APPLICATION OF MARINE MAGNETIC AND GRAVITY DATA IN MAPPING BASEMENT AND SEDIMENTARY HORIZONS IN THE ROVUMA BASIN, MOZAMBIQUE

I. Kivior[1], S.K. Chandola[2], Lee P. K.[2], S.F.B.M. Zohdi[2], S. Damte[1], S.L. Markham[1]

Archimedes

1 - Archimedes Consulting Pty Ltd, 31 Stirling St, Thebarton, SA 5031, Australia
2 - PETRONAS Carigali, L-15, T-2, PETRONAS Twin Towers, 50088, KLCC, Kuala Lumpur, Malaysia

PETRONAS

INTRODUCTION

A study of potential field data covering the offshore Rovuma Basin in Mozambique was conducted to map the crystalline basement and two intra-sedimentary horizons of Cretaceous and Jurassic age, as well as to determine the major fault structures within the basement.

The magnetic and gravity data were acquired at the same time as marine seismic and the survey had a shiptrack spacing of 2.5 km in the northwest and 5 km elsewhere. Data was acquired in both north-south and east-west directions. It was gridded at 500x500m where the shiptrack spacing was 2.5 km and at 1x1 km for the whole area.

The Multi Window Test (MWT) spectral technique was applied to gridded magnetic and gravity data to identify the horizons while the Energy Spectral Analysis Moving Window (ESA-MW) was used to conduct detailed mapping of basement and the two sedimentary horizons that were identified.

GEOLOGICAL SETTING

The formation of the Rovuma Basin is related to the break-up of Gondwanaland. N-S and NW-SE trending faults evolved as a consequence of the opening of the Madagascar Strait (Rusk et al 1998) (Figure 1).

The region has undergone two major tectonic phases. Firstly; rifting occurred in the Triassic as Gondwana started to break up. This resulted in the formation of N-S to NW-SE trending faults and the formation of a horst/graben system. Rifting ceased in the Jurassic and active sea floor spreading took place to the north and to the south of Madagascar. This resulted in transform faults forming along the N-S fault system developed in the Triassic. As a result of this tectonic activity, the offshore Rovuma basin is structurally dominated by a horst/graben system along with tilted block/half grabens.

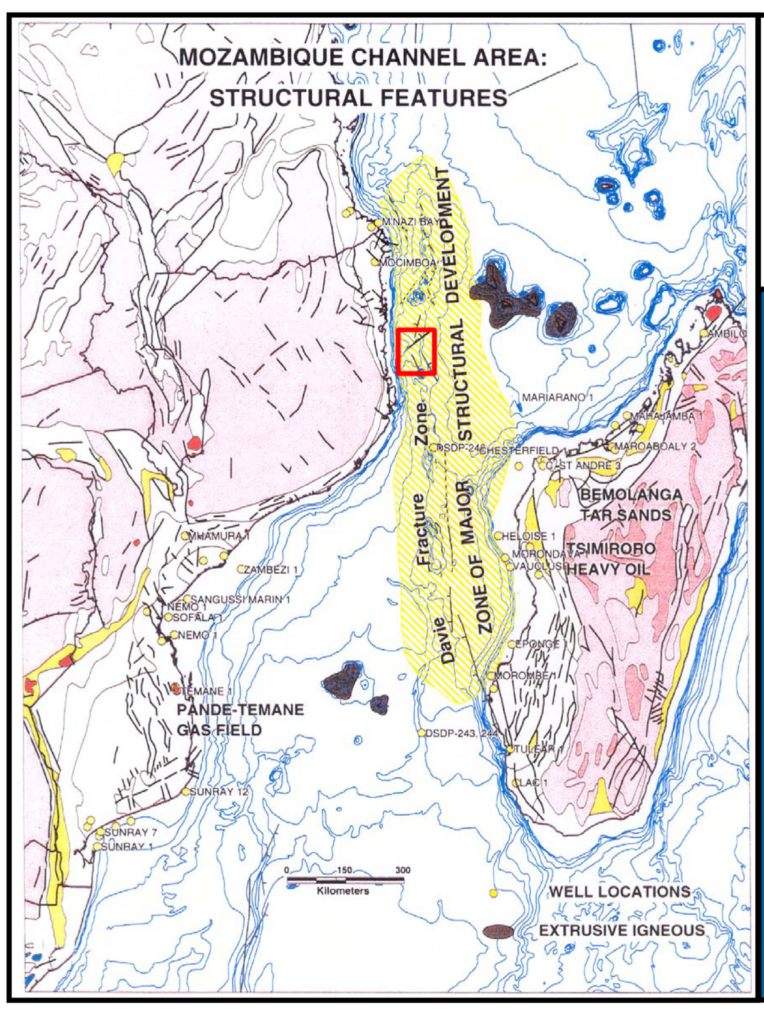

Figure 1 - Location Map of the study area marked in red (Modified after Rusk et al 1998).

