Aeromagnetics assists Oil & Gas exploration in the Bedout Sub-basin, offshore Canning Basin

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SUMMARY

Finder Exploration and its joint venturer Carnarvon Petroleum commissioned Fugro Airborne Surveys to acquire and interpret 21,622 line kilometres of airborne magnetic data over Petroleum Exploration Permits WA-436-P and WA-438-P in the Bedout Sub-basin, offshore Canning Basin within the Northwest Shelf, Western Australia. These data were acquired to augment the existing sparse 2D seismic data in the study area.

The newly acquired aeromagnetic data were integrated with selected seismic profiles, regional structural and geological data; tied to the well data to provide an interpretation of the tectono-structural evolution of the Bedout Sub-basin, a depth to magnetic basement and total sediment thickness estimation in the study area.

The interpretation revealed a complex basin architecture reflecting multiple structural and depositional features which contributed to the development of the Bedout Sub-basin. The estimated depths to magnetic basement are consistent with previous assessments of sediment thickness derived from the interpretation of the existing 2D seismic dataset, with the exception of previously unrecognised thick sedimentary deposits interpreted in the eastern part of the study area.

The interpretation of the aeromagnetic data shows variations in sediment thicknesses of up to 5kms over relatively short lateral distances in the vicinity of the Bedout High in the northern part of the study area. A significant shallowing of the basement towards the Lambert Shelf in the south is also identified.

As part of the ongoing exploration effort, this new aeromagnetic data and interpretation has added to the understanding of the study area by identifying a possible additional hydrocarbon source kitchen and improving the tectono-structural understanding of the Bedout Sub-basin.

Key words: Offshore Canning Basin, Bedout Sub-basin, Aeromagnetics, Depth to Magnetic Basement, Sediment Thickness, Oil & Gas Exploration.

INTRODUCTION

Airborne magnetic techniques have been applied in hydrocarbon exploration since the early 1920's but mainly to identify regional structural features and delineate basement blocks. However, in conjunction with other geological and geophysical methods, airborne aeromagnetics can play a greater role in identifying favourable geological settings for locating prospective target areas for hydrocarbon exploration. It is well known that neither seismic nor gravity methods alone can fully map the basement character. Therefore, aeromagnetic data is in a unique position to divulge the basement characteristics in greater detail, over a larger area and at a significantly lower cost of acquisition than seismic.

Finder Exploration and their joint venturer Carnarvon Petroleum conducted an aeromagnetic survey during May 2010 in the Bedout Sub-basin. The survey covers an area of 15,856km^2 and consists of 21,622 line km of data acquired along N-S flight lines spaced at intervals of 1km and tie lines flown E-W at intervals of 3km (Figure 1). The survey was flown at a nominal flying height of 150m above sea level with no HSE incidents recorded during the survey. The acquired data is an improvement on pre-existing regional airborne magnetic data, covering a large study area at a relatively lower cost compared to the acquisition of seismic data. The newly acquired HRAM (High Resolution Airborne Magnetic) dataset integrated with other available datasets was used to determine the structural framework and depth to magnetic basement in the Bedout Sub-basin. Identifying the location of basement highs, sedimentary depocentres and possible stratigraphic pinch-outs against the basement highs highlight the value of characterising the basement topography.

This case study presents the exploration results that are emerging and their correlation with the integrated analysis of geophysical and geological data of the Bedout Sub-basin, offshore Canning Basin.

The offshore Canning Basin developed as a result of multi-phase rifting and has undergone a complex structural evolution (Kennard et al., 1994; Department of Resources Energy and Tourism, 2008). The Bedout Sub-basin contains a Palaeozoic to Tertiary sedimentary succession which is believed to be a continuation of the proven Palaeozoic oil and gas bearing sediments in the onshore Canning Basin. It is bound to its south by the Lambert Shelf, to the north by the Rowley Sub-basin and to the west by the Beagle Sub-basin.

