The Officer Basin, a Proterozoic basin exploration case study

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Summary

Petrex has undertaken an innovative strategy for reassessing an underexplored Neoproterozoic salt basin. Despite the limited availability of seismic data, the use of recent airborne geophysical technologies including airborne gravity, airborne electromagnetics (AEM) and audio electromagnetic – passive transient impulse survey (AEM-PTP) has enabled a comprehensive multi-domain approach. This method focuses exploration activities across an extensive area.

Introduction

Situated in the southern region of central Australia, the Officer Basin offers a promising avenue for the discovery of significant oil and gas deposits. Despite its potential, it has seen minimal exploration with only 100 relevant wells drilled and 23,000km of 2D seismic data collected across its vast 525,000 square kilometres (129,730,325 acres) sedimentary expanse.

The Officer Basin, an expansive intra-cratonic basin, contains sediment layers dating from the Neoproterozoic to Cambrian period. It forms part of the Centralian Superbasin, a network of Neoproterozoic basins, and boasts a sediment depth that reaches up to 10,000 metres at its deepest point – as illustrated in Figure 1.

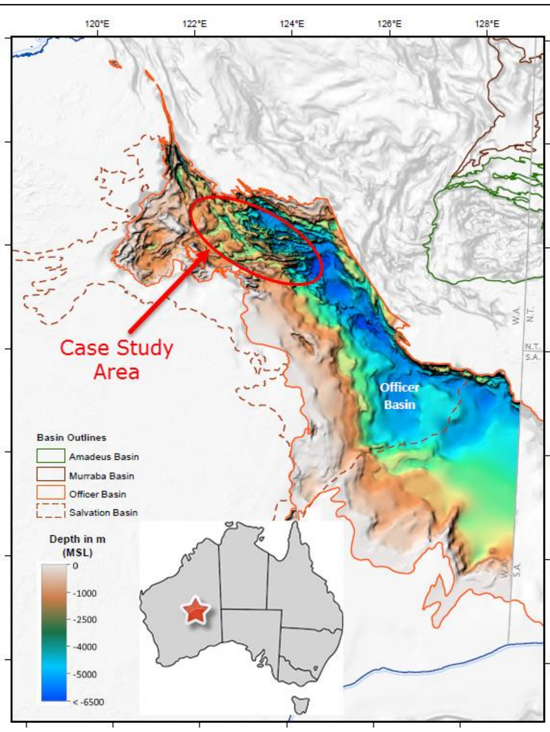

Figure 1. SEEBASE imagery illustrating location of the Officer Basin and case study area (Geognostics 2022).

The surface morphology of the Officer Basin is characterized by its primarily Cainozoic cover consisting of sand dunes) with limited outcrop. The scarcity of outcrops, coupled with inadequate biostratigraphic control of the Neoproterozoic era, as well as sparse availability of fossils and seismic data, complicates the process of making stratigraphic correlations within this vast sedimentary basin. Nonetheless, the stratigraphy has been elaborated in greater detail by several authors including Jackson and van de Graff (1981), Townson (1985), Phillips et al. (1985), Iasky (1990), Williams (1992, 1994), Perincek (1998), Carlsen et al. (199) and Apak and Moors (2000, 2001) have described the stratigraphy in more detail.

Method

Petrex's initial exploration special prospecting authorities (SPAs) covered an area of approximately 155,000 Km^2 (slightly larger than the State of Georgia, USA). Large tracts of the basin have no seismic information, sparse drilling results, relatively no outcrop information, but vast coverage of potential field datasets. With only a limited vintage seismic database available, the basin analysis approach relied mostly on airborne geophysical datasets. Aeromagnetics coverage is nominally at 400m line spacing, airborne gravity at 1500m, Radiometrics at 400m and recently acquired Airborne Electromagnetic (AEM) profiles at 20km providing Petrex with a basin wide coverage of airborne geophysical data. As part of the application process for petroleum acreage in Western Australia Petrex undertook flying of AEM-PTP (Passive AEM) data at a coverage of 18 km spaced flight lines. This was over 155,000 km^2 with the results from this survey providing screening information to help define areas of fluid migration pathways. Part of the conditions of the regulatory bodies, Special Prospecting Authority (SPA) is a 50% relinquishment of acreage, whereby a company is then given the opportunity of being awarded an Exploration Permit with a 5 year term on the remaining acreage. Figure 2 illustrates the workflow used by the Petrex team whereby the new data was integrated with the old and the model updated, allowing easy facilitation of a ranked lead portfolio.