METHODOLOGY

Energy Spectral Analysis (ESA) is a well established technique for estimating the depth to a magnetic/density interface, originally based on Spector and Grant (1970). Such an interface is modelled as a statistical layer of multiprisms. The logarithm of the radially averaged spectrum plotted versus radial frequency indicates depth to this statistical layer. The decay of the spectrum function shows the depth to source(s) (Figure 7D). An estimate of depth in a localized area is obtained from ESA applied to a windowed sub-region of the potential field data. By performing the ESA-Moving Window (ESA-MW) procedure at multiple locations on a regular mesh, a depth map of the interface can be produced (Kivior et al. 1993).

The most important factor for applying the ESA-MW procedure is determining the correct window size. A small window would not include enough data to successfully image the horizon; while a window that is too large will be dominated by deeper sources. The Multi-Window Test (MWT) procedure estimates the depth over a series of increasingly larger window sizes centred over a point of interest, a MWT station (Figure 7C). Ranges of window sizes where the estimated depth value is nearly constant, "depth-plateaus", indicate the approximate depth to magnetic/density interfaces. These also indicate a suitable window size for detailed mapping (ESA-MW) in the vicinity of the station (Figure 7E). At each MWT station, multiple depth-plateaus may be detected, and these can often be successfully identified as distinct magnetic susceptibility or density interfaces (Figure 8).

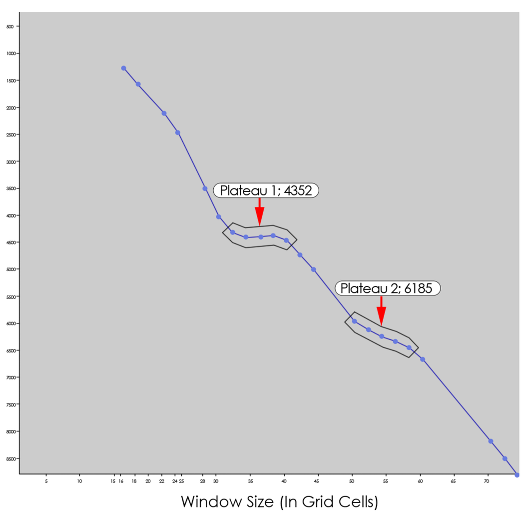

Figure 8 - An example window size versus depth plot showing 2 depth-plateaus corresponding to 2 mapped horizons

DATA DESCRIPTION

The marine magnetic and gravity survey data was acquired by Fugro Gravity and Magnetic Services, on behalf of Sea-Bird Exploration, over part of the offshore Rovuma Basin, Mozambique between June 13th and August 29th 2010. The whole survey area is between 12° 53' 1.7" and 14° 11' 45.5" South, and between 40° 36' 44.8" and 41° 50' 49.5" East. The survey has a shiptrack spacing of 2500m in the higher resolution area and 5000m elsewhere (in both north-south and east-west directions) (Figure 2). Bathymetry data was acquired using an echo sounder system.