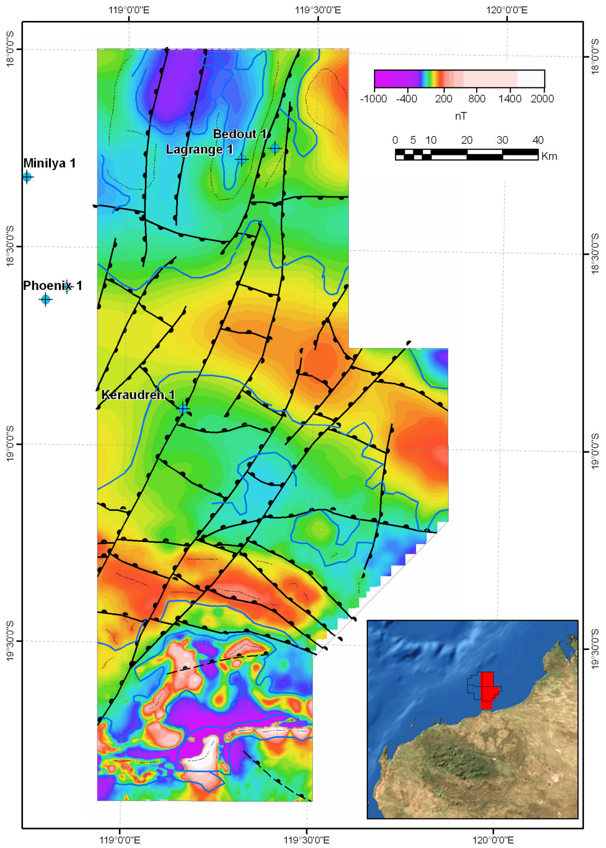

Figure 1. Image of the TMI-DRTP (total magnetic intensity differentially reduced to the pole) data with structural interpretation from the survey and showing the location of the study area (insert).

Up to 2.5km of Palaeozoic sediments have been deposited during an intracratonic sag phase in the offshore Canning Basin which is overlain by up to 7km of Mesozoic passive margin sediments. The Palaeozoic sequence onlaps the Lambert Shelf (south) and the Broome Platform (northwest) and is overlain by a prominent regional unconformity that is related to the Bedout and Fitzroy movements (Colwell and Stagg, 1994). Rifting of Argo Land from the West Australian margin in the Late Jurassic marks the transition from intracratonic to rift and passive margin sedimentation (Department of Resources Energy and Tourism, 2008).

The Bedout High is a structural feature that separates the Bedout Sub-basin to the south from Rowley Sub-basin (Roebuck Basin) to the north. The Bedout High consists of uplifted and eroded Permo-Carboniferous sediments above an interpreted faulted basement core and is capped by Late Permian volcanic rocks (Colwell and Stagg, 1994). Mesozoic sediments pinch out against and partly drape over the Bedout High.

The first significant phase of exploration in the offshore Canning Basin began in the 1960's and continued through to 1982 with acquisition of seismic data. Around fifteen surveys were completed during this time, focusing on the Bedout Sub-basin and the Rowley Sub-basin. The initial phase of exploration drilling in the Bedout Sub-basin (Bedout-1, Keraudren-1 and Minilya-1) occurred during 1970-1974 with the three more wells (Phoenix-1 & 2 gas discoveries and Lagrange-1) being drilled during 1981-1983. During 1986-1994, six more seismic acquisition surveys were conducted in the Bedout Sub-basin. More recent activity includes several seismic surveys conducted during 1998-2001. Also, the Bedout Sub-basin has been the focus of 2D and 3D seismic surveys during 2009-2010 to delineate prospects on recently released acreage.

INTERPRETATION

Depth to Magnetic Basement

A visual qualitative assessment of the wavelengths of the magnetic data over the study area suggests a variable depth to magnetic basement confirmed by the depth to basement model which shows a large range of depth values from less than 1km on the Lambert Shelf in the south, to depths of the order of 4km on the Bedout High and depths in excess of 12km in the central (deepest) parts of the Bedout Sub-basin.

