys, the along line sampling rate is typically 7 to 10m whereas on airborne platforms is from 55 to 60. The impact is that a marine survey's wider signal bandwidth captures a higher frequency content. This has implications for advanced exploration challenges such as detailed depiction of near seabed / shallow geological complexity. The increased sampling rate permits high confidence imaging.

For exploration projects targeting deeper and / or larger sized structure, the capture of the high frequency content is less critical as such targets are imaged equally as well with a sampling rate of 55m as it is with a sampling rate of 7m. In such applications, FTG data are acquired on airborne platforms at a constant elevation from 100 to 120m above the water surface, thus maintaining a fixed and smooth acquisition surface. Data quality is insensitive to wave motion facilitating acquisition of high quality data in rapid time.

Marine surveys are acquired at speeds of 12 to 15 knots on dedicated vessels. Airborne surveys are acquired at speeds of 110 to 120 knots. The relative slow motion of shipborne surveys allows acquisition of a higher frequency content suited for detailed imaging of complex near sea-bed and shallow geology. The faster rate of acquisition for airborne surveys makes it better suited for largescale projects where survey objectives are more focussed on resolving complex larger geological body shapes at depth.

Bathymetry

The single most and largest density contrast presented in FTG surveys is bathymetry. Scours, channels and rugged bathymetric topography yield high amplitude, varied wavelength responses that can mask the response from deeper sub-seabed geology. These are particularly critical when surveying in shallow water. In such applications, bathymetry data is acquired concurrently with the FTG on marine surveys. For airborne applications, where survey line spacings are wider, FTG's sensitivity to bathymetry is less critical. In such applications, bathymetry data retrieved from satellite and / or seismic surveys are considered. The bathymetry FTG effect is modelled and removed from the raw FTG data for sub-seabed imaging.

The water layer acts as a buffer on FTG's ability to resolve sub-seabed geology. Deep water creates a large distance from sensor to source, resulting in a reduced capacity for FTG to image detailed geology. Low amplitude, long wavelength signature patterns arising from largescale structures are retrieved. Shallower water results in sensor being closer to the target and the resultant FTG response will yield a higher frequency and higher amplitude anomaly.

Tight line spaced surveys are planned in shallow water to adequately capture such focussed responses. In such an application, then there is a fundamental need for detailed depiction of the sea-bed in order to correct for its contribution from the data. Wide line spacings in deeper water means that FTG is less sensitive to sea-bed effects allowing consideration of lower resolution bathymetry data for corrections.

Summary and Conclusions

FTG measures the rate of change of gravity in all directions as preserved by sub-seabed geology. Individual tensor component data delineate and resolve complex structural shape to target geology. When combined, they produce a high quality gravity field that is seamlessly merged with pre-existing lower resolution conventional gravity data. FTG are a key a data type for offshore, nearshore and transition zone exploration projects and acquired on board marine and airborne platforms. Marine acquisition retrieves a higher frequency content that is used in resolving near seabed / shallow geological challenges. Airborne acquisition is used in nearshore and transition zone settings. Survey time is rapid leading to efficient risk reduction in underway exploration programmes.

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