The AEM-PTP airborne surveying technique is a passive technique measuring transients of secondary electromagnetic fields associated with micro-seepage plumes (upward fluid flow) related to Redox activity – See Figure 3. Redox cells are known to form under the following conditions: Micro-seepage plumes above hydrocarbon accumulations; Migration of fluids associated with hydrocarbon charge; Migration of hydrothermal fluids associated to minerals deposits; REDOX cells are characterized by areas of higher EM field transient density. While non-unique, these anomalous areas help provide focus for follow-up exploration methods such as on-ground soil and gas sampling.

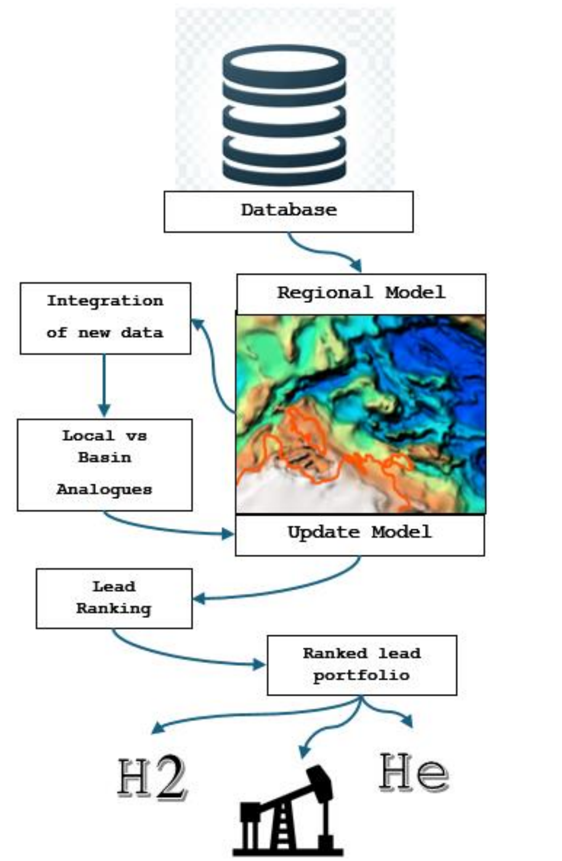

Figure 2. Petrex Workflow describing the methodology of high grading areas of hydrocarbon and He/H2 exploration leads.

The survey line spacing (see Figure 4) was determined to ensure that at least two lines were collected over large structural features identified on the gravity data and provide an indication of increased Redox activity. Anomalies that could be tracked across two or more flight lines and associated with structure were considered to be anomalous and worth of further investigation. Anomalies not associated with structure or only observed on a single flight line was discounted to be of less interest.

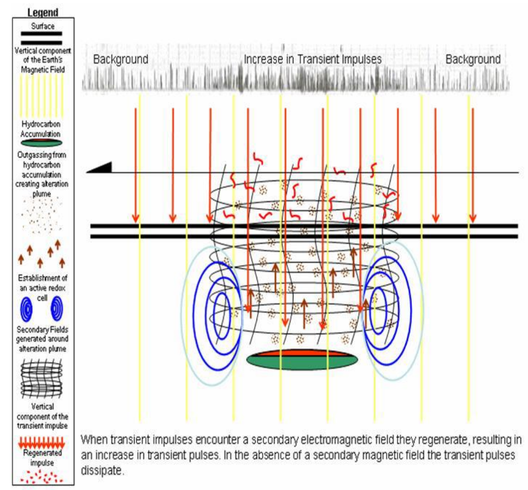

Figure 3: Schematic of the impact REDOX cells have on the transient impulses detected in the Earth's EM-Field (from Pinemont Technologies publication).

The exploration team considered all the data available at the time, looking at each prospective lead before making choices to choose exploration acreage with the boundary of each SPA-AO permit. This ended up being 14 permits, each being between 5,000 – 7,000 km^2 (~1900-2700 sq. miles). A variety of different geological terranes were selected, including deep sedimentary basinal areas with possible large 4 way dip closures, areas of intra-basinal salt structuring and shelving environments on the edge of deep troughs. Currently, two of these fourteen EP's have been granted as Petrex moves forward through Native Title negotiations.

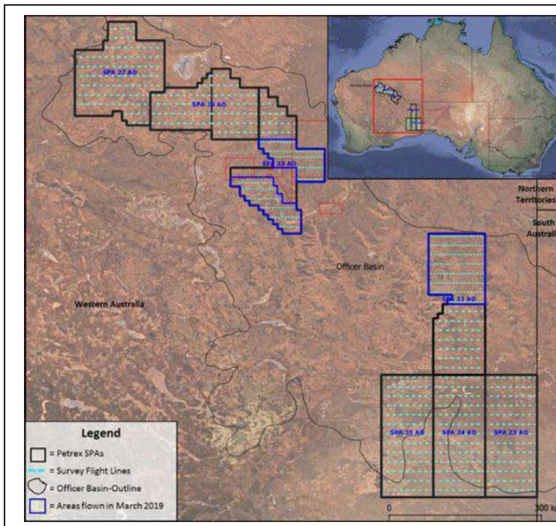

Figure 4. 2018-2019 AEM-PTP survey of Petrex's SPA-AO permits (~155,000 km^2)