Depth determinations on the Bedout High are quite variable due to sources at different depths. Reasonably consistent depth estimations of 3.5 to 5km were derived from the SI 1 Euler profiles and from the Located Euler grid methods. This range of source depths is comparable with results of seismic interpretation presented by Colwell and Stagg (1994). Both methods of interpretations have control for the Top Permian from the Lagrange-1 well. The well indicates a two-way-time to the Late Permian to Early Triassic volcanics of 2.06s (approximately 2,862mSS). Basement interpretation from both sources indicates a two way time of approximately 3s (less than 5,000m).

The depth solutions obtained over the Bedout High are interpreted to be imaging the depth to the volcanics, with some deeper responses from the underlying magnetic basement. The range of solution depths, from the profile based interpretation, may be a result of the weathering of the volcanics (Lipski, 1994). Differing weathering profiles through the volcanics can result in differing magnetic susceptibilities within the succession, resulting in the observed magnetic depth estimate solution range. Away from the Bedout High, the only other control is provided by the Keraudren-1 well, which terminates at 3,844mRT in the early Middle Triassic units. In this area, the depth to magnetic basement solutions indicates a depth of approximately 7,500m. It can be inferred that there is around 3,500m of Early Triassic and older sediments in this locality.

The results of the depth to magnetic basement interpretation (Figure 2) show the shallow basement on the Lambert Shelf gradually deepening northwards to the centre of the Bedout Sub-basin and then rising at the Bedout High. The variation in calculated depth to magnetic basement is of the order of 10km. The very prominent NNE trending linear structures which are visible on the magnetic imagery also correspond to variations in the depth to basement estimations. Presentation of the depth to magnetic basement interpretation, as 3D perspective plots, aids the visualisation of these features as well as highlighting the division of the Bedout Sub-basin into two distinct depocentres separated by a fault bounded, N-S trending basement high. At their deepest points both of these depocentres are of the order of 12km deep.

Comparison of the depth to magnetic basement results with the Total Magnetic Intensity Differentially Reduced to the Pole (TMI-DRTP) indicates the eastern depocentre is characterised by a very long wavelength, relatively high intensity magnetic signature. The magnetic response over the western depocentre is of much lower amplitude. The anomalous response in the eastern depocentre could indicate the presence of the extensive Late Permian to Early Triassic intra-sedimentary volcanics. Both wells, Bedout-1 and Lagrange-1, terminate in the volcanics at depths of 3,073mRT and 3,260mRT respectively. Where the wells are located, the magnetic basement is shallowing rapidly (forming the Bedout High) and differentiating the basalt from the magnetic basement response is difficult. Away from the Bedout High and the eastern depocentre there are local indications that possible magnetic sources exist above the magnetic basement.

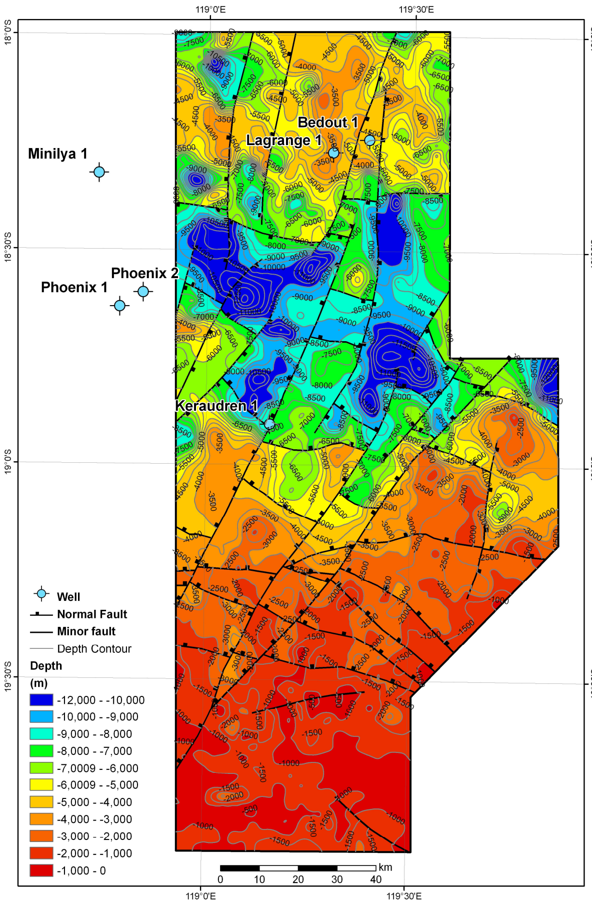

Figure 2. Depth to magnetic basement interpretation.

