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2-D seismic interpretation of the Outer Ex mouth of Barrow Sub-basin of Perth, Western Australia

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Abstract:- 6 seismic data lines were acquired by Esso Australia Ltd from the Outer Ex mouth of Barrow Sub-basin of Perth Australia the data was interpreted for possible oil or gas production. The analysis was carried out using the Dug Insight software. The main events picked were the sea floor at a depth of 1371m, Base Tertiary at a depth of 1826m, Cretaceous at a depth of 2170m and Triassic at a depth of 2403m with some minor events. Two distinct areas where found to have been productive and the porosities of the two areas are 31.5% and 31.2% with shale volumes of 0.25256 and 0.11687 having thicknesses of 4.0metres and 1.1metres respectively. The basin is characterized by tectonic effects which produce potential structures for both movement, escape with small accumulation as well as traps. The Triassic Limestone formation forms the source rock, the Lower Cretaceous Sandstone forms the reservoir while the Upper Cretaceous Limestone forms the seal. The huge 3D seismic data acquired over the area of the margin has not resulted in large exploration successes. This is because of the simple effective traps at base regional seal level being beneath the amplitude floor, however, some quantity of gas reserves remains undeveloped, together with some potential condensate reserves.

I. INTRODUCTION

Because rocks are opaque, it is very difficult to see through them and thus it is difficult to know what is the three-dimensional geometry of the structures there in.To that effect, the need for geophysical technique to remotely sense the subsurface using sound waves is paramount. The Seismic reflection profiling has been a standard practice in the oil and gas industry industries for more than 70 years and is so also, is the most commonly used technique for mapping the subsurface. Some of the most profound structural observations about our planet such as thrust belts, decollements, and low-angle normal faults that exists are best demonstrated with seismic reflection data. Numerical models were developed to understand the seismic-geological relationships by imaging the real-world in an approximate fashion. Some models were used to calculate the seismic velocities (V_p and V_s) and the Poisson's ratio (μ) as a function of crack density parameters. Interpretations of seismic data are mostly based on V_p (Sjøgren et al., 1979, Moos and Zoback, 1983 or Mooney and Ginzburg, 1986). Other studies take v_s and v_p into account, like Barton and Zoback (1992) and Kuwahara et al. (1995). Generally, a primary shear-wave *S* propagates within an anisotropic region and splits into two polarised shear-waves with different velocities (Christensen, 1971 and Crampin, 1981). The two shear-waves, a leading S_1wave and slower S_2 wave, are polarised in mutually perpendicular planes. The S_1wave shows in most cases a motion direction parallel to the plane of structural anisotropy, like fractures or foliation, whereas the S_2wave is perpendicularly oriented to the S_1wave.

Some of the drawbacks of seismic in-situ data are their complexity, noise, non-linear relation to the geology. Several geological and technical parameters may be related to the noise. These parameters vary simultaneously under in-situ conditions and do not remain constant, like during laboratory experiments and theoretical modelling. In addition, if the geological measurements are less qualitative due to the observer's subjectivity or the restriction of the measurement method, interpretations are difficult. Especially conventional methods, like correlations and spatial profile descriptions, leading to uncertain rock mass characterisations of poor quality and less overview.

Many field studies show that interpretations of in-situ data, which are based on one or two seismic parameters, tend to provide results of poor quality. Moos and Zoback (1983) concluded that it is not possible to simply relate fracture density to $V_{p.}$ Mooney and Ginzburg (1986) could not exhibit a significant reduction of velocities in saturated micro cracked and medium fractured rocks. Moos and Zoback (1983) and Stierman (1984) outlined that also parameters like macroscopic fracturing influence the mechanical properties of the rock mass and hence the seismic velocities.

The correlation quality is better for more competent rock mass. The relationships do not only relate to an average value of fracturing but also include the effects of other factors such as rock type, mineral content and water content. Green halgh et al. (2000) also concluded that engineering geological interpretations of tomograms, which were carried out in the Kambalda nickel mines of western Australia, are problematic, because velocities do not change only due to different rock types and mineralisation but they can also change due to alteration and weathering.

Under in-situ conditions, the geological rock mass parameters vary in poorly defined ways and often lead to ambiguous seismic interpretations. For example, Moos and Zoback (1983) conclude "it is not possible to simply relate fracture density to V_p". A systematic reason for ambiguous seismic interpretations, especially under in-situ conditions, is that analyses between geological and seismic properties are mostly based on pair wise comparisons, which do not show all the information of the high-dimensional geological and seismic feature space. Hence, with focus to understand the geological-seismic relationships under in-situ conditions, the geological rock mass properties should be classified with all seismic features in combination. The high noise of seismic data is considered simultaneously. The noise results from limitations of the seismic measurements and from the spatial variations of the geological rock mass conditions. Six (6) seismic line were acquired by Esso Australia Ltdat the Outer Exmouth of Barrow Sub-basin of Perth Australia area and a well (Eendratch-1) figure 1, were analysed using the Dug Insight software. As part of interpretation of the data, synthetic well tie was done and a two-way travel time events created as seen in figure 2. Two-ways travel time for isochrons for all the main events were analysed which is followed with depth conversations. Depth events, depth isopachs and porosity depth trend were also done. The plays of the general geology that could set up plays in this area are faults and block traps that are found within the mangrove formation, pinch outs and seals were formed by the clay stones. The Pre-rift Triassic succession comprises marine shale which form the source rock (Upper Triassic shales forms the main hydrocarbon source). Sandstones of lower Cretaceous are the primary reservoir in the basin, regional seal were formed by lower to upper Cretaceous Marine Shales below is the regional and tectonic setting of the study are in figure 1.

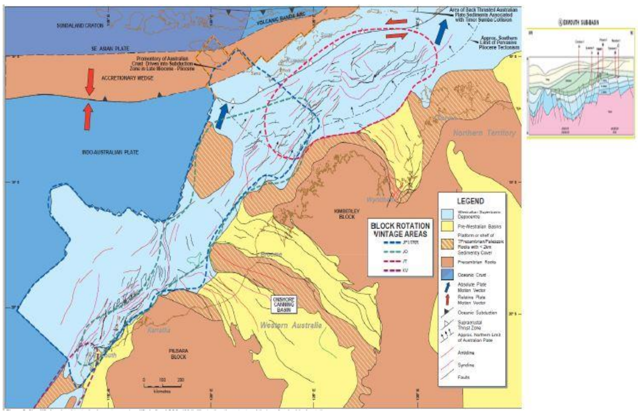

Fig 1:- Regional and Tectonic setting of Outer Exmouth Of Barrow Sub-basin of Perth Australia

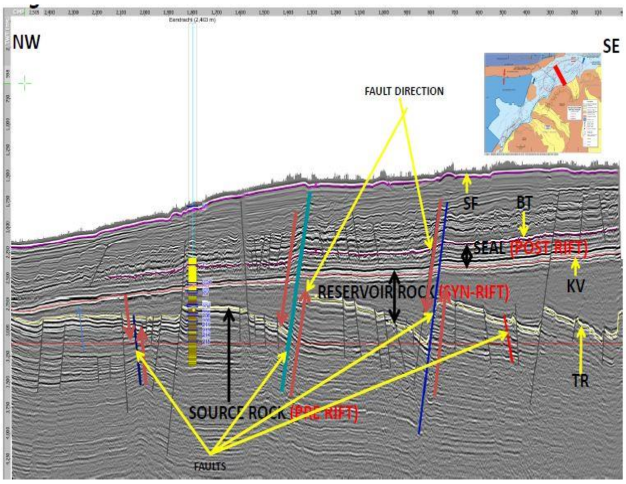

Fig 2:- Regional 2D Seismic Line of the Outer Exmouth of Barrow Sub-basin of Perth Australia

II. METHODOLOGY

6 seismic data lines were acquired by Esso Australia Ltd from the Outer Exmouth of Barrow Sub-basin of Perth Australia with the view to interpret the data for possible oil or gas production (figure 4). A well Eendratch-1 was also tied to the data for interpretation. Both major and minor faults are picked, the major faults are mainly found within the pre-rift though few have transcended to the post rift. The main events picked were the sea floor, Base Tertiary, Cretaceous and Triassic with some minor events. The loaded well Eendratch-1 indicate the positions of the main events (sea floor, Tertiary, Cretaceous and Triassic events). The base of the well is the base of top Triassic. The regional 2D seismic section of the study area is shown in figure 2. While the stratigraphic section is shown in figure 3.

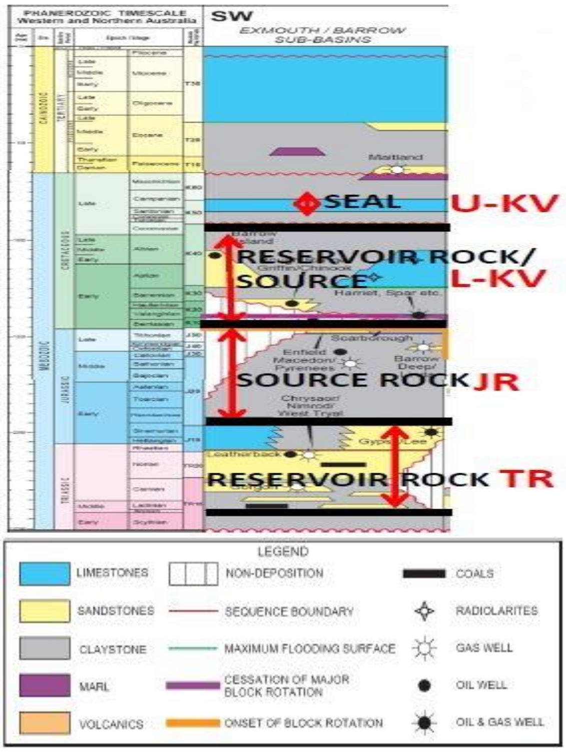

Fig 3:- Stratigraphic Chat Outer Exmouth of Barrow Sub-basin of Perth, Australia

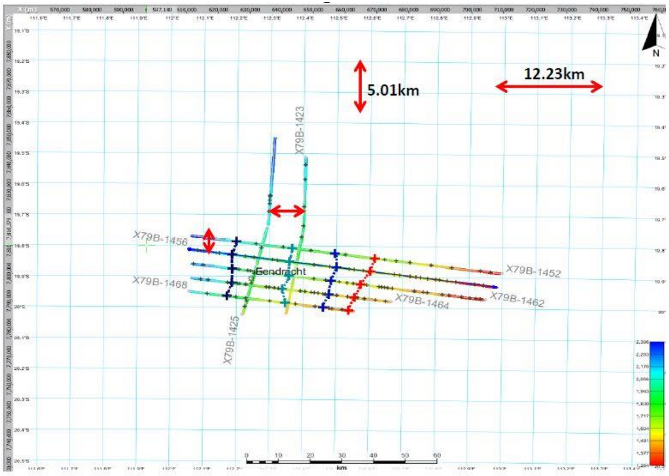

Fig 4:- The six (6) seismic lines with the Well (Eendtracht-1) data coverage of the Outer Exmouth of Barrow Sub-basin of Perth, Australia.

III. RESULT

From middle Triassic to early part of Jurassic period is a reservoir rock because it is made of the siliclastic materials (Sandstone) early Jurassic to Late Jurassic serves as both Source rock because of the limestone as well as reservoir because of the sandstone likewise from early Cretaceous to Late Albian is another Reservoir having significant Sandstone however this can also serve as source rock because it has dominance of claystone and Limestone. The Seal of the Reservoir is at Late Cretaceous (Santonian-Campanian) and is Limestone.

The sea bed is at a depth of 1371m, followed by the Tertiary event at a depth of 1826m and followed by the Cretaceous at a depth of 2170m then lastly by the Triassic at a depth of 2403m. There are major and minor faults on the seismic section, the major faults are the faults that were correlated in these research work as can in figure 5.The pre-rift terminated at Triassic whereas syn-rift terminates at Cretaceous while Post Rift terminates at Tertiary.Both major and minor faults are picked, the major faults are mainly found within the pre-rift though few have transcended to post rift.The main events picked within this research work are the sea floor, Base Tertiary, Cretaceous and Triassic with some minor events. The loaded well indicate the Positions of the main events (sea floor, Tertiary, Cretaceous and Triassic events). The base of the well is the base of top Triassic

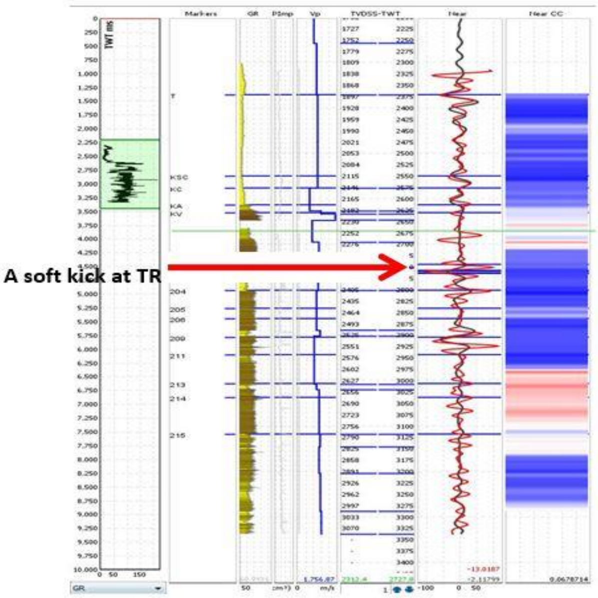

Fig 5:- Synthetic well tie of the Outer Exmouth Sub-basin of Perth, Australia

A. Two-way travel time event of Sea bed.

The two-way time for events for Sea bed shows lower travel times at the South-eastern regions while Higher values of travel times were observed at Eastern and North-western part of the survey area as shown in figure 6 below.

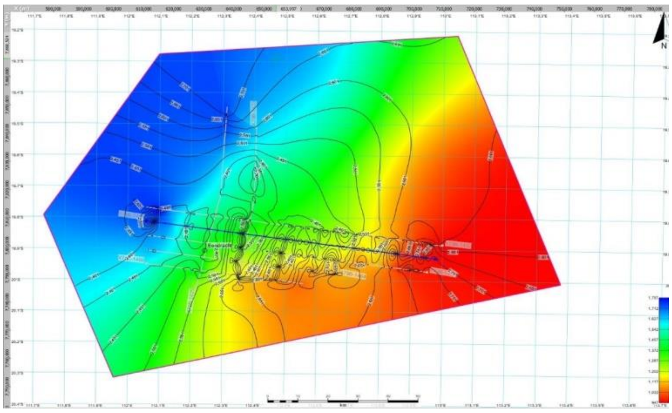

Fig 6:- Two-way Travel Time of Sea bed of the Outer Exmouth Sub-basin of Perth, Australia.

B. Two-way travel time event of Base tertiary.

The two-way travel time event for the Base tertiary show a lower travel times at the South-eastern region while higher values of the travel times were observed at the Eastern and North-western part of the research area as shown in figure 7 below.

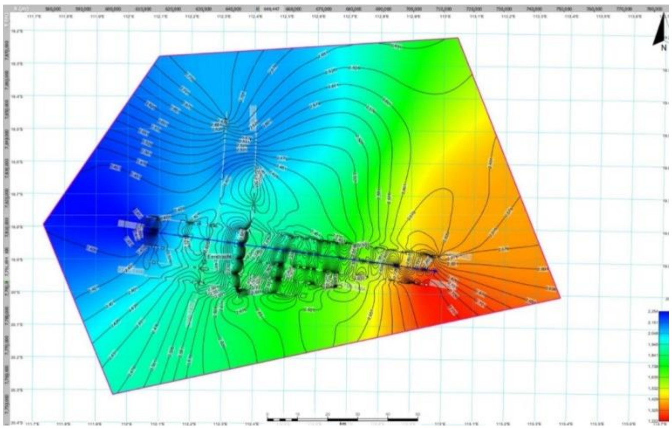

Fig 7:- Two-way Travel Time of Base Tertiary of the Outer Exmouth Sub-basin of Perth, Australia.

C. Two-way travel time event of Valanginian.

The two-way time for events for Triassic to Pre-rift shows lower travel times at the North west and Southeast regions while Higher values of travel times were observed at the central and North-western part of the survey area as shown in figure 8 below.

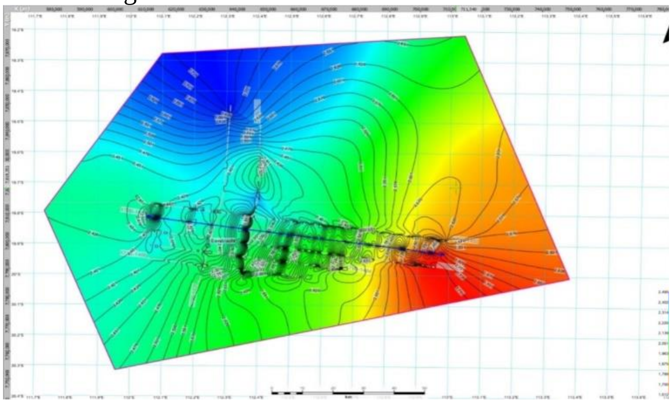

Fig 8:- Two-way Travel Time of Valanginian of the Outer Exmouth Sub-basin of Perth, Australia

D. Two-way travel time event of Triassic.

The two-way travel time events for Triassic to Pre-rift shows lower travel times at the eastern and central regions while higher values of travel times were observed at the South-eastern part of the research area as shown in figure 9 below.

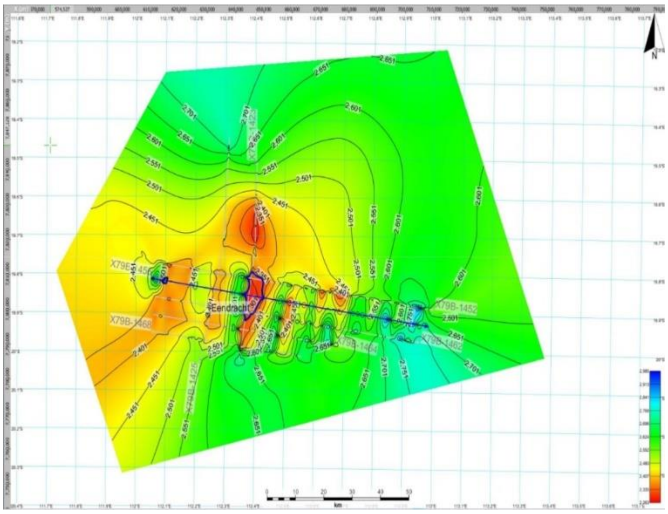

Fig 9:- Two-way Travel Time of Triassic to Pre-rift of the Outer Exmouth Sub-basin of Perth, Australia

E. Two-way travel time event of Sea bed to Base Tertiary.

The two-way time for events for Sea floor to Base Tertiary shows lower travel times at the North west and Southeast regions while Higher values of travel times were observed at the Southern part of the survey area as shown in figure 10 below.

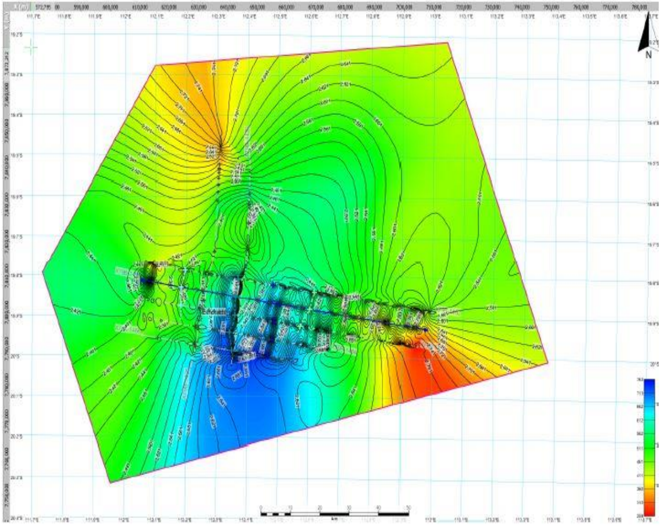

Fig 10:- Two-way Travel Time of Sea bed to Base Tertiary of the Outer Exmouth Sub-basin of Perth, Australia.

F. Two-way travel time event of Base Tertiary to Cretaceous.

The two-way time for events for Base Tertiary to Cretaceous shows lower travel times at the North west and Eastern regions while Higher values of travel times were observed at the South-eastern and Northern part of the survey area as shown in figure 11 below.

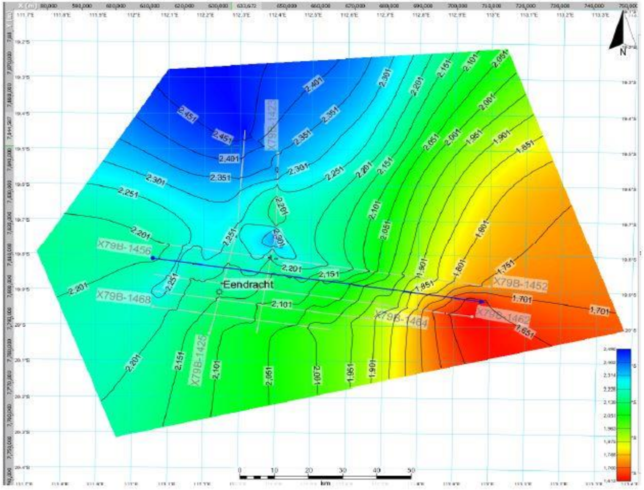

Fig 11:- Two-way Travel Time of Base Tertiary to Cretaceous of the Outer Exmouth Sub-basin of Perth, Australia.

G. Two-way travel time event of Cretaceous to Triassic.

The two-way time for events for Cretaceous to Triassic shows lower travel times at the Southeast and Northern regions while Higher values of travel times were observed at South-eastern part of the survey area as shown in figure 12 below.

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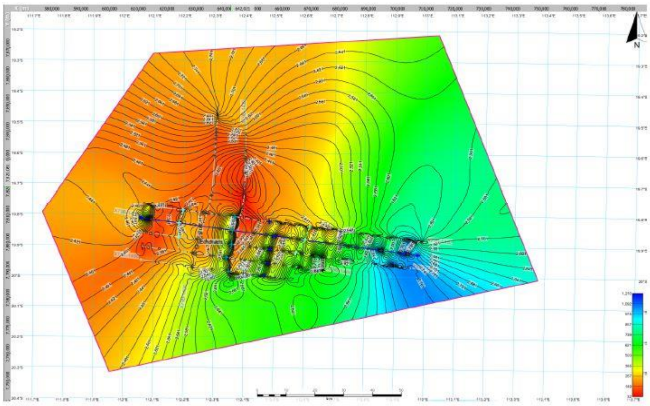

Fig 12:- Two-way Travel Time of Cretaceous to Triassic of the Outer Exmouth Sub-basin of Perth, Australia.

- *Depth conversion*

$$\text{Depth of sea floor} = (\text{Average velocity between sea floor and Tertary x } (c - b)/2\text{x}1000$$

$$\text{Depth of Base Tertiary} - \text{Depth ofSea bed} + (\text{Average velocity between Tertiary and Createceous x } (c - \frac{b}{2}\text{x } 1000$$

$$\text{Depth of Createaceous} = \text{Base Tertiary depth} + ((\text{Average velocity between Cretaceous and Triassic } (c - \frac{b}{2}\text{x } 1000$$

The average velocity between horizons is gotten by summing all the velocities between the horizons and dividing the number of velocities.

$$\text{Average velocity} = 2611.74 + 983.307 + \frac{3603.34}{2} = 2400\text{m/s}$$

By checking the middle of the cursor between are of interest I read the values as the internal velocity of the Sea floor two-way-travel time is 1924ms, Cretaceous is 2400ms and Triassic is 2165ms.

