SUMMARY

Three phases of 2D seismic acquisition and PSDM processing were completed by ION GeoVentures from 2008 to 2012. The objective was to provide regional evaluation of the untested NE Greenland Atlantic passive margin. In 2012 ARKeX completed an airborne Full Tensor Gravity (FTG) survey over the area for both the pre-round blocks open to the KANUMAS Group and the blocks for the 2013 Greenland Licensing Round. The FTG survey is the largest ever acquired offshore and covers 50,000 sq.km. The high resolution gravity gradiometry and magnetics have been integrated with the Northeast GreenlandSPAN data interpretation to develop an improved understanding of basement composition, distribution of igneous/volcanic components, the geometry of salt structures within the area, and of fault linkages both within and above Caledonian basement.
Integration of 2D seismic, gravity gradiometry, and magnetic data on a passive margin - NE Greenland

Jackson, D. (1); Helwig, J. (2); Dinkelman, M.G. (2); Silva, M. (1); Protacio, A. (1)
(1) ARKeX, Cambridge, UK; (2) Ion GeoVentures, Houston, TX, USA.

Three phases of 2D seismic acquisition and PSDM processing were completed by ION GeoVentures from 2008 to 2012. The objective was to provide regional evaluation of the untested NE Greenland Atlantic passive margin (Helwig et al, 2012). In 2012 ARKeX completed an airborne Full Tensor Gravity (FTG) survey over the area for both the pre-round blocks open to the KANUMAS Group and the blocks for the 2013 Greenland Licensing Round. The FTG survey is the largest ever acquired offshore and covers 50,000 sq.km. The high resolution gravity gradiometry and magnetics have been integrated with the Northeast GreenlandSPAN data interpretation to develop an improved understanding of basement composition, distribution of igneous/volcanic components, the geometry of salt structures within the area, and of fault linkages both within and above Caledonian basement. Two areas located within and close to the boundary of the high resolution FTG Survey (Figure 1) are analysed in this study: Area A - The Danmarkshavn Ridge and the Thetis Basin; Area B - The Permian Salt Province - Danmarkshavn Basin.

PSDM seismic data is imaged to 40km depth and provides a coherent image between 10-30km. These data combined with high quality shallower seismic signal (<10km), provide an excellent starting point to build different interpretation models, which can be interrogated using potential fields modelling to ensure consistency of interpretation across all datasets. Some regional seismic dip lines show the high
resolution gravity gradiometry and magnetic trends are aligned; however, there are regions where the datasets show offset between crestal gravity and magnetic highs. Detailed 2D/3D iterative modelling allows the architecture and the nature of the highly heterogeneous basement to be interpreted. It demonstrates a linkage between the extensional/transtensional (and localised transpressional) faulting of the Late Palaeozoic, Mesozoic, Cretaceous, Tertiary and inter-crustal detachments, which were initiated during the Caledonian Orogeny. The two study areas have been chosen to show how the incorporation of the high resolution FTG survey enables a better interpolation of basement edge faults, intra-basement faults, and basement type (Area A); and how salt geometries and related salt structures on a sparse grid of 2D seismic can be interpolated using the FTG survey to construct a 3D architecture (Area B) between 2D seismic lines 20 km apart.

**Study Area A: The Danmarkshavn Ridge and the Thetis Basin**

In this area three adjacent seismic lines (A1, A2, and A3 – Figure 1) and the high resolution FTG survey are used to investigate the tectonic fabric. Each seismic line was interpreted and followed by a series of 2D modelling interrogations to ensure that both seismic and high resolution FTG datasets are honoured by the geological interpretation. To illustrate the procedure we discuss the 2D modelling of one of the lines, and then illustrate how the 2D models are used to generate fault linkages and investigate basement heterogeneity. The matching of gravity and magnetic signal is possible using regional-scale boundaries, as indicated by the modelling of Line A2 (Figure 2). However, a detailed interpretation of the upper 5kms of section needs to be incorporated in order to maximize trends from the FTG into the structural understanding.

![Figure 2: Regional scale modelling of Line A2 honouring gravity and magnetic data – the Gzz data requires a more detailed interpretation of the upper 5Kms of section – see Figure 4](image)

In Figure 2 a simple regional model is shown which includes a variation in the Moho boundary, and a difference in density and magnetic susceptibility between upper and lower crustal regions. These regional features coupled with a sedimentary package draping the Danmarkshavn Ridge, produce a reasonable match of the observed and calculated gravity and magnetic profiles. However, in order to maximize what the higher resolution Gzz profile shows, a more detailed analysis of the upper 5-10kms of the section was performed.

Figure 3A shows an enlarged view of the Danmarkshavn Ridge illustrating how the trends in the gravity and magnetic data are offset. A simple explanation is that the western (landward) side of the section comprises of magnetic basement, and the eastern (seaward) side is non-magnetic basement. Figure 3B shows the Gzz and Gz profiles. The yellow-shaded area shows seismic coherency indicating highly variable tectonic fabric within this low magnetic area. The observed high Gzz values in the central part of the ridge have been matched using slightly higher basement values for the core of the eroded sub-cropping “basement” anticline immediately below the sedimentary cover. i.e. the Gzz signal is indicating tectonic fabric boundaries, indicated by the red arrows.
The dashed lines indicate the interpreted amount of erosion indicated by the sub-cropping tectonic fabric. An integrated map of the data (Figure 4) show how the 2D modelling and potential fields is combined in the development of the 3D earth model. The magnetic data allows interpolation of the eastern bounding fault of the Danmarkshavn Basin to be interpolated between seismic lines over 35 km apart. The tectonic fabric (red-green) within the non-magnetic basement in lines A1 and A2 show geometries which appear to reflect an extensional regime that is followed by compression. A key question that remains is whether the presence of non-magnetic (seismic coherent) versus magnetic basement indicates imaging of tectonic fabrics produced by the Caledonian orogeny?

**Figure 4: 3D visualization of magnetic and seismic data**

**Area B: The Permian Salt – Danmarkshavn Basin**

Study Area B covers the northern part of the Permian Salt Basin. This section shows how high resolution gravity gradiometry is integrated with regional 2D seismic to improve the architectural understanding of salt geometries within a basin. Figure 5 shows seismic line B1 (location shown in Figure 6) and indicates that the presence of low density halite in the upper 5 kms of the section affects the observed Gzz profile. 2D modelling similar to that described in Area A was also conducted but is not described here. The Gzz “lows” in the Permian Salt Basin are tied to seismic and modelled to delineate salt volume and geometry.
Figure 5: Seismic Line B1 and the observed Gzz profile

Figure 6A shows the resolution of salt bodies identified from regional 2D seismic and highlights the salt structures as small as 1-2km². Using the Gzz signal to interpolate away from seismic control reveals that many of the smaller structures identified on seismic are part of much larger salt bodies (Figure 6B). Figure 6C shows that some of these salt structures are salt walls extending over 60 kms in length and trending NNE-SSW. The terminations of some of the salt bodies are indicated by NW-SE linear trends in the Gzz.

Figure 6: Combining regional seismic 2D with high resolution gravity gradiometry to improve definition of salt and related structural trends

Integration of regional 2D seismic data and high resolution full tensor gravity and magnetic surveys in these two study areas demonstrates the value in understanding frontier basin architecture, and in reconciling the linkages of the inherent tectonic fabrics. From these data a higher resolution 3D structural model of the Northeast Greenland margin can be built in order to guide structural interpretations and implications for petroleum systems on this margin.

Reference: