

# Defying volcanic rifted passive margin models - World class Aptian source rock proven in the Orange Basin opens Venus, Graff and Mopane equivalent future “Golden Lanes” offshore Namibia and beyond

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## Summary

“There are no oil mature source rocks south of the Walvis Ridge”, a myth which was finally busted in 2022 when Shell and Total Energies respectively announced the giant Graff and Venus discoveries in the Orange Basin offshore Namibia. This was the grand finale of a long-standing debate in which model and data fought a hard battle. On the one hand, there was a model that did not support the presence, quality and oil maturity of source rocks in the Orange Basin and much less over oceanic crust. On the other hand, seismic evidence was pointing to the presence of a world class source rock generating hydrocarbons migrating into large traps. Finally, in 2023, the Mopane discovery announced by Galp, extended the presence and quality of this source rock to the east, inboard of the Outer High basement ridge, opening up a whole new play fairway and hopefully eliminating any remaining negative perception of the hydrocarbon and oil potential in the Orange Basin.

## Introduction

The Orange Basin formed in Late Jurassic to Early Cretaceous as part of a volcanic passive margin generated as South America and Africa rifted apart. It can be divided into two major sub-basins separated by the Outer High basement ridge and it contains continental to marine sediments of Mesozoic to present day age overlying the stretched African continental crust and extending outboard over oceanic crust (Figure 1).

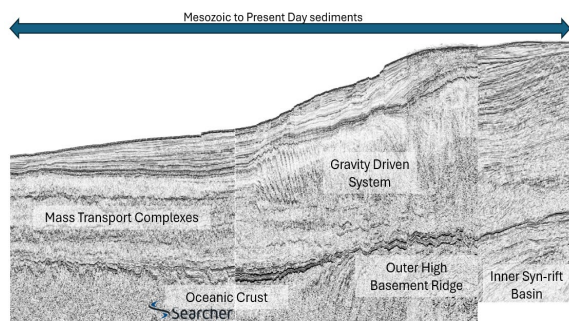


Figure 1: Northern South Africa Orange Basin legacy composite 2D seismic line, compensated for water depth, illustrating the main tectonostratigraphic elements of the Orange Basin

Hydrocarbon exploration in offshore Namibia goes back to the late 1960s, with exploration in the Orange basin starting in 1974 and resulting in the Kudu 9A-1 gas discovery in Barremian aeolian sandstones. Due to the results of the drilling campaign which followed this discovery, a gas-prone paradigm was established for this basin which discouraged further exploration, until 2012 when Galp reported the identification of two well-developed source rocks, rich in organic carbon and both within the oil-generating window in the Wingat-1 well (Galp Investor Announcement, 2013). It was also reported that the Wingat well encountered several thin-bedded-sandy reservoirs that were saturated by oil. Four samples of this oil were collected and the analysis of these samples indicated the presence of light oil, 38° to 42° API, with minimal contamination.

## Venus Discovery – Future Golden Lane 1 - Outboard of the Outer High, Basin Floor Setting Over Oceanic Crust

Before entering any frontier basin, de-risking the source rock is a crucial step. Prior to the drilling of the Venus well, a full source rock de-risking exercise was carried out on the Aptian source rock which included plate tectonic reconstruction and analysis of the tectonostratigraphic evolution to identify suitable environments for source rock deposition (Rodriguez et al., 2022). Conjugate Margin evidence was key, together with well information, such as the DSDP-361 and HRT wells all of which encountered a thick interval of Aptian source rock. Geochemical seabed sampling and coring results as well as sea surface naturally occurring oil seeps were also considered. However, the strongest indication came from seismic evidence and included identification of a regional high amplitude soft kick event associated with an AVO Type IV anomaly, calibrated with all the wells in the basin and considered to be a positive source rock character (Davison et al., 2018). This study strongly indicated the presence and maturity of a world class source rock. Other seismic evidence included DHIs (Direct Hydrocarbon Indicators), fluid escape and seabed features, as well as BSRs (Bottom Simulating Reflectors) found at the base of methane hydrate zones, where the thickness of the methane hydrate stability zone can be used to estimate shallow geothermal gradients and associated surface heat flow (Vohat et al., 2003 and Rodriguez et al., 2021).

The evidence for an Aptian source rock extending out over oceanic crust, as indicated by the study, defied existing

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models for hydrocarbon generation. However, the seismic data available in this deep water setting, when converted to depth to correct the geometry at depth, not only showed the Outer High as a structurally high feature, but also pointed to turbidites in huge counter regional dipping traps (Figure 2). It was the huge potential of this play that drove TotalEnergies to finally drill the Venus prospect at the end of 2021. Needless to say that the results exceeded all expectations, finding two fan sequences with a significant net pay indicating a multibillion barrels accumulation.

