[PS]Play Analysis of the Natal Valley and Durban Basin, Off the East Coast of South Africa*

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Abstract

The Aptian source rock is a prolific hydrocarbon producer and has been proven in the Bredasdorp and Pletmos basins along the south coast of South Africa. Although not yet encountered along the east coast, this study focuses on the modelling of this interval as the primary source rock. Basin modelling suggests an oil mature Aptian source during the Upper Cretaceous and Paleogene. The Aptian surface is buried deepest (9 km) within the Natal Valley, and at it shallowest (4.5 km) within the Durban Basin. Despite the Aptian interval being largely underlain by oceanic crust within the Natal Valley, it does not automatically preclude it from generating hydrocarbons within the region.

Apart from basement heat flow history, sediment thermal properties, together with depositional history are often ignored when considering source rock maturity. Studies have shown that source rock over oceanic crust can obtain maturity of 1% (Ro) at present day depths of approximately 5 km. In addition to overburden and burial depth, using paleo-heat flow and estimated erosion of roughly 2 km, the postulated Aptian source rock is likely to be mature to generate hydrocarbons within the Natal Valley and Durban Basin.

Several new play types were identified and mapped along the east coast including contourite drifts and a basement draping sedimentary wedge. The Oribi contourite drift, Eocene to Oligocene in age, is a substantial feature that covers an area of nearly 40000 km^2 and is up to 270 m thick. A second, Miocene aged contourite drift, known as the M-drift has an aerial extent of 20,000 km^2 and a thickness of 270 m. These drifts are located in water depths of 3-4 km at depths of 4-5 km below the seabed. A sedimentary wedge overlying and downlapping onto basement may provide a likely new hydrocarbon target within the northern Natal Valley despite it being in ultra-deep water. It resides in water depths between 2.5 km and 3.5 km, about 8 km below the seabed. This large feature has been mapped in a region extending across 15,000 km^2 with thicknesses of up to 450 m. Various leads are recognised and differ in size from 850 km^2 to 2500 km^2. Best estimates range between 887 MMbbl and 5186 MMbbl recoverable oil, and 1.76 Tcf of gas. In addition to the mapped leads, numerous other leads such as mounded sedimentary features, carbonate build-up and basin/slope fans are observed on seismic data along the margin. Major risks are source presence, migration distance and biodegradation.

Play Analysis of the Natal Valley and Durban Basin, off the East Coast of South Africa

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1. Introduction

The South African eastern offshore extends from the Mozambique border in the north to the Port Alfred Arch near East London in the south. The Natal Valley situated in the northern sector of the eastern offshore is bounded by the Mozambique Ridge in the east and merges into the Transkei Basin to the south. To the west the Natal Valley is confined by a narrow coast-parallel shelf of between 4 and 15 km wide (Figure 1). The Durban Basin extends from the Port Shepstone Arch in the south and merges into the Zululand Basin in the north, which effectively forms part of the southern tip of the Mozambique Basin. The continental shelf is approximately 35 km wide between Durban and Richards Bay (Figure 1).

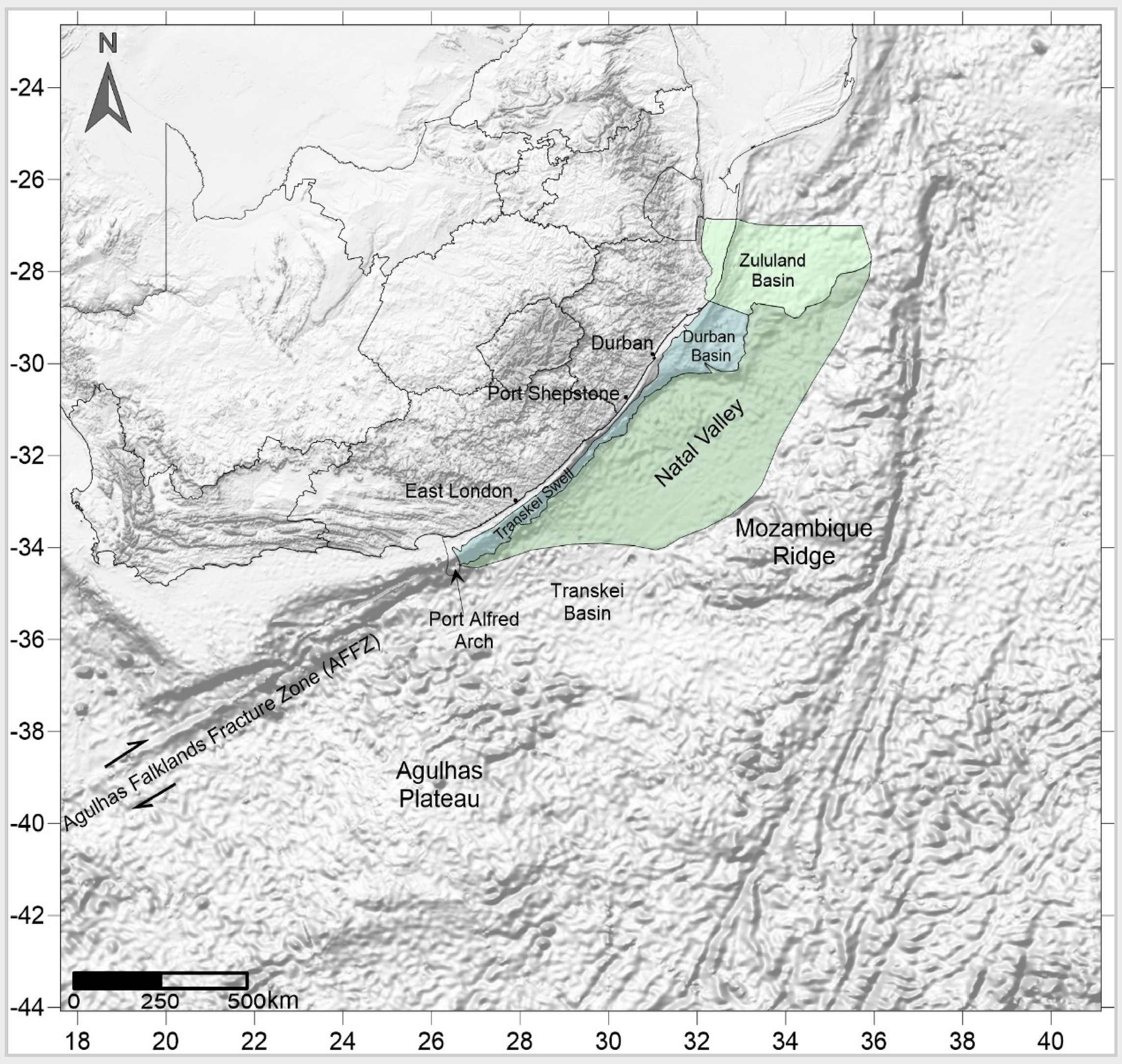


Figure 1: Main structural elements and location of the Natal Valley, Zululand, Durban, Transkei Basins.

The Durban Basin is structurally complex as a result of its tectonic history and has accumulated more than 7000 m of sediments resting on volcanic basement. The Mesozoic rift basins are bounded to the south by the Port Shepstone Arch and to the east by the Mozambique Ridge, merging northwards into the Zululand Basin, which represents the southern extension of the large Mozambique Basin. The Zululand Basin is structurally less complex than the Durban Basin and is confined to the west by the Lebombo Group volcanics (180-140Ma), which dip gently eastwards underneath the onshore and offshore parts of the basin where they are buried underneath Mesozoic and Cenozoic sediments. The Zululand Basin has a shallower basement resulting in a sediment thickness of 2000 to 3000 m. The Transkei swell represents a narrow elongated shelfal area along the Agulhas Falkland Fracture Zone and its deep-water extent. The Natal Valley is bounded by the Mozambique Ridge in the east and merges into the Transkei Basin to the south.