- *Depth events*

The depth events of the sea bed show south and south-eastern part of the survey area to be shallower (951m) While the Western and North-western part of the survey area are dipper (1,751m) and my depth is 1371km figure 13.

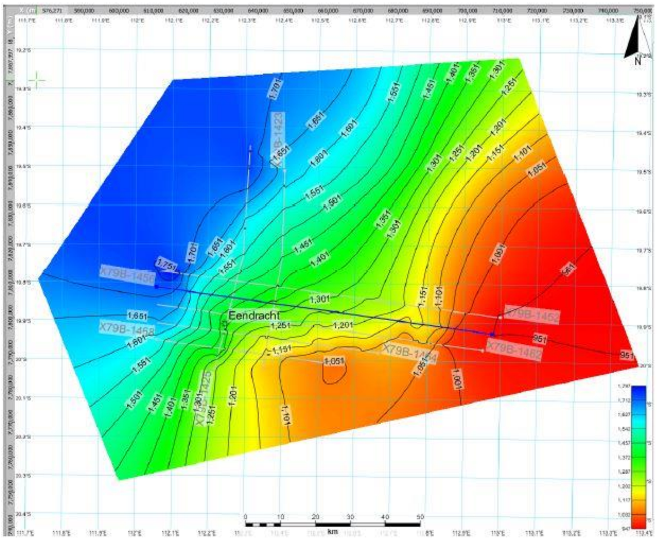

Fig 13:- Depth events of Sea bed of the Outer Exmouth Sub-basin of Perth, Australia.

The depth events of Base Tertiary show south and south-eastern part of the survey area to shallower (1251m) While the Western and North-western part of the survey area are dipper (2,251m) and my depth is 1826km see figure 14.

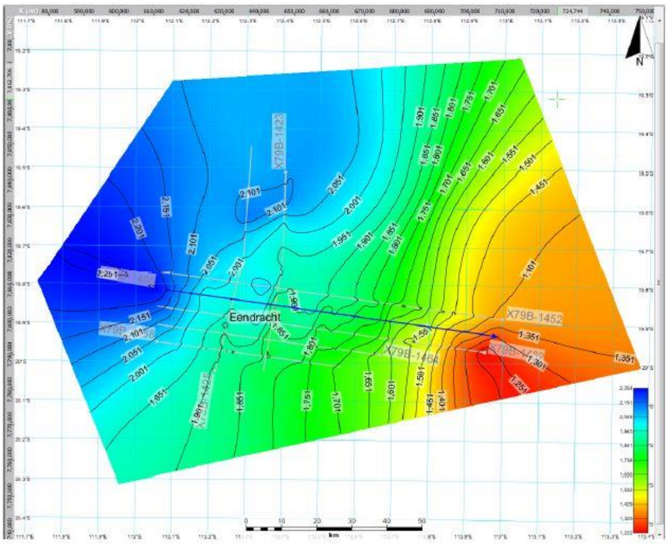

Fig 14:- Depth events of Base tertiary of the Outer Exmouth Sub-basin of Perth, Australia.

The depth events of Base Tertiary show south-eastern part of the survey area to shallower (1,651m) While the Western and North-western part of the survey area are dipper (2,451m) and my depth is 2170km see figure 15.

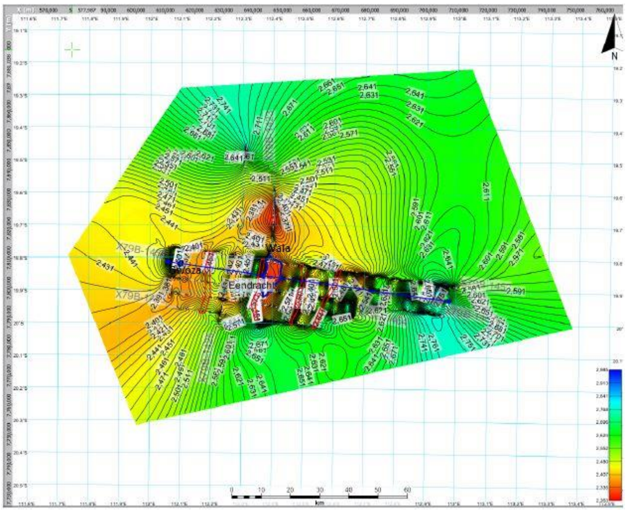

Fig 15:- Depth events of TR to top Pre-rift shows of the Outer Ex mouth Sub-basin of Perth, Australia

The depth events of TR to top Pre-rift shows Eastern part of the survey area to shallower (1,301m). While the North western and South-eastern part of the survey area are dipper (2,751m) and my depth is 2371.0km see figure 15.