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One of the granted EP's, EP502 was used as a test case and as part of the Year 2 work program Petrex conducted a review of all the new geophysical datasets (Airborne Gravity 2019 and AEM 2020). The combination of the different geophysical techniques using complementary colour palettes, overlaying geophysical attributes and displaying seismic and AEM profiles across the imagery provided opportunity to observe different correlations and anomalous areas of interest. The rock outcrop observable was able to provide some reference to the stratigraphy below the surface, particularly in areas away from the limited seismic control. (see Figure 5).

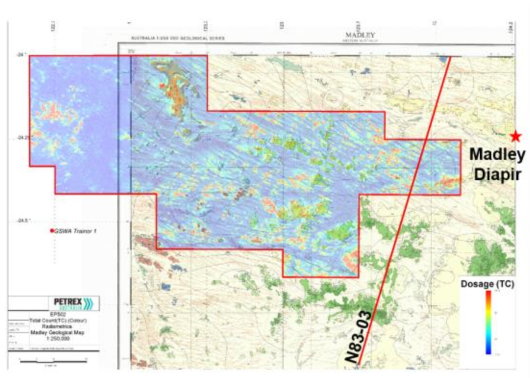

Figure 5: Overlay of Total Dose Radiometrics (Rainbow 50% transparent) over the Madley 1:250k geological map sheet.

The seismic line indicated in Figure 5 is shown in Figure 6 and highlights the areas of shelving basinal areas to areas of structural complexity through deformation due to salt tectonics. The airborne magnetic database has been very instructive in interpreted salt walls and diapirs away from limited seismic control. This appears to be due to more buoyant salt disrupting and upturning weakly magnetic sedimentary layers, in turn providing an interpretable surface to map the intrusive bodies.

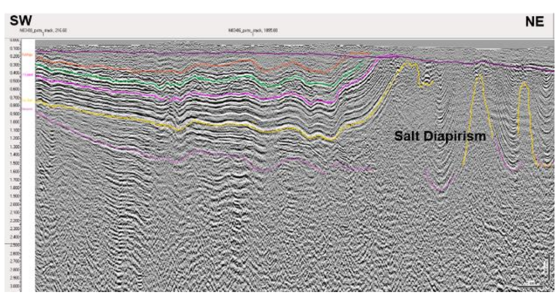

Figure 6: Interpreted seismic line N83-03 (N-S) highlighting some salt structures present in the Officer Basin.

The combination of radiometics and the 1st vertical derivitive of airborne magnetics data has proven to be useful as a diagnostic tool to help facilitate interpretation of different rock units across the block. Figure 7 shows three (3) distinct NE-SW trending magmatic dykes cross cutting the sedimentary structures, with no radiometric signtaure. In other areas of subtle magnetic signatures structural deformation of sedimetary is highlighted by the radiometic signatures.

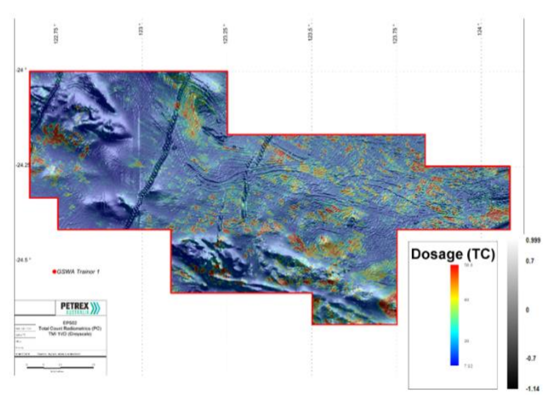

Figure 7: Overlay of Total Dose Radiometrics (Rainbow 50% transparent) over the Total Magnetic Intensity 1st Vertical Derivitive image (Greyscale).

Geoscience Australia (in conjunction with GSWA) acquired a grid of AEM data using the CGG Tempest system in 2021. Four of the (E-W) AEM lines cross cut EP502 and highlight areas of higher conductivity (hotter colours) and areas of higher resistivity rocks (cool colours) (see Figures 8 and 9). Although depth limited to ~300m and complicated by near surface ground water it can provide information about the shallow sub-surface rocks. Figure 9 illustrates an example of an AEM line across a salt diapir which is exposed at the surface. The Madley diapir is approximately 35km to the ENE of EP502 and displays a distinct resistivity signature over the salt structure. Although the grid of lines is sparse at 20km, when combined with other geophysical data it becomes a very useful diagnotic tool for interpreting shallow salt formation, such as salt walls illustrated in Figure 8.