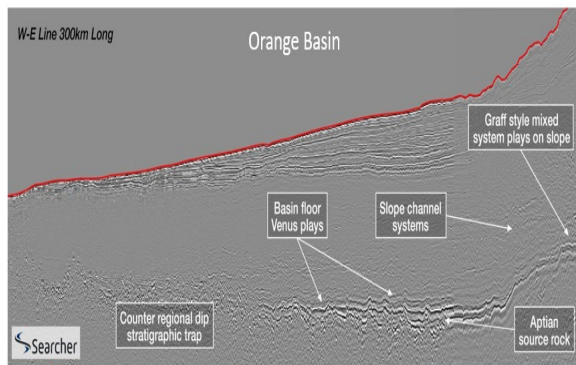


Figure 2: Northern South Africa Orange Basin West to East 300 km Legacy 2D seismic line illustrating the Venus and Graff play types

### Graff Discovery – Future Golden Lane 2 - Outboard of the Outer High, Slope Setting Over Transitional Crust

Based on publicly available exploration activity, it seemed Shell were initially mainly focused on the Cullinan “carbonate platform” prospect within their Orange Basin block. However, at some point their focus shifted towards the clastic plays and they started presenting a mixed turbidite contourite system prospectivity model at conferences (Bijkerk et al., 2021). Soon after, towards the end of 2021, they began drilling the Graff well. The discovery was the first to confirm that there was a world class source rock in the basin and that all other elements of the petroleum system were also present. Graff is located outboard of the Outer High, as are all the subsequent discoveries made by Shell (Jonker, La Rona). As can be seen on Figure 2, they are further inboard than Venus, in a slope setting. The traps seem to have a strong stratigraphic component, associated with the fold and thrust belt which could be providing part of the seal for some of the discoveries, while some others seem to be associated with mixed turbidite contourite systems. From available seismic data, these discoveries are seen to be sourced by hydrocarbons generated by the same Aptian source rock charging the Venus discovery.

### Mopane Discovery – Future Golden Lane 3 - Inboard of the Outer High, Shelf/Inner Basin Over Continental Crust

Before the Mopane discovery, a very high-quality off the boat fast track PostSTM 3D dataset acquired at the end of 2022 over the PEL-85 Block offshore Namibia, clearly indicated the extension of the Aptian age world class source rock to the east and inboard of the Outer High. The seismic event inferred to be the source rock was interpreted as a regional AVO Type IV high amplitude anomaly. Overlying this source rock, a series of large (up to 200 km<sup>2</sup>) NE-SW aligned AVO Type III anomalies, of similar age to the Graff, Jonker and La Rona discoveries, were mapped (Figure 3). The trapping mechanism was observed as combined structural and stratigraphic as the events onlap the Outer High or terminate against the gravity driven fold and thrust belt. However, due to the different depositional setting expected inboard of the Outer High and despite good seismic evidence for a thick, good quality source rock, this element remained a perceived risk.

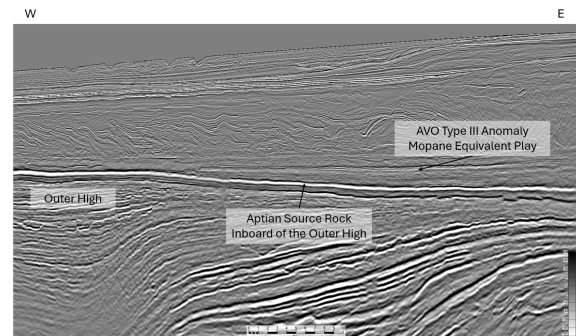


Figure 3: PEL85 Bridge 3D PSDM W-E line showing the extension of the Aptian Source Rock inboard of the Outer High and a clear extensive AVO Type III anomaly, a Mopane equivalent play type

In early 2023 the Mopane discovery was announced by Galp. This discovery lies inboard of the Outer High (Figure 4). A 3D survey acquired at the end of 2023 to the north of PEL-85, covering part of the Mopane “channel complex”, clearly shows the anomalies associated with the proven accumulations. The Aptian source rock and the associated play type, now proven to work inboard of the Outer High, can be confidently extrapolated into a very large area extending all the way into South Africa.

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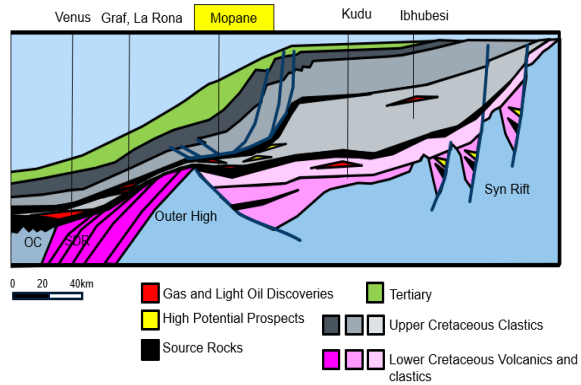


Figure 4: Geological schematic section showing the three “Golden Lanes” Venus, Graff and Mopane play fairways

### Conclusions

There are working source rocks south of the Walvis Ridge and they are world class! Recent discoveries in Namibia have proven not only the presence and maturity of an Aptian source both outboard and inboard of the Outer High, but also its ability to generate sufficient hydrocarbons to charge very significant accumulations and prospects. The Mopane discovery inboard of the Outer High has opened up the “Third Golden Lane” in the Orange Basin, indicating huge potential for future exploration.