2. Tectono-Stratigraphy

The Durban Basin can be subdivided into two sedimentary successions, (Broad and Mills, 1993) a synrift and later drift succession. The synrift is further divided into two synrift phases, while this is also relevant for the drift phase comprising of an early and late drift phase (fig 2). The synrift phases comprise shelf to deep water deposits and the early drift phase is predominately lower slope claystone, while the late drift consists of shelfal sediments (Broad and Mills, 1993, Broad et al 2006).

The sediments within the synrift grabens identified on seismic and intersected by the four wells (JC wells) drilled offshore the Durban Basin have been dated as Valanginian to upper Jurassic in age (Broad et al 2006; Green and Garlick, 2011).

The under explored Zululand Basin with its onshore and offshore portions totals 13 500 km^2 up to the 1500m isobath. To the west, it is bounded by volcanics of the Lebombo Group, dipping eastward under the basin (fig 4c). The combined thickness of the basalt and rhyolite succession is in excess of 5000 m (Broad et al, 2006).

The apparent abrupt southern termination of the Lebombo volcanics in the vicinity of Richards Bay is explained by the presence of a series of north- to northeast-trending normal faults (up thrown to the east), which displace the outcrops to the east, beyond the present-day coastline.

A northeast-trending basement ridge, the Bumbeni Ridge, extends from the Lebombo Mountains into the Zululand Basin and continues offshore, dividing the basin into two troughs (SACS, 1980).

The Transkei Swell is an area of shallow basement located between the Algoa and Durban Basins (figure 4a). In this area, upper Cretaceous and Tertiary sediments onlap the base of the continental slope, seaward of the AFFZ (Broad et al., 2006). Klinker and Lock (1978) recognised Late Cretaceous sediments in outcrops near East London and Port Edward.

McLachlan et al (1976) describe the onshore half-graben sediments along the Transkei swell to be of Valanginian age. In terms of depositional environments, these sediments are in some locations interpreted as distal subaerial alluvial fan deposits and in other areas as deep-water turbidite facies (Karpeta, 1987).

The Natal Valley is a deep ocean basin underlain by oceanic crust formed during the Early Creataceous.

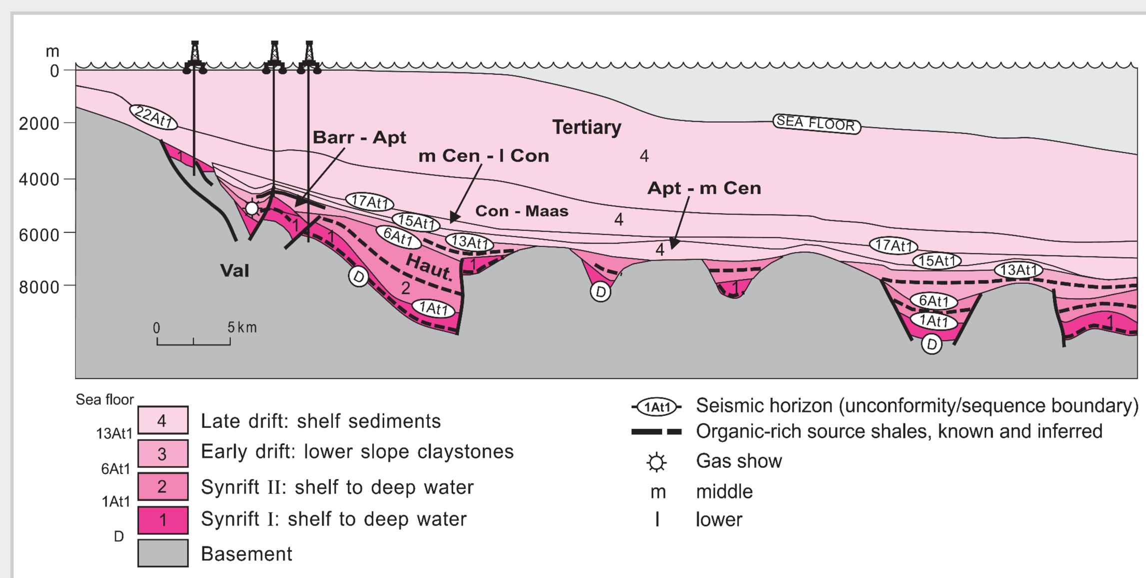


Figure 2: Interpretation of seismic cross section in the Durban Basin showing main structural features and stratigraphic subdivision (Broad et al 2006)

3. Play Analysis

The Aptian source rock is a prolific hydrocarbon producer and has been proven in the Bredasdorp and Pletmos Basins along the south coast of South Africa. Although not yet encountered along the east coast, this study focuses on the modelling of this interval as the primary potential source rock.

Figure 3 shows a depth map of the Aptian surface along the eastern margin for the Natal Valley, Durban and Zululand Basins. The Aptian surface is at its deepest within the Natal Valley, where it reaches depths of about 9000 m, and at it shallowest within the Durban Basin.

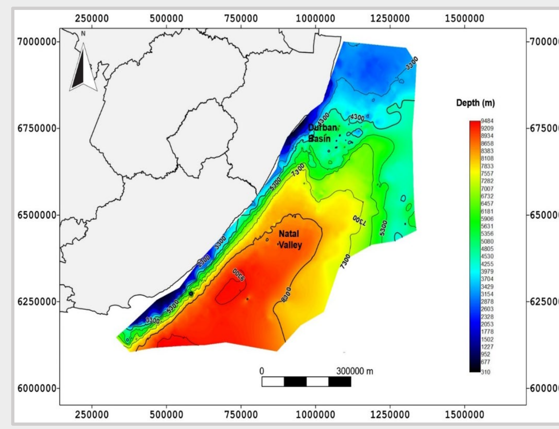


Figure 3: Depth to Aptian surface

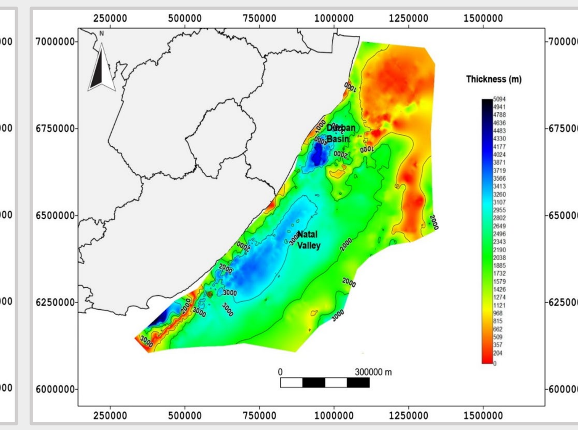


Figure 4: Thickness of the overburden overlying the Aptian surface

In addition to burial depth, overburden was also determined for the sediment pile between the Aptian surface and the seafloor (figure 4). The isopach shows that the overlying sediments are thickest within the Natal Valley as well as the Durban Basin.

Figure 5 illustrates the calculated paleo heat flow from basin modelling for the Aptian interval. Using the overburden, burial depth, paleo heat flow and estimated erosion of approximately 2000m, the Aptian source rock is likely to be mature to generate hydrocarbons within the Natal Valley and Durban Basin (figure 6).

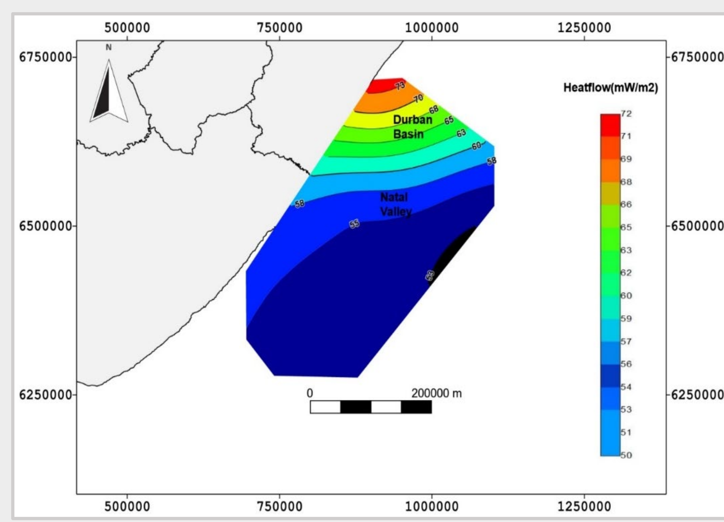


Figure 5: Calculated present day heat flow for the Aptian interval

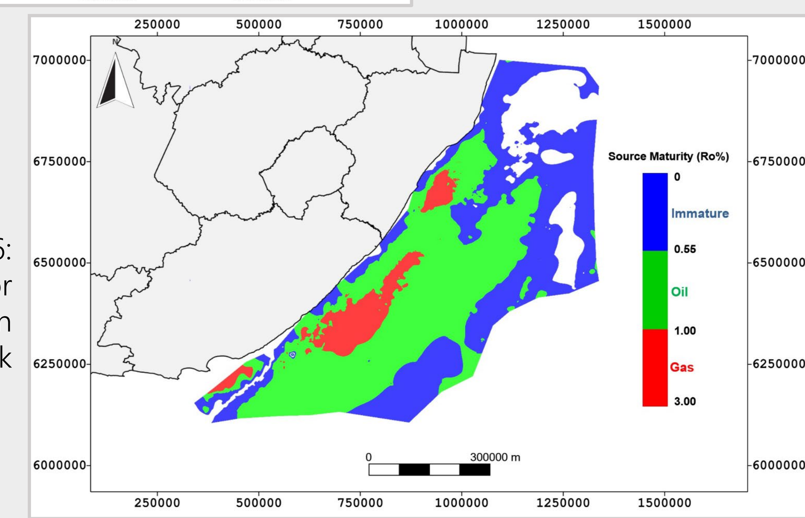


Figure 6: Modelled maturity for the postulated Aptian source rock

4. Plays and Leads

A number of potential new plays have been identified and mapped within the Natal Valley (figure 6). Figures 7 and 11 show seismic lines on which contourite drifts have been interpreted. Contourite drifts are formed by bottom water currents. These bottom currents can create clean, porous and well sorted sands. Figure 7 portrays the Oribi-drift, approximately Eocene-Oligocene in age (Niemi et al, 2000). The Oribi-drift is a substantial feature that covers approximately 40000km^2 and is up to 270m thick (figure 8). It is located in roughly 3-4km water depth at 4-5km depth below seabed. The Oribi-drift is interpreted as a separated, elongated, mounded drift (figure 9).

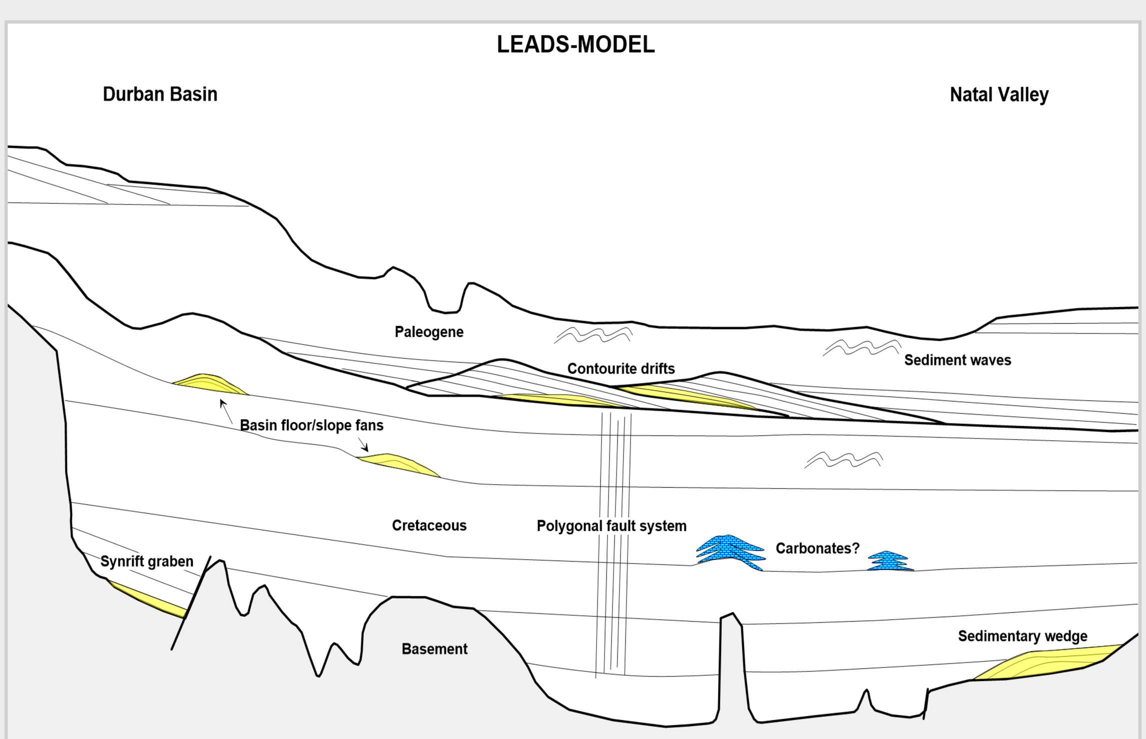


Figure 6: Schematic showing various lead and play types within the Natal Valley and Durban Basin

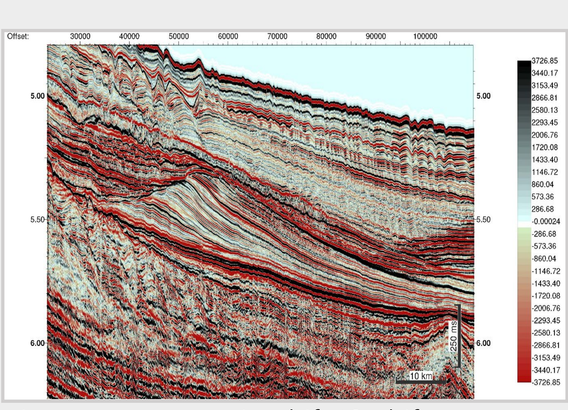


Figure 7: A contourite drift (O-drift) a potential new play along the Eastern margin on a seismic line

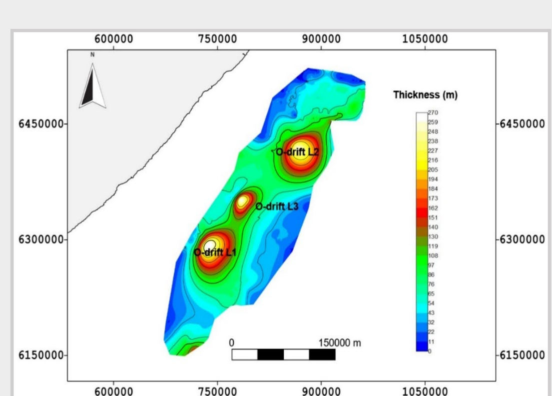


Figure 8: An isopach of the O-drift

Three leads were mapped within the Oribi-drift play (figure 10). These leads vary in size from ~850 to 2500km^2. O-drift L1 falls mostly within the modelled oil mature source section of the basin, O-drift L2 lies completely within the oil mature window while lead O-drift L3 falls within area where modelled source is in the gas window (figure 10)

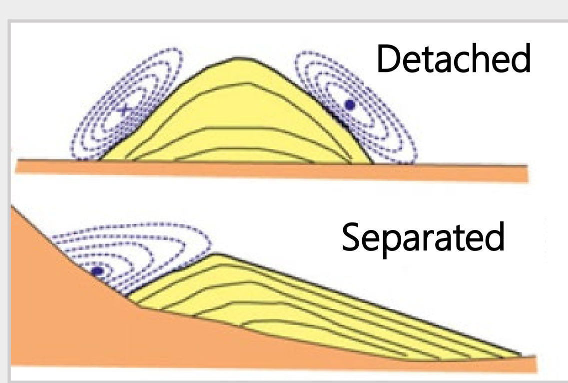


Figure 9: Elongated mounded contourite drifts (Rebesco et al, 2014)

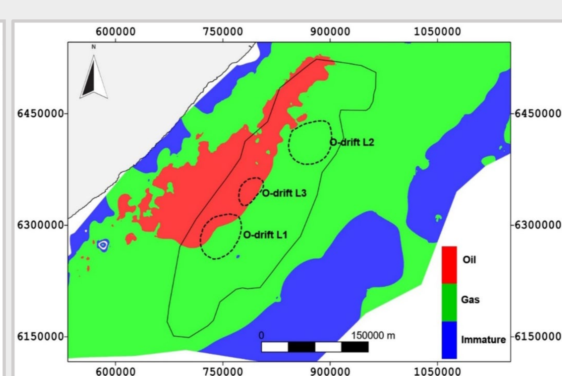


Figure 10: Three leads identified and mapped within the Oribi-drift

Another contourite drift is shown in figure 11, herein referred to as the M-drift. The M-drift is roughly Miocene in age (Niemi et al, 2000). It is 20000km^2 in size and is up to 270m thick (figure 12). It is located in 3-4km water depth at 4-5km depth below seabed. The M-drift is interpreted as a detached, elongated, mounded drift which is discrete from the separated Oribi-drift (figure 13).

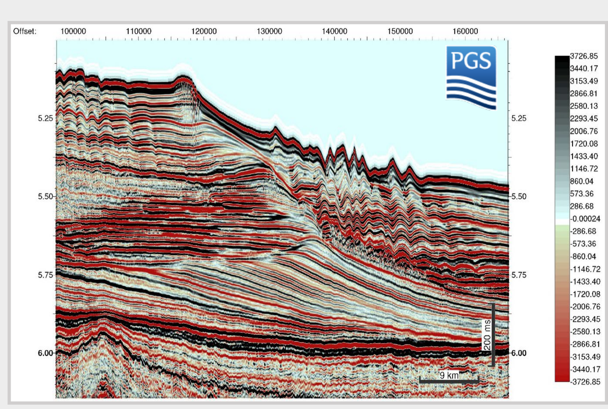


Figure 11: A contourite drift (M drift) a potential new play along the Eastern margin on a seismic line

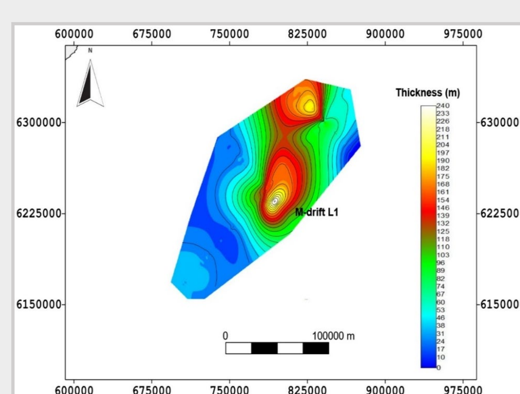


Figure 12: An isopach of the M-drift within the Natal Valley

The (M drift L1) lead was mapped within the M drift in the Natal Valley (figure 13). It is roughly 1500km^2 in size and is located within the oil mature section of the predicted Aptian source kitchen area (figure 14).

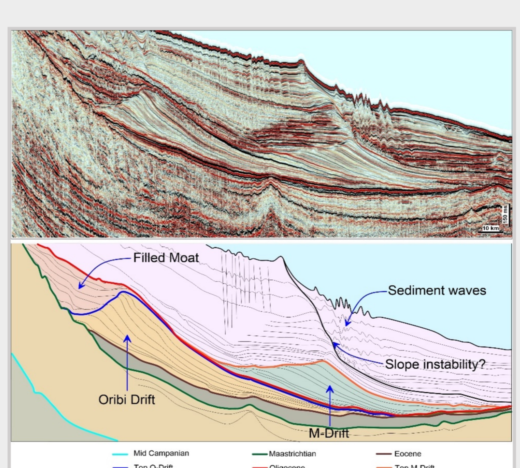


Figure 13: The Oribi-drift and M-drift shown on a geo-seismic section with associated features

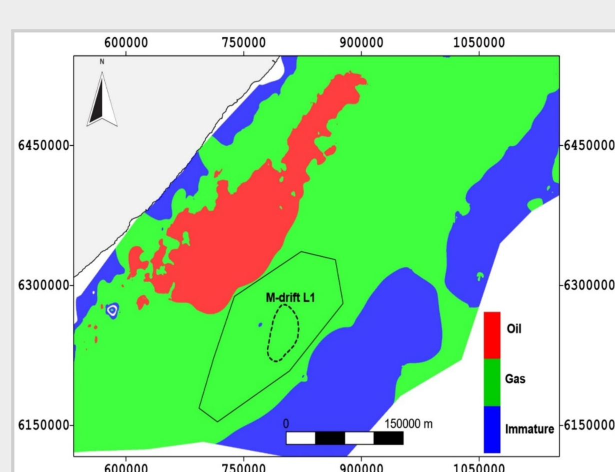


Figure 14: Lead (M drift L1) mapped within the M contourite drift play in the Natal Valley

A sedimentary wedge that overlies and downlaps onto basement may provide a possible new hydrocarbon target within the northern Natal Valley (figure 15), although it is located in ultra-deep water. It resides in 2.5 to 3.5km water depth and is approximately ~8km below seabed. The sedimentary wedge has been mapped in an area extending across 15000km^2 with thicknesses of up to 450m (figure 16). The feature shows a clear increase of amplitude on the far compared to the near angle stack (figure 17).

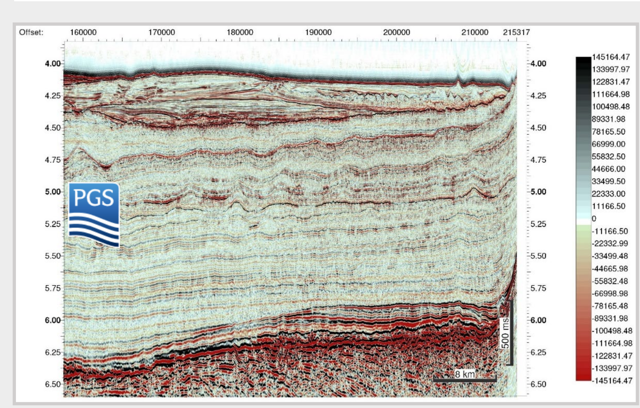


Figure 15: A sedimentary wedge on basement, representing a potential new play along the Eastern margin