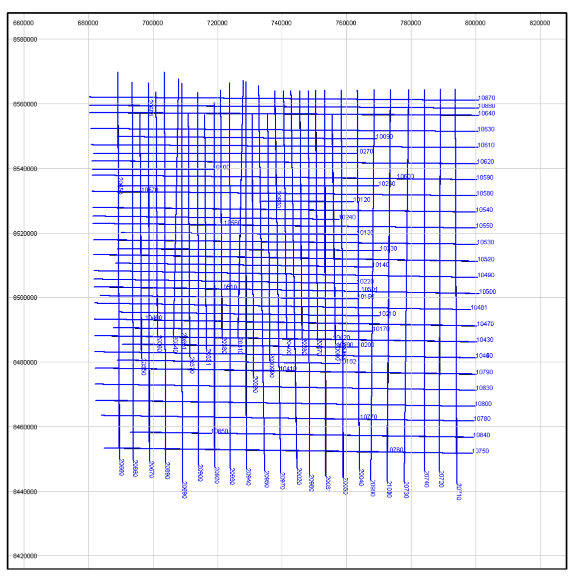

Figure 2 - Magnetic and Gravity Survey, Traverse and Tie Lines

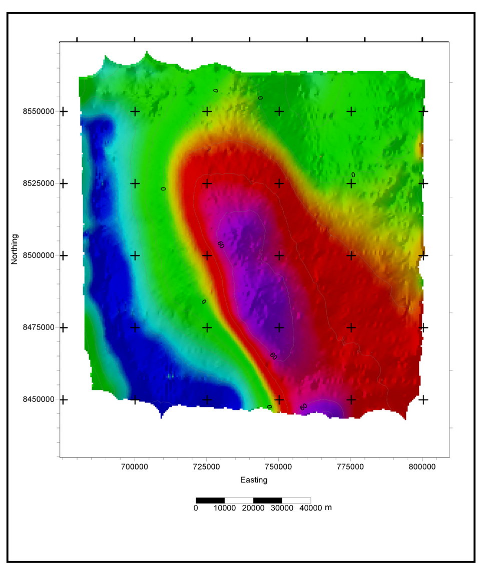

Figure 3 - Free Air Gravity

The survey was supplied by the re-processing contractor in WGS84, zone 37S (UTM projection) coordinates. This was the coordinate system used for all interpretation. At the beginning of the project, the Free Air and Bouguer gravity, and Total Magnetic Intensity (TMI) data were gridded with a 500x500m mesh (Figures 3, 4 & 5 respectively) in the area covered by the 2500m spaced survey and with a 1000x1000m mesh for the whole area. The inclination and declination of the centre of the whole area is -46° 39' and -7° 16' respectively. The Total Field Intensity is 32,759nT.

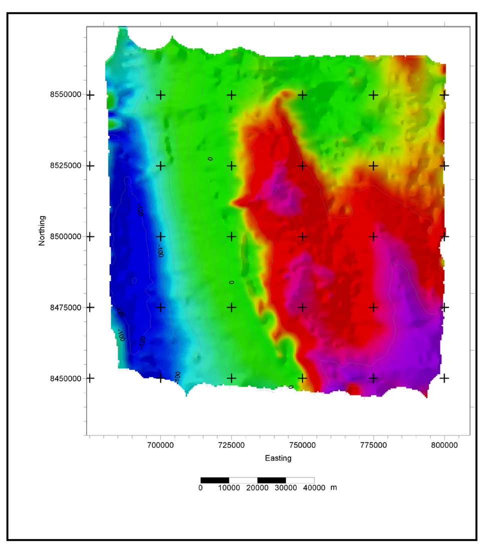

Figure 4 - Bouguer Gravity

Standard transformations, such as Reduction To the Pole (RTP) (Figure 6) and Vertical Gradient of RTP were applied to the magnetic data. The most prominent feature on the RTP image is the north-northwest to south-southeast trending ridge across the project area. This ridge has an amplitude of greater than 500nT at one location and is likely be generated by deep-seated intra-basement bodies because of the long wavelength of the anomalies.

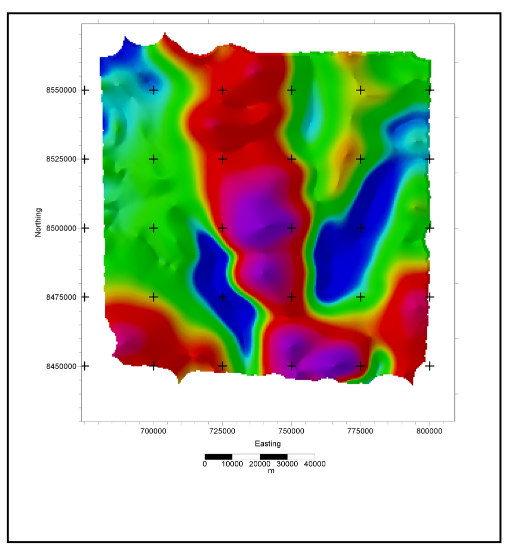

Figure 5 - Total Magnetic Intensity (TMI)

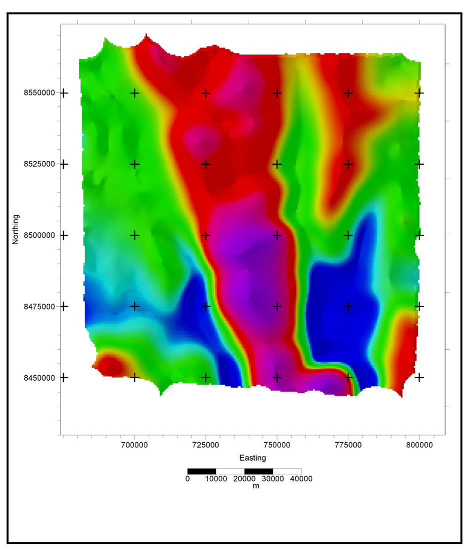

Figure 6 - Reduced to Pole (RTP)