Seismic Depth to Top Permian

The initial aeromagnetic interpretation was completed independently of the existing seismic interpretation. A qualitative comparison of the interpreted depth to basement from the aeromagnetic survey and the seismically derived Top Permian horizon (Figure 3) shows many similarities, supporting the interpretation methodology. The Top Permian seismic marker, based on the variable data quality of the existing 2D seismic dataset (1970's and 1980's vintages) is the deepest reliable seismic horizon across the study area and a good marker to correlate against the aeromagnetic interpretation.

The study area has two main ESE-WNW and N-S to NNE-SSW structural trends. The ESE-WNW faults represent the development of a discrete rift depocentre during the Palaeozoic, associated with the wider development of the Canning Basin. The N-S to NNE-SSW structures represent uplift, faulting and volcanism during the Bedout Movement, which established a basin system into which thick Permo-Triassic sediments accumulated.

The study covers three major tectonic elements, a structural high in the northern portion of the survey area, a generalised E-W trending structural low through the central portion of the study area, and a ramp shallowing to the south of the study (Lambert Shelf). In the northwest of the study area a series of N-S trending, westward dipping, faulted basement blocks are interpreted from the aeromagnetic data culminating at the Bedout High. This agrees with the Top Permian seismic interpretation where the westernmost basement block is the underlying structure for the Bandy lead with significant closure at multiple levels within the Jurassic and Triassic.

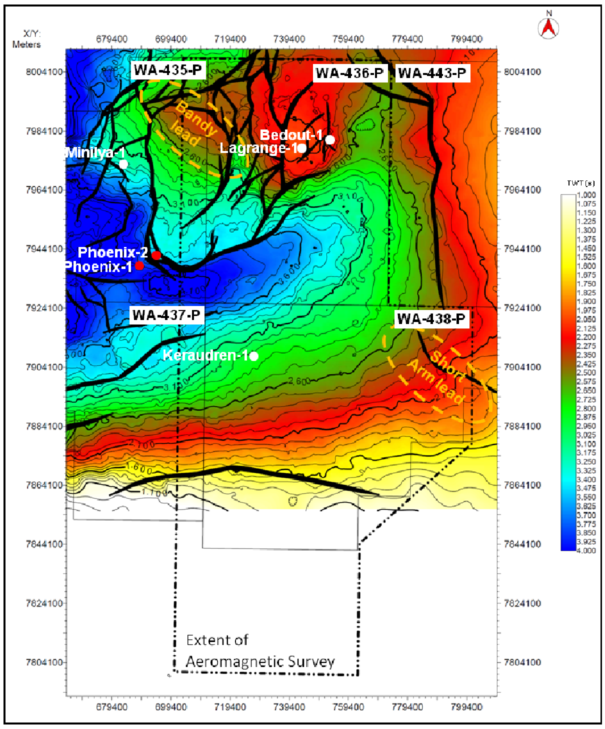

Figure 3. Top Permian two-way-time structure map. Bold black lines represent interpreted structures.

While the E-W oriented Palaeozoic rift depocentre in the central part of the study area can be seen on both interpretations, a "Central NNE High" cross-cutting the graben is only identified on the aeromagnetic interpretation. This high may represent an intra-sedimentary magnetic anomaly, affecting the magnetic depth to basement estimates.