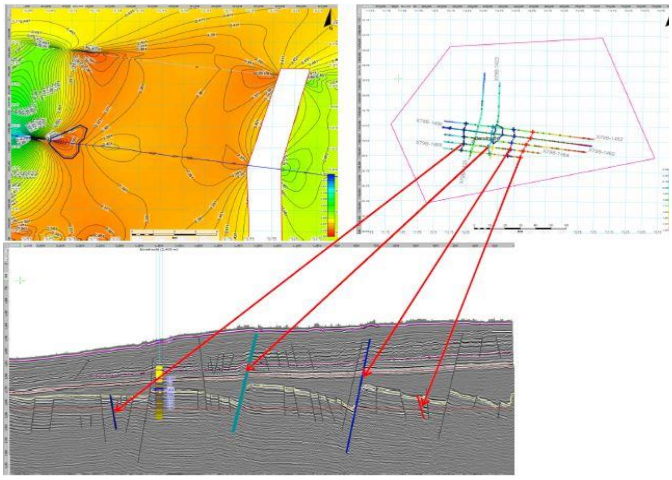

Fig 16:- Estimating the reserve study area of the Outer Ex mouth Sub-basin of Perth, Australia

Figures 16 and 17 show the reserve estimates of the two areas (Lead 1 and Lead 2) respectively.

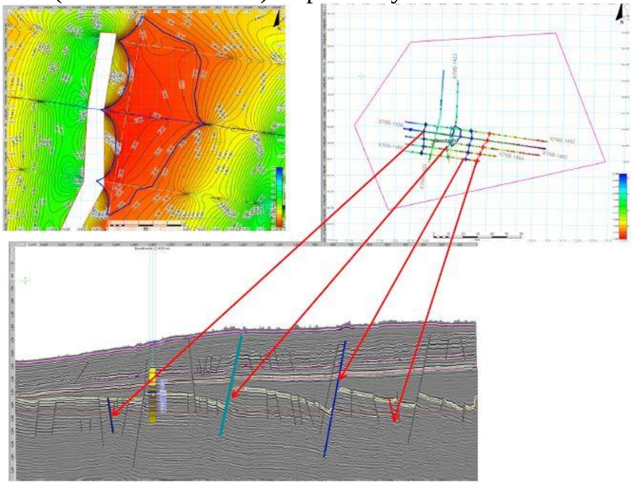

Fig 17:- Estimating the reserve of the study area of the Outer Exmouth Sub-basin of Perth, Australia

In the Isopach Cretaceous to Triassic, the central and north-western part of the study area is deeper while the south-eastern part is shallower and the Triassic is at a depth of 2371m figure 18.

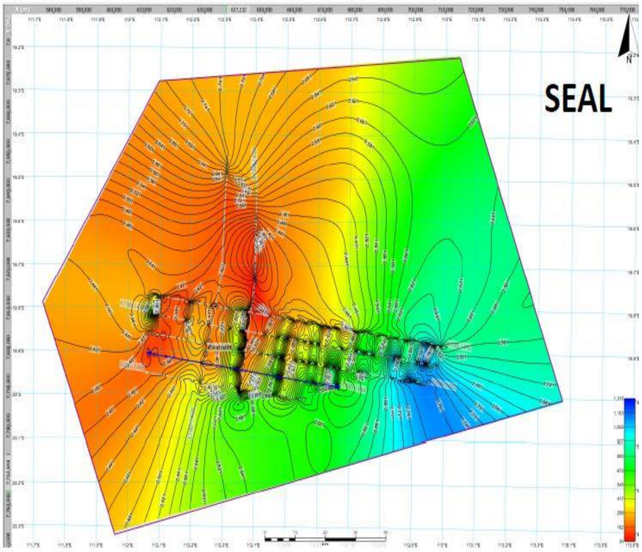

Fig 18:- Isopach Cretaceous-Triassic of the Outer Exmouth Sub-basin of Perth, Australia.

Porosity high were encountered at depths1160 – 1180, 1460 – 1480, 1680 – 1700, 1780 – 1800 and 1860 – 1880 these are zones that are likely to be sandstone zones and serves as the reservoir zones while,1270 – 1280, 1480 – 1510, 1720 – 1740 and 1810 -1830 are zones that are likely to be the lime stone Source rocks figure 19. The summary of the depth events are presented in table 2.