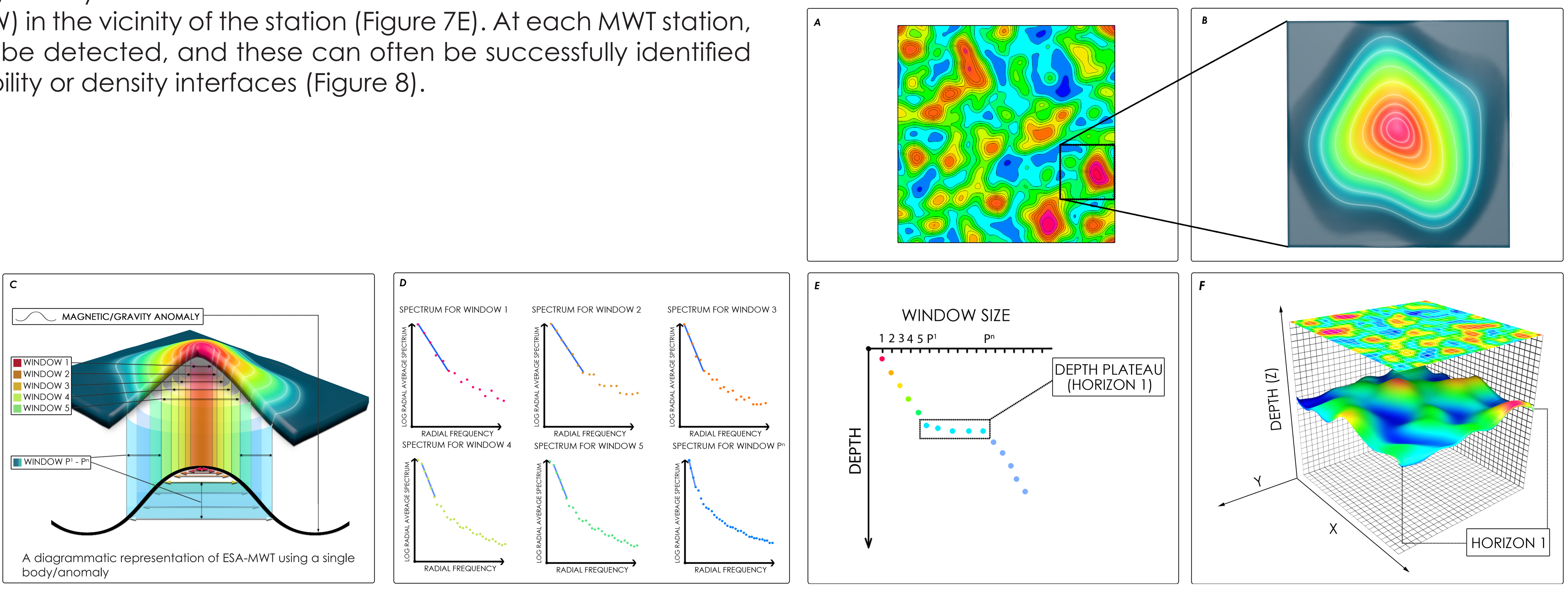

Figure 7 - A simplified representation of the ESA-MWT horizon mapping procedure; beginning with a magnetic/gravity anomaly map (A & B), over a statistical layer of an ensemble of multi-prisms (C), ESA-MWT, applied through interpretation of spectra computed from windows of increasing size (D), identifies a depth-plateau (E); analysis of depth-plateaus detected over a coarse mesh of ESA-MWT stations covering the study area produces a skeleton map of a magnetic/gravity horizon (F).

APPLICATION OF MARINE MAGNETIC AND GRAVITY DATA IN MAPPING BASEMENT AND SEDIMENTARY HORIZONS IN THE ROVUMA BASIN, MOZAMBIQUE

I. Kivior[1], S.K. Chandola[2], Lee P. K.[2], S.F.B.M. Zohdi[2], S. Damte[1], S.L. Markham[1]

1 - Archimedes Consulting Pty Ltd, 31 Stirling St, Thebarton, SA 5031, Australia
2 - PETRONAS Carigali, L-15, T-2, PETRONAS Twin Towers, 50088, KLCC, Kuala Lumpur, Malaysia