The eastern extension of the Phoenix structural high containing the Phoenix-1 and Phoenix-2 gas discoveries (to the west of the survey area) can be seen on both interpretations. An "Eastern High" on the aeromagnetic basement interpretation correlates to the Short Arm lead, identified on the 2D seismic as a potential sediment draped basement high in adjacent Exploration Permit WA-438-P. The interpretation of the aeromagnetic dataset in the south and east of the survey area also allowed for an increased confidence in fault correlations in areas of sparse and/or poor quality 2D seismic data. Such revised correlations and their impact on basin architecture at a semi-regional scale, allows better exploration for sediment drape traps over basement blocks in these areas. This play concept is similar to the Wandoo and Stag fields in the Carnarvon Basin.

One major difference from the aeromagnetic interpretation to the Top Permian seismic interpretation is the presence of a previously unrecognised Palaeozoic "thick" in the east of the study area. This depocentre is likely to have been formed as a result of the Palaeozoic rifting that is evident within the onshore Canning Basin. The recognition of this Palaeozoic depocentre offshore has positive hydrocarbon charge implications for the WA-436-P and WA-438-P Exploration Permits in the east of the study area and also the WA-443-P Exploration Permit operated by Carnarvon Petroleum. Although the Phoenix gas discovery is traditionally thought to be sourced from the Triassic Locker Shale, no hydrocarbon sample from the Phoenix gas discovery has been recovered. Therefore, the possibility remains that the Phoenix hydrocarbons could also be charged from the deeper Palaeozoic, such as Permian gas-prone source rocks. If this is the case, then the Palaeozoic "thick" recognised by the aeromagnetic interpretation may provide an analogous source kitchen for prospects in the east of the survey area and within Exploration Permit WA-443-P.

Another of the major findings from the interpretation of the aeromagnetic survey is the extent of the volcanics intersected at the base of the Bedout-1 and Lagrange-1 petroleum exploration wells. These volcanics, combined with poor seismic data quality has led the petroleum industry to view the Bedout High as a basement high with no to little hydrocarbon exploration prospectivity below the acoustic basement. However, the aeromagnetic interpretation demonstrates that the anomaly of the magnetic body is of a much higher frequency than of a usual magnetic basement. This could imply that the volcanics intersected in Bedout-1 and Lagrange-1 may be basalt flows thereby increasing the potential for sub-volcanic sediments within the Bedout high below what has previously been interpreted as economic basement, deepening the potential productive targets in the area, for example the Bandy Lead.

CONCLUSIONS

This case study provides an interpretation of the basement structure across the Bedout Sub-basin and Bedout High; a detailed depth to magnetic basement model as well as a comparison with two-way-time to near acoustic basement.

Comparison of the magnetic basement interpretation with near seismic basement shows a very good correlation between the two datasets especially, in the deepest part of the basin and at the southern end where the basement is shallowest. Correlation is not as good in the vicinity of the Lagrange-1 well, most likely due to the magnetic depth solutions imaging the volcanic sequence in the Late Permian-Early Triassic instead. In various parts of the basin there are local indications that possible magnetic sources exist above the basement (intra-sedimentary magnetic units). The presence of high depth gradients and their coincidence with the interpreted structures are consistent with the formation of discrete, fault-controlled depocentres.

It has previously been interpreted that these volcanics intersected in Bedout-1 and Lagrange-1 were relatively limited in extent; however, the interpretation of the aeromagnetic dataset along with the regional magnetic data indicates the limits of the volcanics are much more extensive, extending well to the north, east and southeast of the study area. The ability to constrain the extent of the volcanics vertically and laterally will allow targeting of sediments on the Bedout High and Bandy lead in the Late Permian to Early Triassic.

The study provided an updated interpretation of basin architecture that will be integrated into future source and sediment modelling over the Exploration Permits. The identification of a Palaeozoic sediment depocentre on the magnetic data may provide an active Permo-Carboniferous source kitchen in addition to the Triassic Locker shale in the east of the study area. The confidence in basement block interpretation in the south of the study area afforded by the aeromagnetic interpretation will allow for a more direct exploration strategy for sediment drape and traps in the future.

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