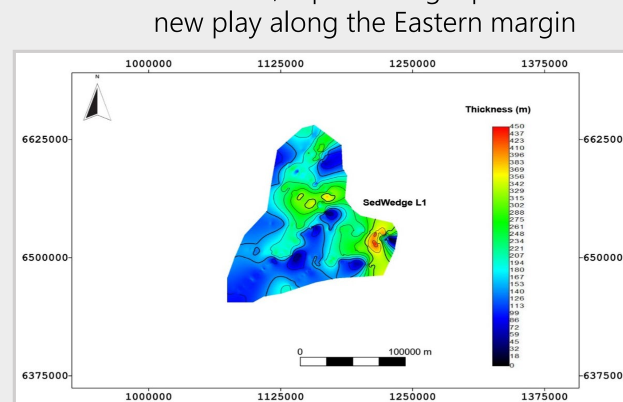


Figure 16: Isopach of sedimentary wedge

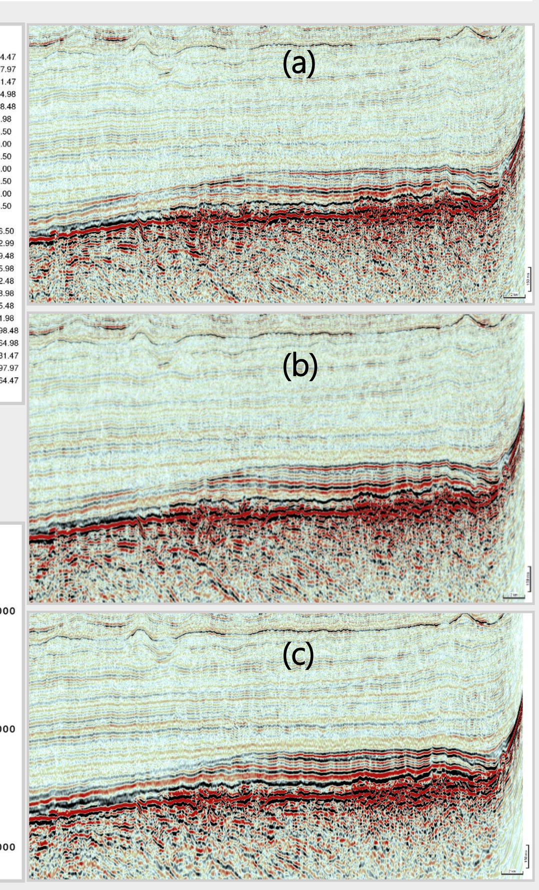


Figure 17: Near(a), mid(b) and far(c) angle amplitude display of sedimentary wedge

One lead was mapped within the sedimentary wedge play (figure 16) SedWedge L1 is approximately 850km^2 in size and is partially located within the oil mature part of the modelled Aptian source rock (figure17).

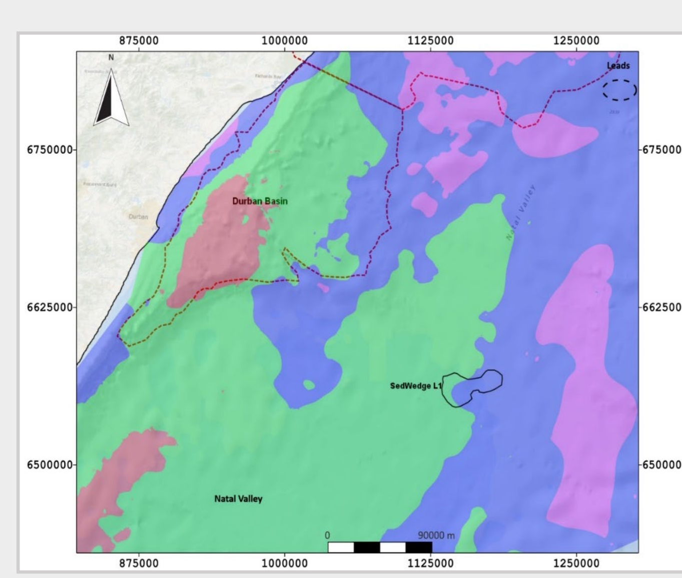


Figure 18: Lead (SedWedge L1) within the sedimentary wedge play in the Natal Valley.

5. Play Analysis

Figure 19 shows the various leads mapped along the margin. These are summarized in the following section. Each of the leads shows a location map, a seismic section through the lead, a thickness map and deterministic volumetric estimates.

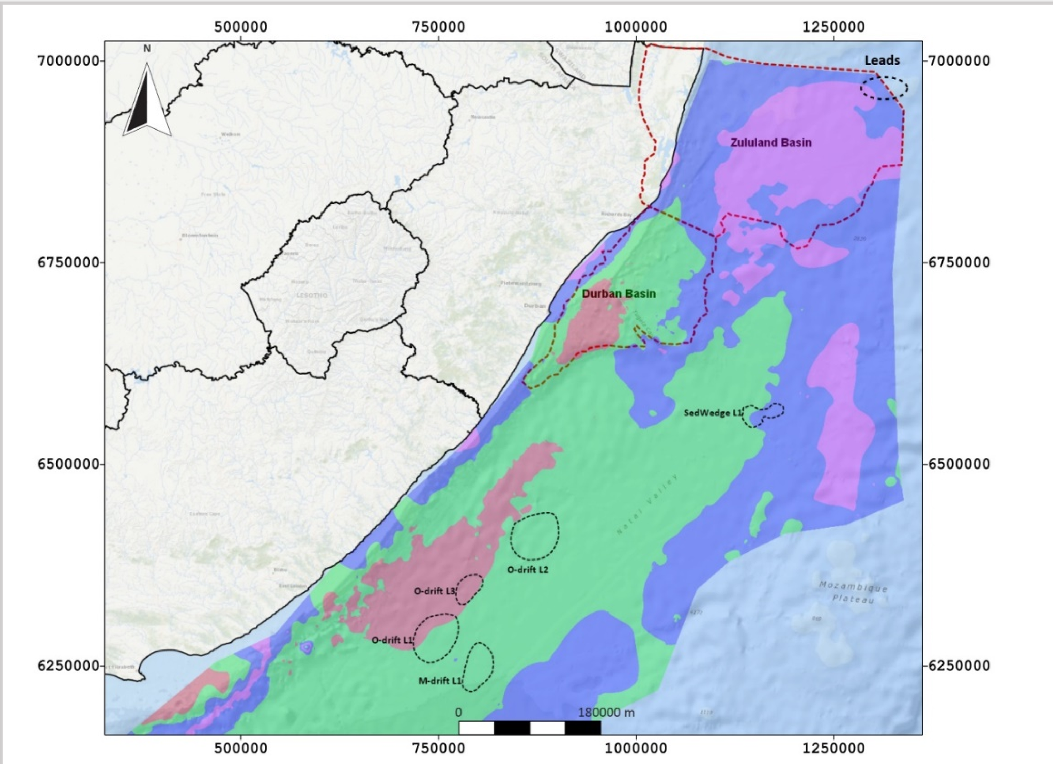
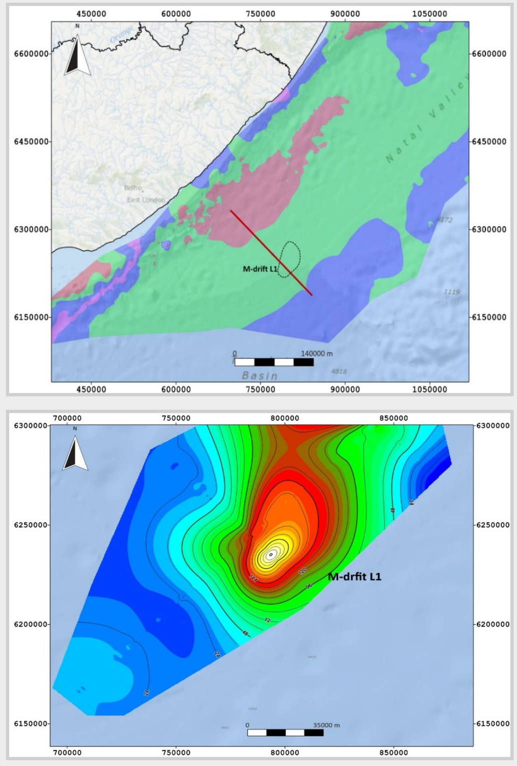
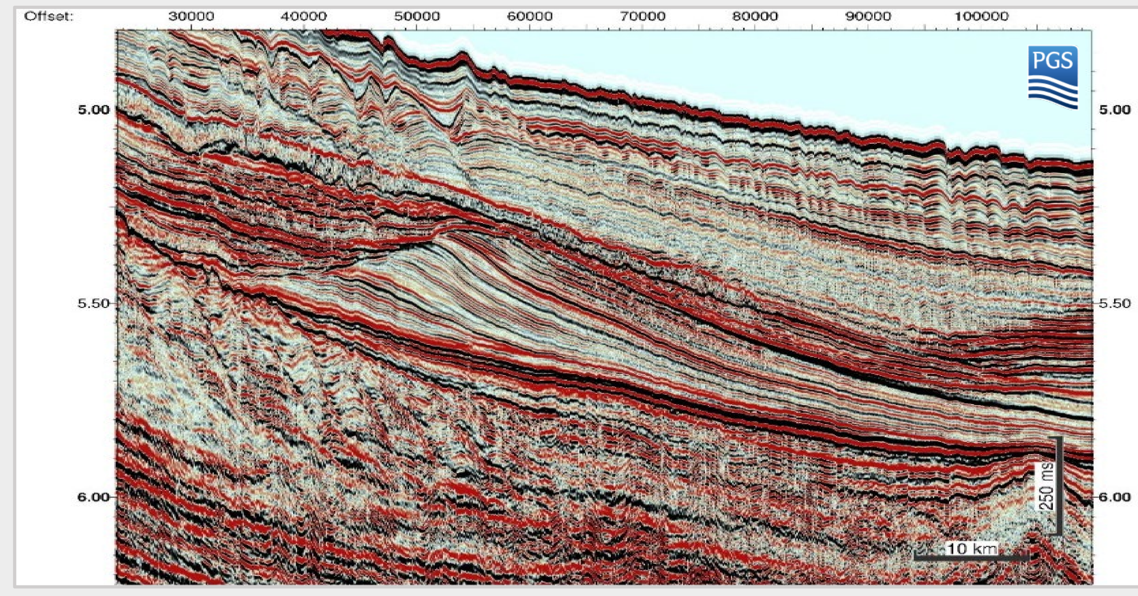