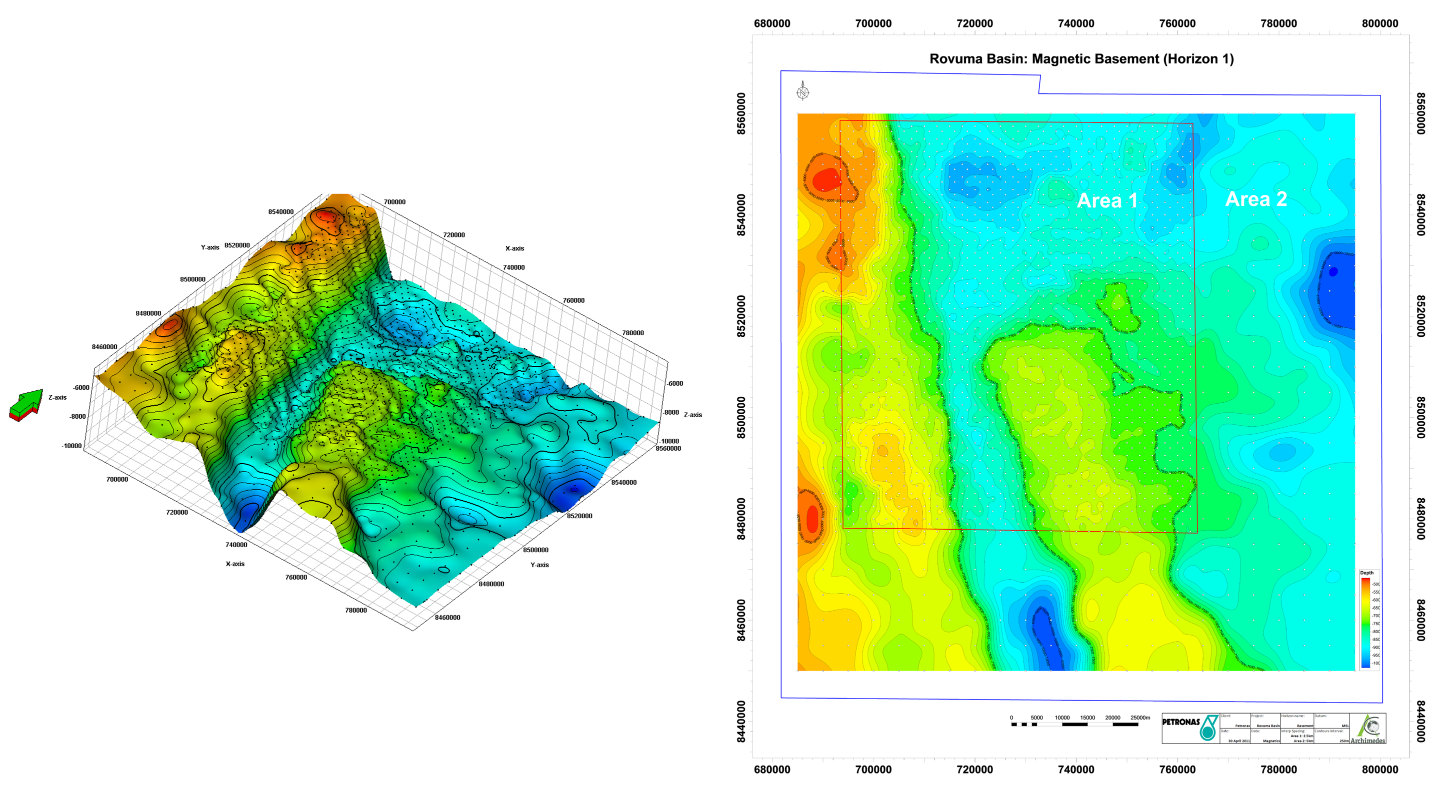

Figure 9 - Horizon 1 (Top of Basement) final detailed map (right) and in 3D (left); dots represent interpretation locations; Contour interval: 250m; Depth Datum: Mean Sea Level.