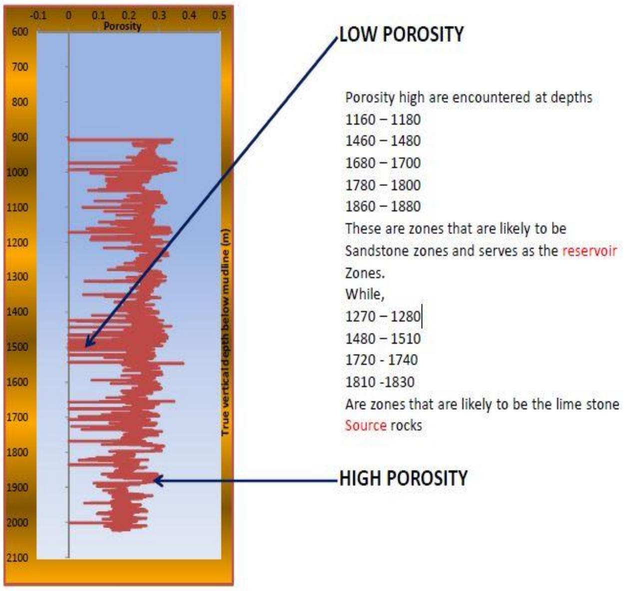

Fig 19:- Porosity log of the Outer Exmouth Sub-basin of Perth, Australia.

In the Isopach Triassic to Sea floor, the western part of the study area is deeper while the south-eastern part is shallower this is at a depth of 2403m figure 20.

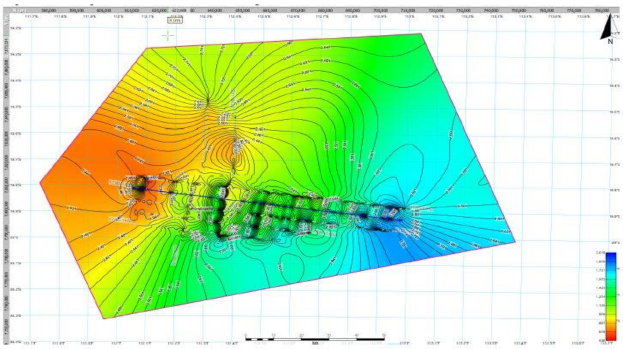

Fig 20:- Isopach of Triassic to Sea Floor of the Outer Exmouth Sub-basin of Perth, Australia

The porosities of the two areas are 31.52 1nd 31.23 with shale volumes of 0.25256 and 0.11687 while the thicknesses are 4 and 1.1metres. Table 1.

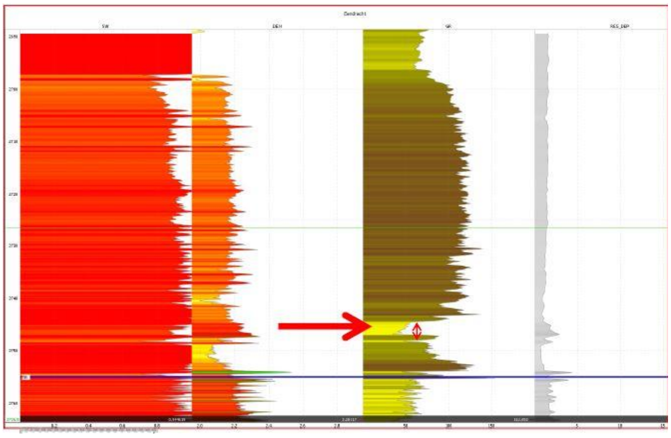

Fig 21:- Reservoir Evidence of Outer Exmouth Sub-basin of Perth, Australia

S/No	Sea bed	Age	Area (km)	Crest	Porosity	Shale
Lead 1	1371	TR	2.0	2892	31.52	0.25256
Lead 2	1371	TR	56	2923	31.23	0.11686

Table 1: Table of porosity and shale percentages

Event	Depth (m)
Sea bed	1371
Tertiary	1826
Cretaceous	2170
Triassic	2404

Table 2: Table of depth events

IV. DISCUSSION AND CONCLUSION

The huge 3D seismic was acquired over the area of the margin and has not resulted in large exploration successes. This is because of the simple effective traps at base regional seal level being beneath the amplitude floor. Some quantity of gas reserves remains undeveloped, together with some potential condensate reserves. The basin is characterized by tectonic effects which produces potential structures for both movement, escape with small accumulation as well as traps. The Triassic Limestone formation forms the source rock, the Lower Cretaceous Sandstone forms the reservoir while the Upper Cretaceous Limestone forms the seal.

The depths of the main events are as follows Sea Floor 1371m, Tertiary 1826m, Cretaceous 2170m and Triassic 2404m.The reservoir thickness in Lead 1 is 1.1m with a total area of 2km^2 and Lead 2 is 4m with a total area of 56km^2. Regional tectonic faulting (migration channels) that forms grabens leads to formation of reservoirs. The future of Exmouth sub basin as hydrocarbon province largely lies in developing these resources and exploring for traps surrounding the future infrastructure.

The province is still under-explored by global standards, mostly outside of proven oily areas. There may be large potential volumes that remain in untested deep-water Mesozoic part of the basin, and possibly poorly explored Palaeozoic section of the basins. Newly advance mode of oil recovery method should be employed to enhance optimum recovery.The drilling exercise of Eendracht took two days to be completed

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