Figure 19: Various leads within the Natal Valley

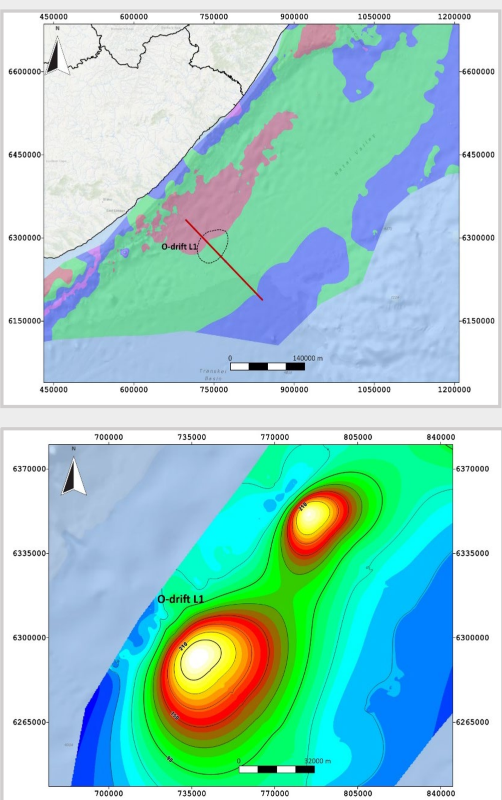
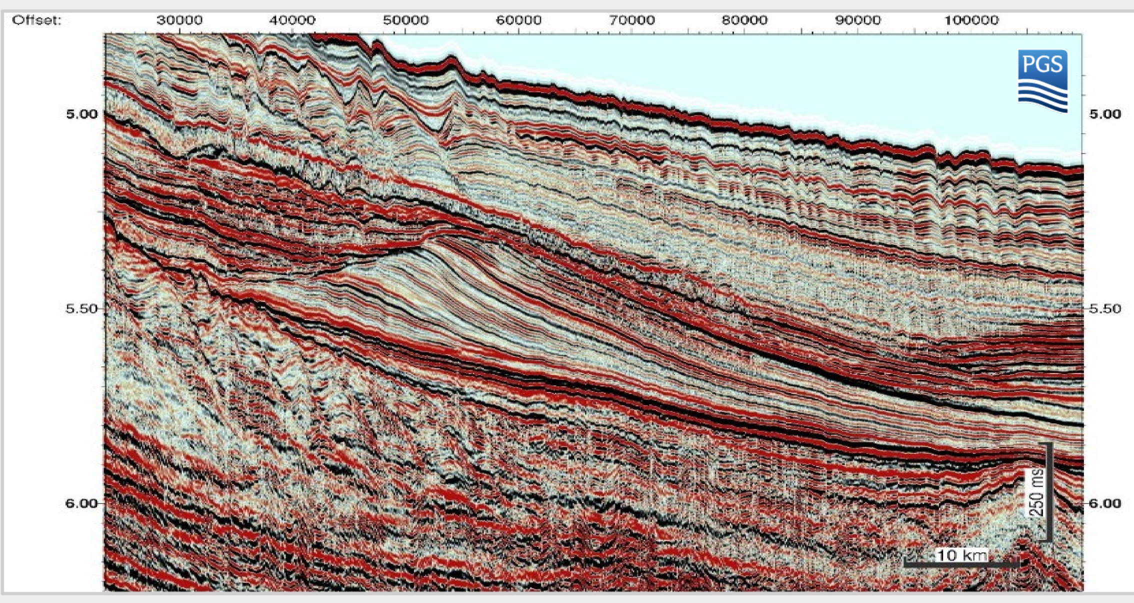
M-drift L1

Water depth (m)	3000-4000
Depth BML (m)	4000-5000
Area (km^2)	350
Thickness (m)	160
Play Type	Contourite drift
Age	Miocene
Risks	Source presence Migration Degradation

Best estimate Recoverable Oil (MMbbl)
887

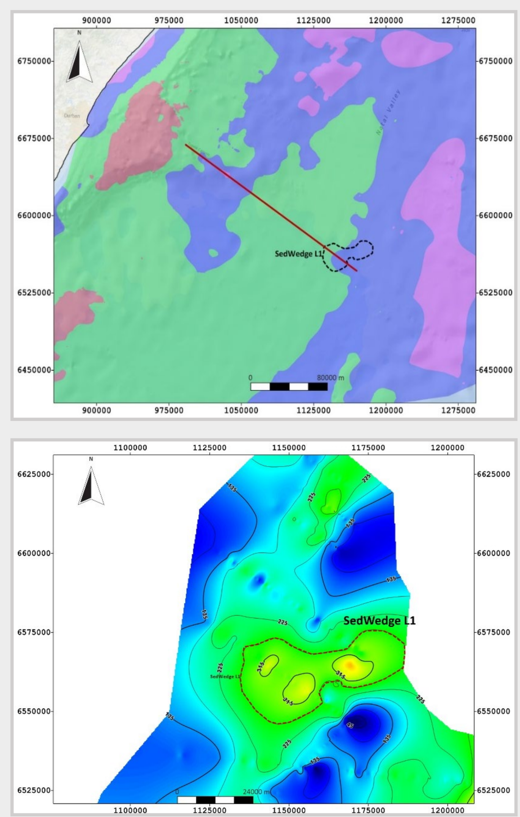
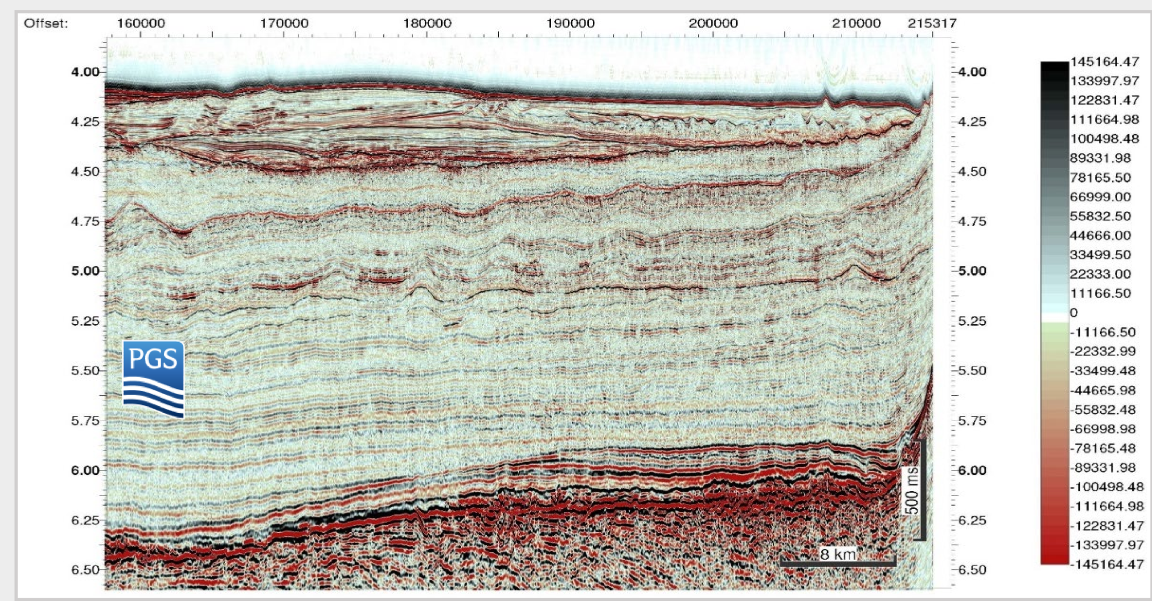
O-drift L1