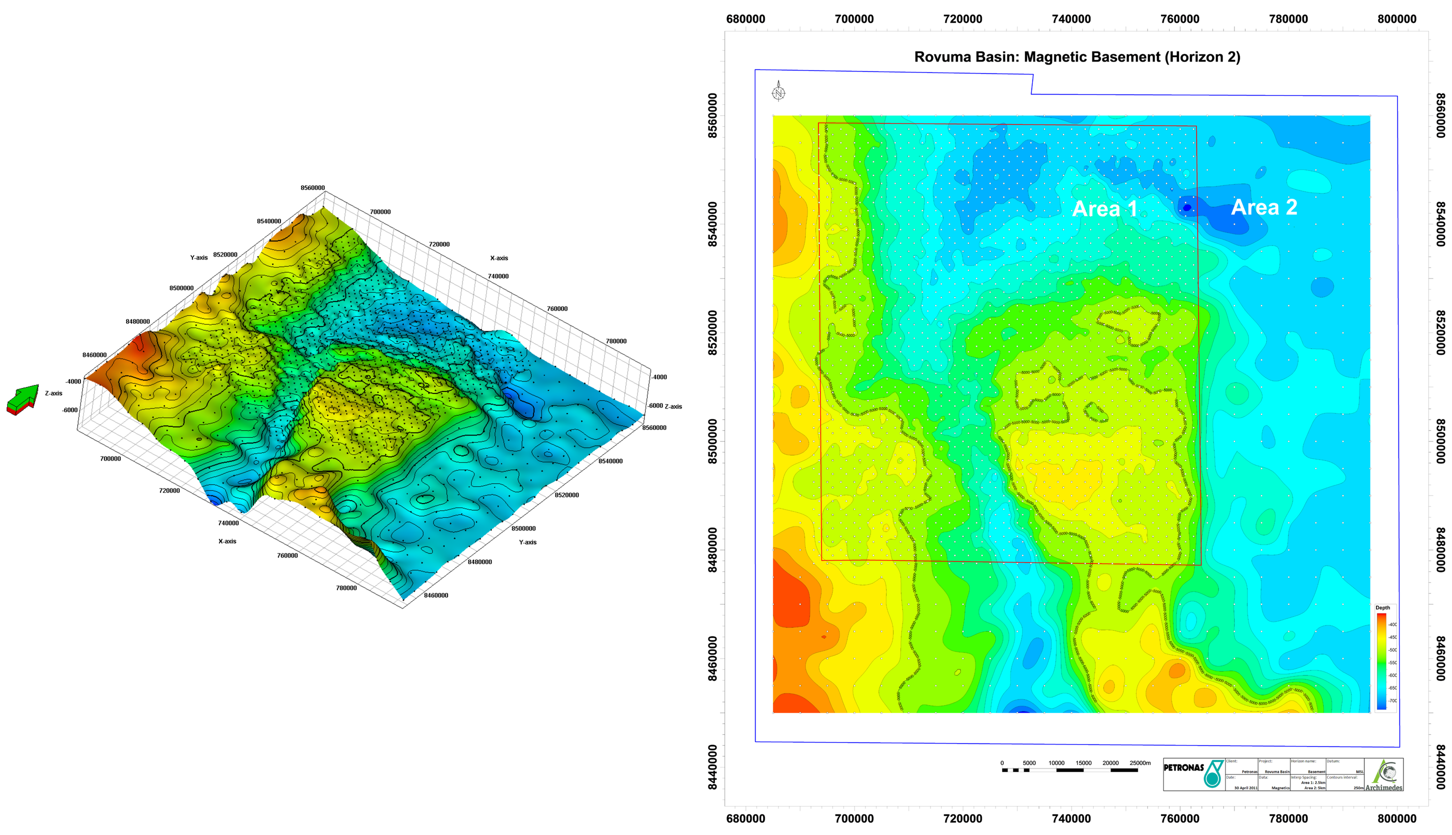

Figure 10 - Horizon 2 (Top Jurassic) final detailed map (right) and in 3D (left); dots represent interpretation locations; Contour interval: 250m; Depth Datum: Mean Sea Level.