Figure 10 is an example of the type of data collected by the passive airborne AEM-PTP surveying, and is displayed showing the areas in increased transient pulse densityabove the background level. Although transient pulses are recorded all across the survey area, the data outliers are of much greater interest as indicators of upward fluid flow potential. Even more so when the anomalous areas can be matched across several or more lines. The red/blue colouring is achieved by gridding the data using a simple gridding algorithm that keeps the focus on the data along the flight lines (rather than interpolating the data 18kms to the adjacent line). There does appear to be an interesting area of anomalous transient pulses that is congruant with the area of salt diaparism.

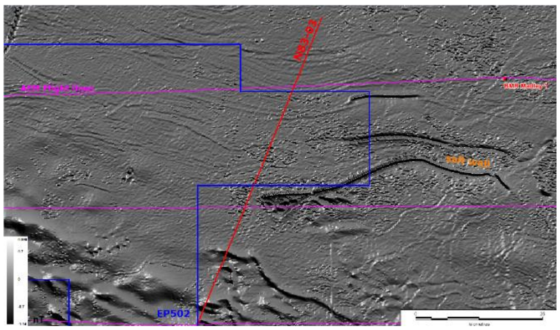

Figure 8: TMI_1VD greyscale image illustrating the features displayed on the N83-03 seismic line and the Madley diapir displayed in Figure 9 by the AEM survey line

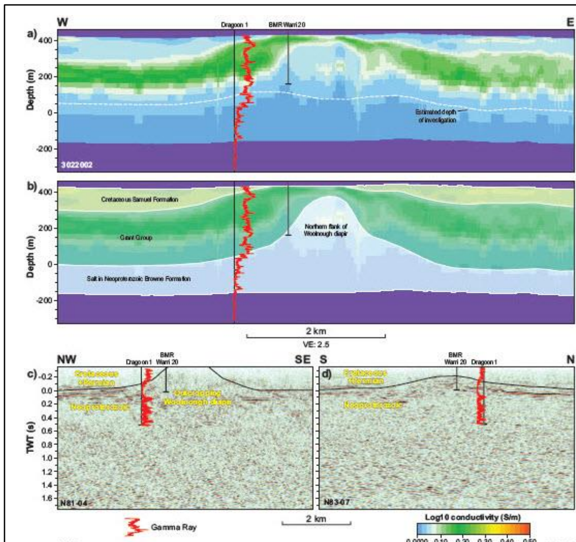

Figure 9: AEM and Seismic progiles across the Woolnough salt diapir: a) uninterpreted CDI 3022002; b) interpreted CDI 3022002; c) seismic section N81-04; d) seismic section N83-07 (Zhan, 2022)

Conclusions

The Officer Basin is complex sedimentary basin that has undergone several periods of shortening and structuring with limited seismic and well information. This lack of sub-surface geoscientific information encourages the interpreter to look elsewhere for clues to interpret the sub-surface stratigraphy and structural regime. Large (whole of basin) potential field datasets have been collected by successive state and federal geoscientific agencies and is provided free of charge through online portals (GADDS).

In order to make sense of these large datasets and help area selection and delineation the geophysical data was combined with newer techniques such as AEM and AEM-PTP surveys. The use of different colour palettes and transparency masks were very useful in highlighting areas of overlapping anomalies. These highlight areas of anomalous resistivity and conductivity and areas of higher redox potential relating to upward fluid flow. A series of leads and prospects could then be ranked, high graded or down-graded based upon whether anomalies are associated with them.

Petrex is then able to plan its future exploration program across its acreage position, such as on-ground soil and gas sampling or further seismic delineation prior to maturation to drillable status. AEM-PTP provides the explorer with a focusing tool which is complementary to most other geophysical techniques, providing insights into fluid migration or outgassing pathways. While virtually all remote sensing techniques suffer from non-uniqueness, this emphasizes the need for integration during the interpretation process. When combined with the other potential geophysical imagery, which are mostly associated with mapping rock structure it becomes a very powerful tool in ranking one prospect above another.

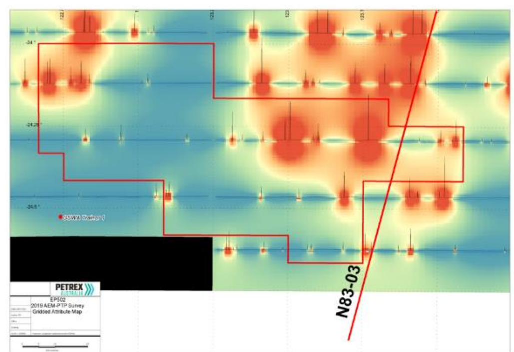

Figure 10. AEM-PTP Gridded attribute map highlighting areas of anomalous impulse readings.

Acknowledgments

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