Water depth (m)	3000-4000
Depth BML (m)	4000-5000
Area (km^2)	1000
Thickness (m)	185
Play Type	Contourite drift
Age	Eocene-Oligocene
Risks	Source presence Migration Degradation

Best estimate Recoverable Oil (MMbbl)
2617

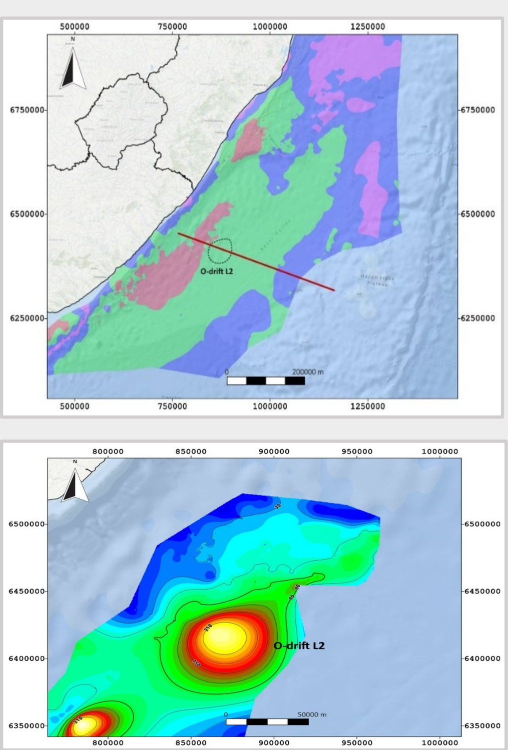
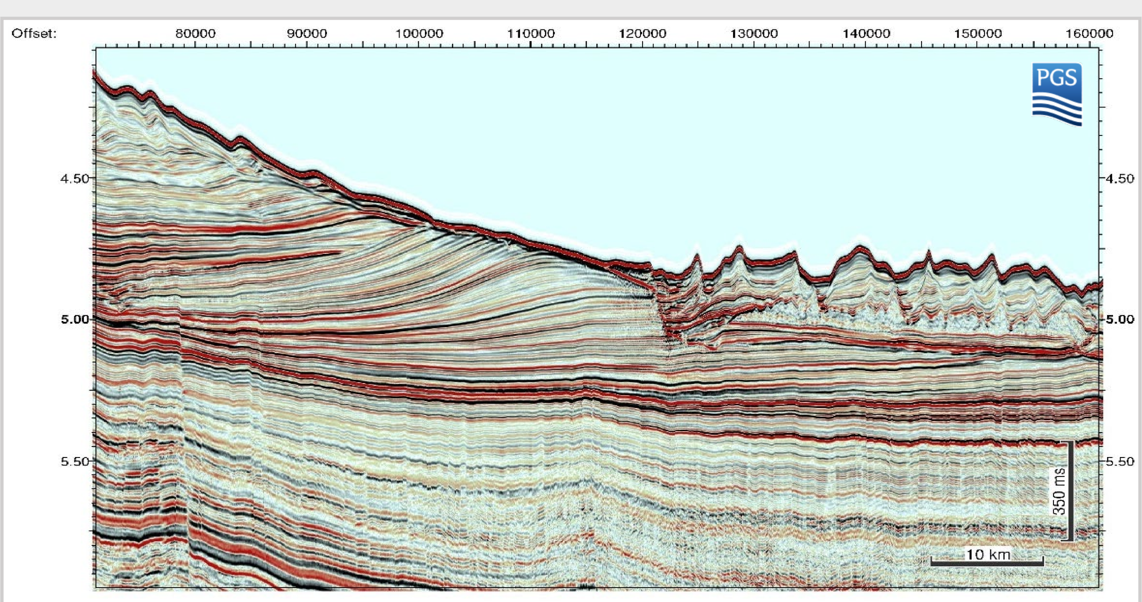
SedWedge L1

Water depth (m)	2580
Depth BML (m)	270
Area (km^2)	8000
Thickness (m)	80
Play Type	Deep-water fan
Age	Early Cretaceous
Risks	Source presence Reservoir quality

Best estimate Recoverable Oil (MMbbl)
2693

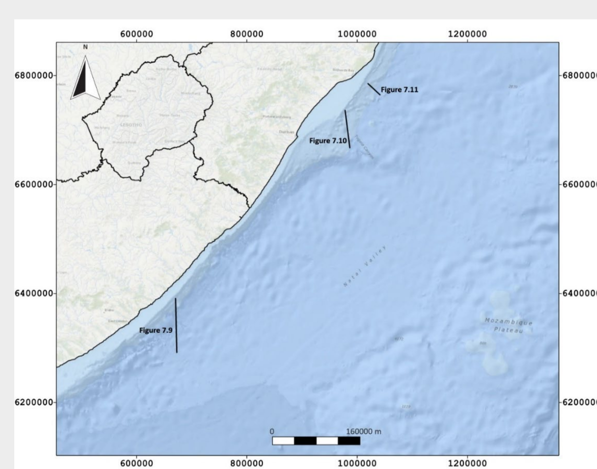
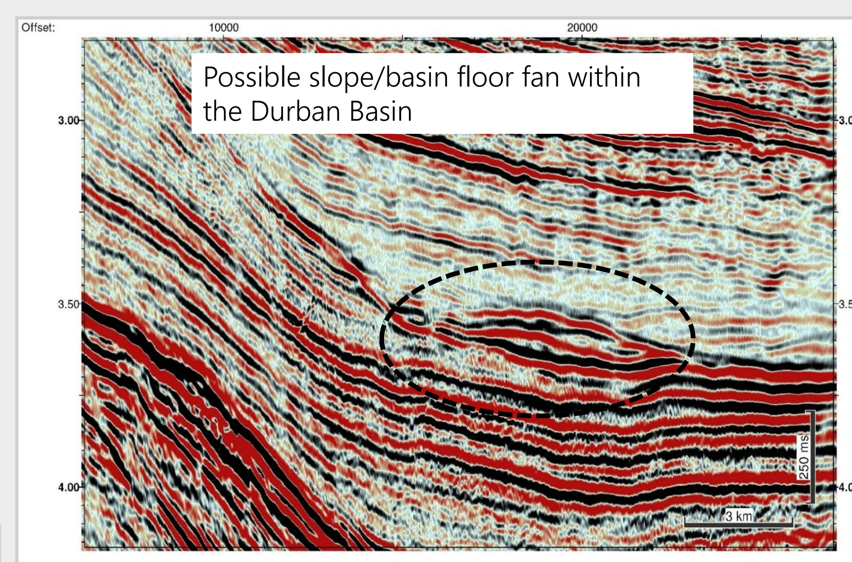
O-drift L2