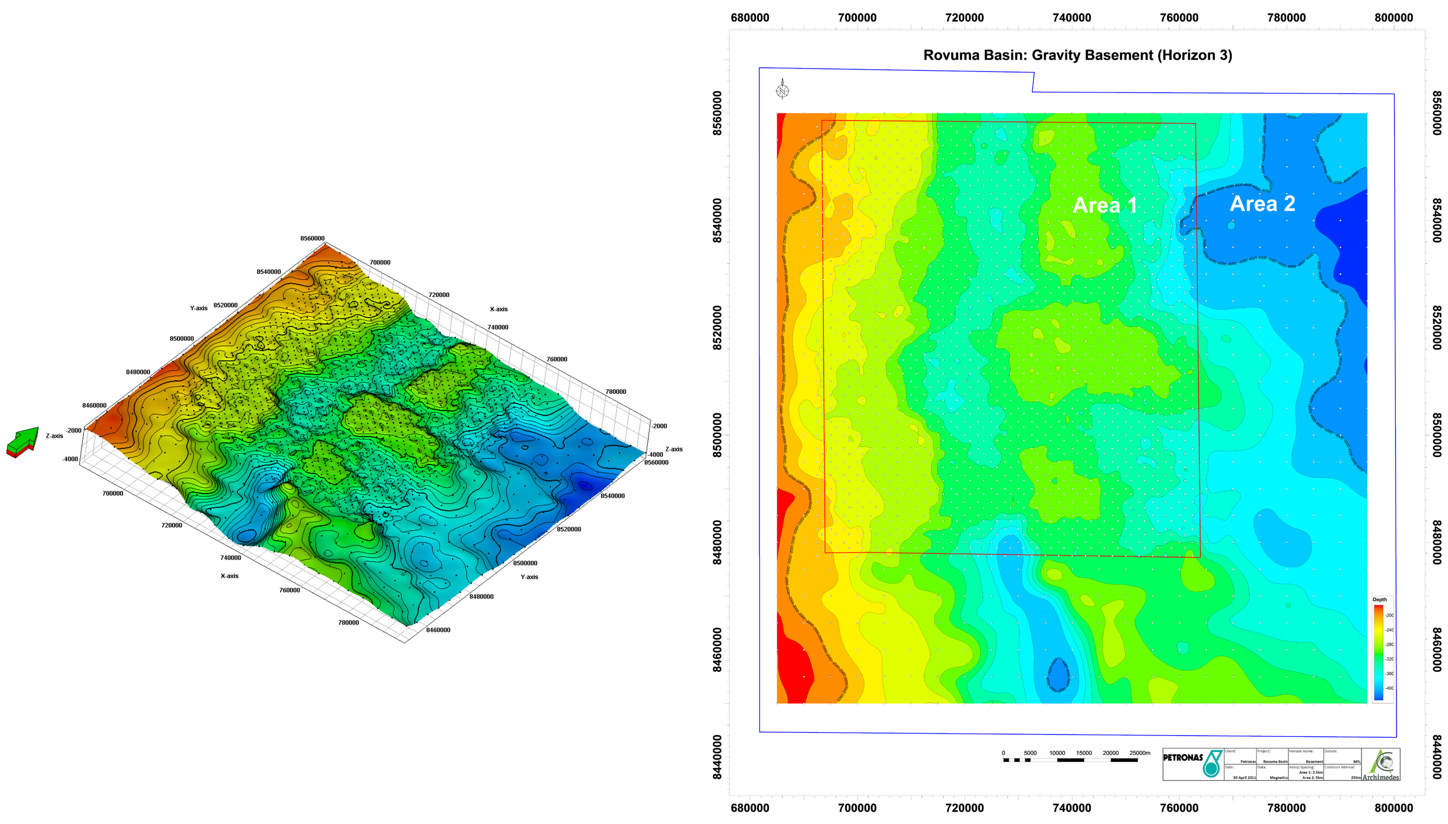

Figure 11 - Horizon 3 (Top Cretaceous) final detailed map (right) and in 3D (left); dots represent interpretation locations; Contour interval: 200m; Depth Datum: Mean Sea Level.

HORIZON MAPPING IN THE ROVUMA BASIN

One of the objectives of the study was to detect and map basement and other intra-sedimentary horizons. MWT conducted at the stations located on a 10x10km + 5th point mesh, was used to estimate spectral decay, in order to detect depth-plateaus to obtain an average estimate of depth to the targeted horizons and to identify optimal window sizes for more detailed horizon mapping (ESA-MW). This was undertaken every 2.5x2.5km plus 5th point in area 1 and 5x5km in area 2. Each depth plateau corresponds to various magnetic or density (in gravity data) interfaces. These depth plateaus are related to the following horizons, Basement (Horizon 1), Top Jurassic (Horizon 2), Top Cretaceous (Horizon 3). In the first stage, depth plateaus were detected and approximate, average depths from plateaus were used to create a skeleton map for the horizons mentioned above. In the next stage, the optimal window size was determined from the depth plateaus and used to conduct detailed horizon mapping.

The detailed mapping interpretation was performed using the ESA-MW technique. For both data sets, spectra of different window sizes were computed on a very dense mesh of 2.5x2.5km. Basement (Horizon 1) and Top Jurassic (Horizon 2) were mapped using spectra computed from gravity and magnetic data and the shallower intra-sedimentary interface (Horizon 3) of Cretaceous age was mapped only from gravity data (Figures 9, 10 & 11 respectively.) As the magnetic and gravity data are derived from sources with different rock properties, the same horizons may not necessarily be mappable using both data sets.

INTEGRATION WITH SEISMIC AND OTHER AVAILABLE DATA

A narrow trough which stretches from north to south is apparent on all horizons. This depression reaches a depth of around 10km in the south at basement level.

All three horizons are dominated by the NW-SE trending horst/graben system present in the basin. As such the basement architecture controls the structures seen in the shallower horizons. The central horst block dips gently to the east in all horizons, correlating well with the tilted block/half-graben structure seen in the seismic results.

Overall, the structures revealed by the ESA-MWT interpretation appear to correlate well with the seismic (Figures 12A & 12B) and known geological information on the area.

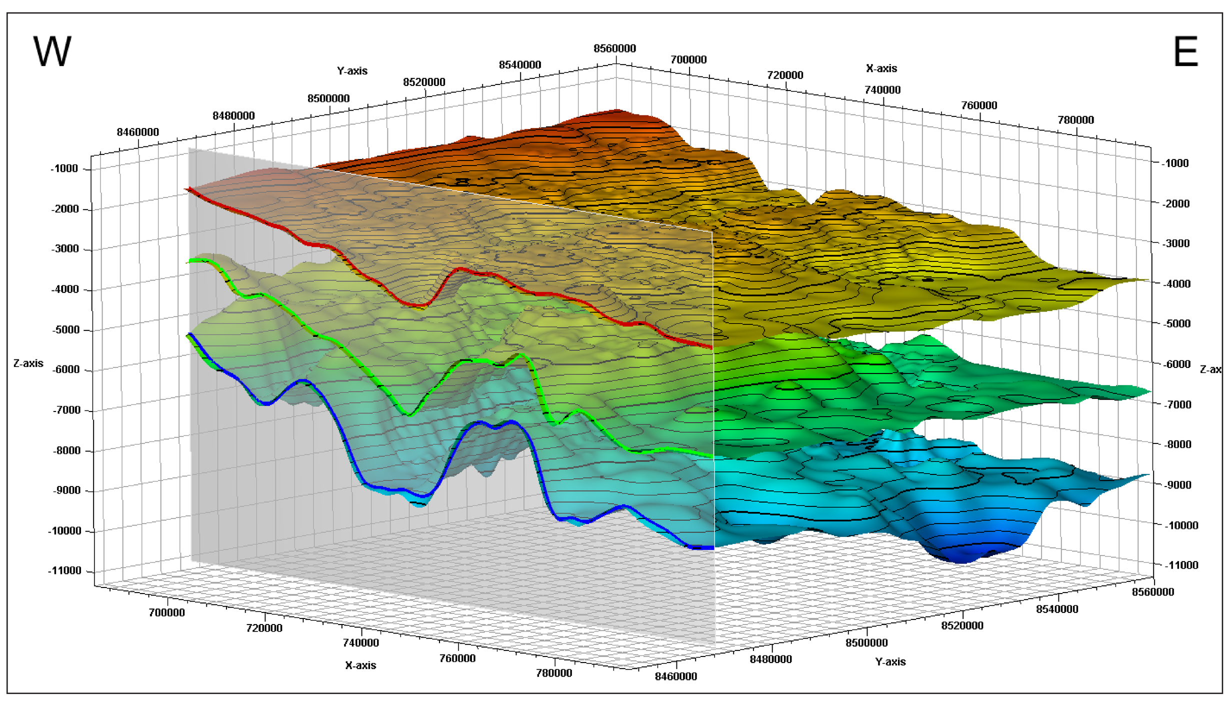

Figure 12A - A Cross section of all 3 horizons along a W-E profile through the centre of the area

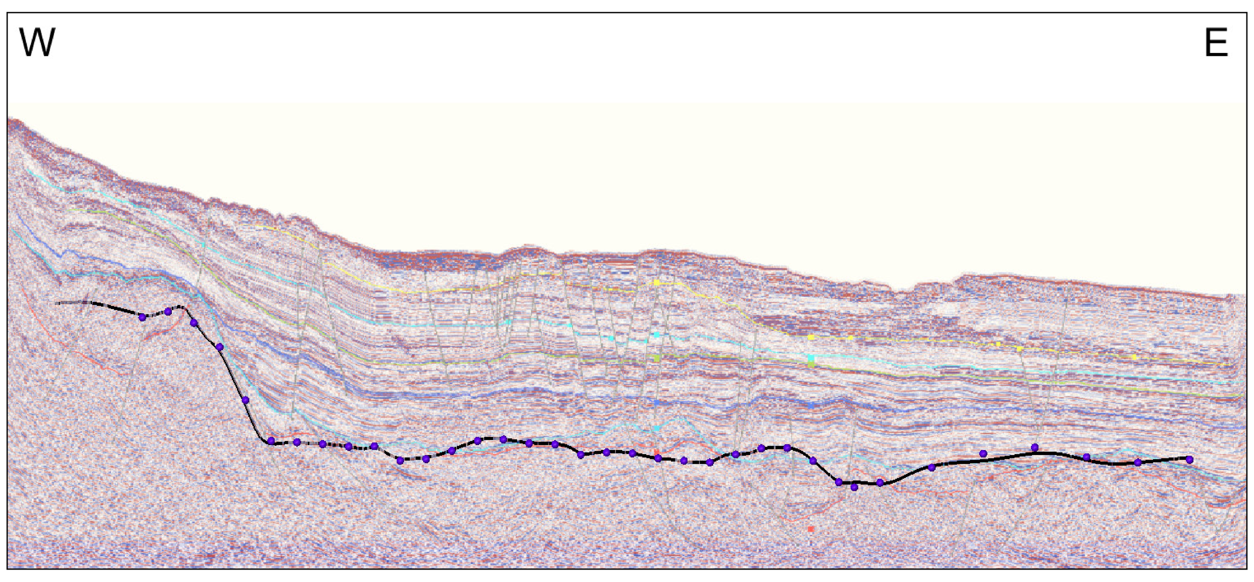

Figure 12B - Magnetic basement interpretation along seismic line (marked in purple dots).

REFERENCES

Kivior, I., Shi, Z., Boyd, D. and McClay, K. R. [1993] Crustal studies of South Australia based on energy spectral analysis of regional magnetic data. Exploration Geophysics 24, 603-608.

Naudy H., 1971. Automatic determination of depth on aeromagnetic profiles. Geophysics 36 (4): 717–722.

G. Salman, I. Abdula, 1994. Development of the Mozambique and Rovuma sedimentary basins, offshore Mozambique.

Spector, A. and Grant, F. S. [1970] Statistical models for interpreting aeromagnetic data. Geophysics, 35, 293-302.

Rusk, Bertagne and Associates and TGS NOPEC [1998] Petroleum Geology and Geophysics of the Mozambique Channel

CONCLUSION

The new spectral technique called Multi-Window-Test (MWT) was used to detect magnetic susceptibility and density contrasts within the sedimentary section at stations located on a regular mesh covering the project area. Lateral correlation between stations allowed the identification of several horizons. The results derived from marine magnetic and gravity data show a good correlation with seismic data and well intersections. The Energy Spectral Analysis (ESA-MW) procedure was successfully applied in the Rovuma Basin and the new MWT technique proved to be a valuable tool in mapping sedimentary horizons from the potential field data.

Acknowledgements: The authors would like to thank PETRONAS Carigali for the permission to publish this work.

AAPG International Conference & Exhibition
Singapore, 16-19 September 2012