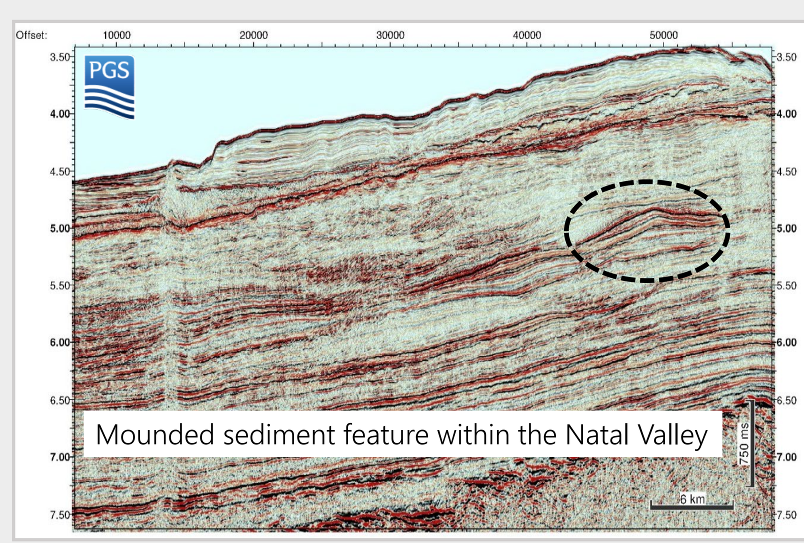



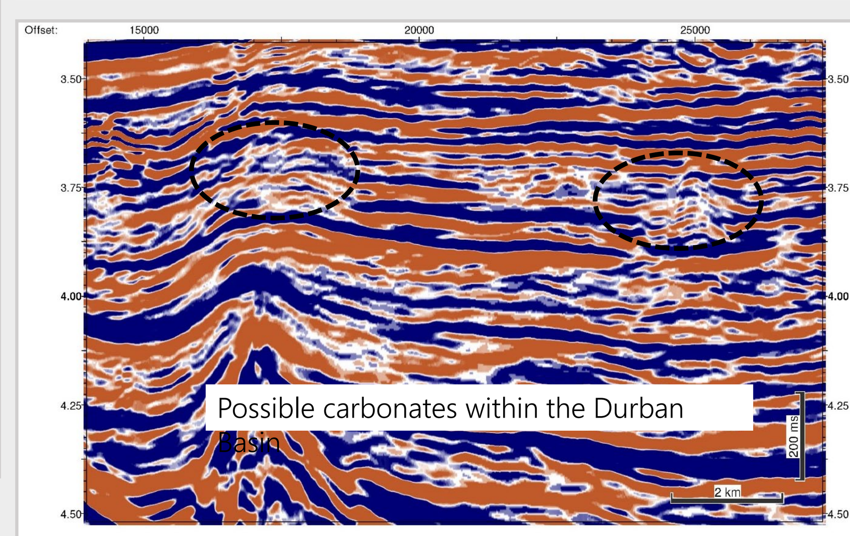
Water depth (m)	3000-4000
Depth BML (m)	4000-5000
Area (km^2)	1000
Thickness (m)	160
Play Type	Contourite drift
Age	Eocene-Oligocene
Risks	Source presence Migration Degradation

Best estimate Recoverable Oil (MMbbl)
2569

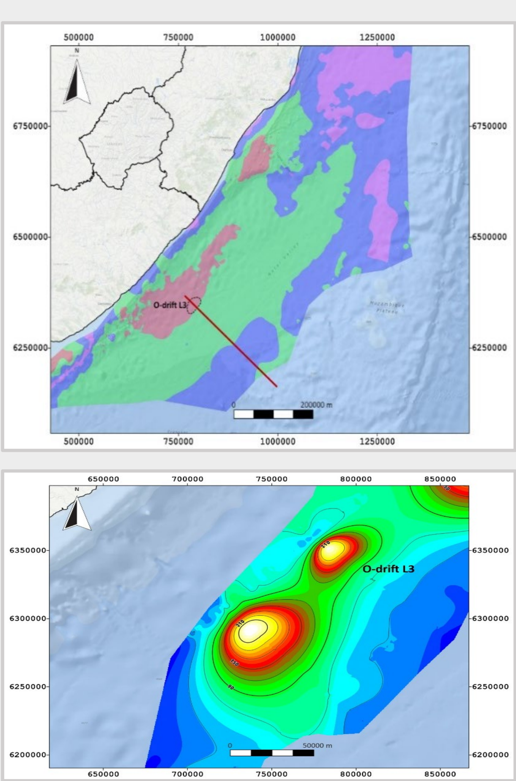
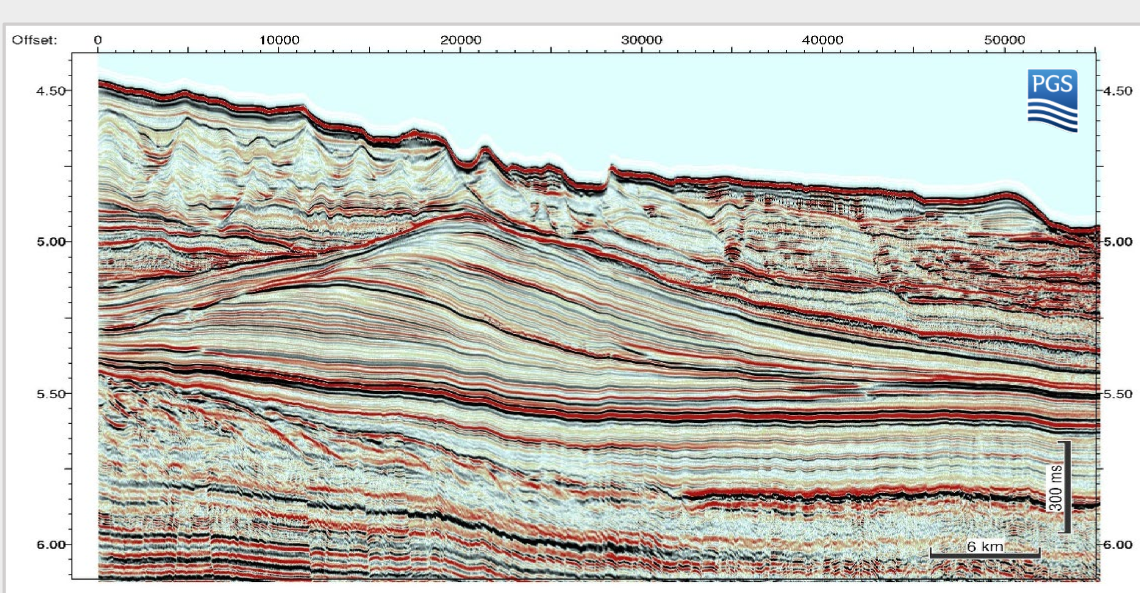
Other Leads





O-drift L3

Water depth (m)	3000-4000
Depth BML (m)	4000-5000
Area (km^2)	450
Thickness (m)	150
Play Type	Contourite drift
Age	Eocene-Oligocene
Risks	Source presence Migration Degradation

Best estimate Recoverable Gas (Tcf)
1,76

6. Summary

The Aptian source rock is a proven good quality marine source rock intersected in several basins offshore South Africa including the Orange, Bredasdorp and Pletmos basins. Although not proven off the eastern South African margin, it was modelled in this study based on its occurrence in other basins offshore South Africa and throughout the world, and its general stratigraphic occurrence with respect to burial along the margin. The postulated Aptian source interval is deepest within the Natal Valley and shallowest in the Durban Basin.
Basin modelling shows that the Aptian source, if present, may be mature for oil within the Durban Basin and Natal Valley, but also may have generated gas within areas off the eastern offshore where sediments are thickest.
Potential new hydrocarbon play types were identified and several leads mapped within these plays. These include contourite drifts, basement draping sediment, wedge plays and slope/basin floor fan complex.

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