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Insights into the Tectonic Evolution and Prospectivity of Madagascar Offshore Basins

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SUMMARY

TGS has completed a geophysical and geological study of the hydrocarbon prospectivity of the entire western offshore margin of Madagascar from the Cap St. Marie Basin in the south to the Ambilobe Basin in the north. An extensive dataset, comprising new and reprocessed vintage seismic data, has provided an opportunity to make observations on the different structural styles across a frontier margin and identified potential new plays. Seismic interpretation demonstrates that the Davie Fracture Zone along the Morondava Basin has experienced major inversion of Mesozoic sediments around the Turonian, as a result of the separation of India and Madagascar. New seismic data in the Majunga and Ambilobe basins reveals exciting exploration targets. For example, large fan complexes extend the lower slope potential of Majunga Basin, in addition to salt related anticlinal four-way dip closures and pinchouts. Seismic interpretation of the Ambilobe Basin, has been integrated with gravity and thermal modelling, and supports the presence of rifted Karoo and Jurassic sediments within tilted fault blocks. Thus providing potential source and trap geometries in an unexplored basin.

Introduction

TGS has completed a geophysical and geological study of the hydrocarbon prospectivity of the entire western offshore margin of Madagascar from the Cap St. Marie Basin in the south to the Ambilobe Basin in the north. The study was based on newly acquired seismic data in partnership with BGP (20,000 km) and supplemented with reprocessed vintages. This provided a continuous dataset of 49,000 km of multi-client 2D seismic (Figure 1). Potential field data and exploration well data, including logs and reports, are used in this integrated study. This extensive dataset has provided an opportunity to make observations on the different structural styles across a frontier margin and identified potential new plays.

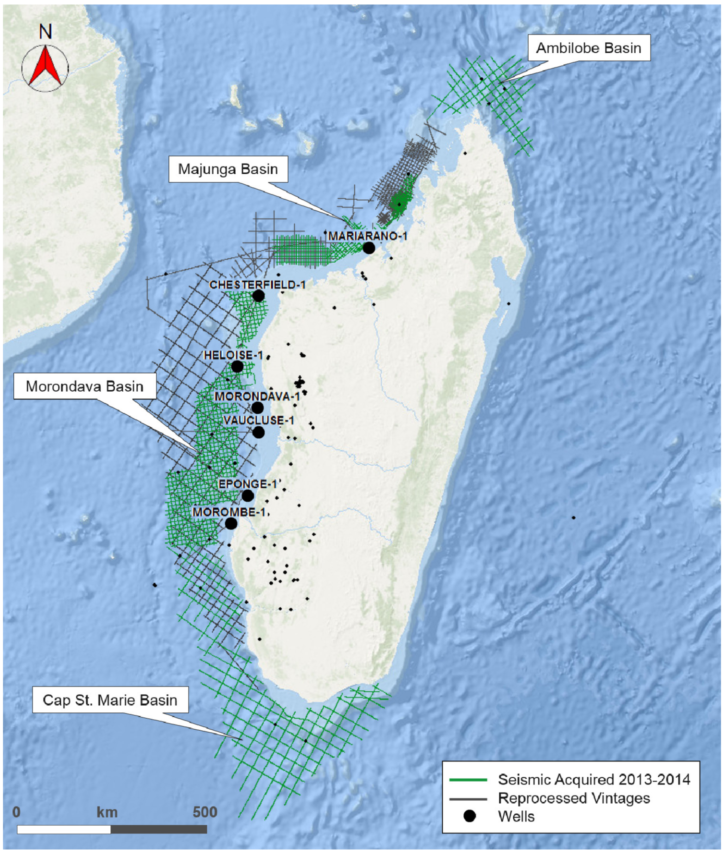

Figure 1 *Base map showing the various offshore basins and seismic data coverage in Madagascar. Newly acquired seismic data in green (Morondava West (MWM13), Morondava South (MOS13) and Majunga (MAJ13) seismic datasets acquired in partnership with BGP) and reprocessed vintages in grey (modified from Esri Inc., 2015).*

Tectonic Setting

Madagascar was originally part of the supercontinent of Gondwana. The Permo-Triassic Karoo phase of rifting along an existing zone of weakness between eastern Gondwana (Madagascar, India, Australia and Antarctica) and western Gondwana (Africa, Arabia and South America) failed in the Late Triassic. In the Early Jurassic the location of rifting shifted west to the present-day continental margin of West Madagascar. This rifting event eventually resulted in the break-up of Gondwana in the Middle Jurassic (Geiger et al. 2004). As a consequence of ocean floor spreading in the Somali and Mozambique Oceans, Madagascar together with India, Antarctica and Australia drifted southward along the Davie Fracture Zone (DFZ), a 1500 km long transform fault (Reeves, 2014; Reeves et al. 2015). Around 120 Ma spreading in the Somali Ocean ceased and the spreading center relocated to the south, separating Antarctica from Madagascar and India. Extension between Madagascar and

India commenced in the Aptian and resulted in a break-up in the Turonian (Reeves et al. 2015). This event was linked to the Marion hotspot and a major volcanic episode (Storey et al. 1995). The rifting and separation between Madagascar and India led to uplift of the eastern margin of Madagascar, which renewed compressional tectonic activity in the basins on the western side of Madagascar and reactivated the DFZ, a major zone of weakness.

The break-up of Gondwana eventually resulted in the creation of several major basins along the western margin of Madagascar. The Cap St. Marie Basin is located in the very south, the offshore Morondava Basin is located along the western margin of Madagascar, the Majunga Basin is located along the north western margin and the Ambilobe Basin to the north of Madagascar (Figure 1).

Late Cretaceous inversion along the Davie Fracture Zone

We have observed major inversion of Mesozoic sediments along the DFZ within the Morondava basin (Figure 2). Sequence stratigraphic mapping correlates lavas to dated igneous rocks in exploration wells drilled in the 1970s and 1980s on the shallow water shelf (e.g. at Heloise-1 and Vaucluse-1). Final well reports, palaeontological data and time-depth data from these wells were used to constrain the stratigraphic framework in which our seismic interpretation was conducted. The lavas and associated intrusives are part of a large igneous province related to separation of India from Madagascar in the Late Cretaceous and has been identified by several authors with ages ranging between 92 – 84 Ma (e.g. Storey et al. 1995; Torsvik et al. 1998). These Late Cretaceous igneous rocks extend throughout the entire Morondava Basin and wedge out against the inverted Mesozoic sediments along the DFZ, thereby dating the inversion event. Therefore it may be concluded that the DFZ was still active during the Turonian-Santonian. This has implications for petroleum prospectivity in the Morondava basin as it affects the age of trap formation and permits migration of hydrocarbons from older source rocks.

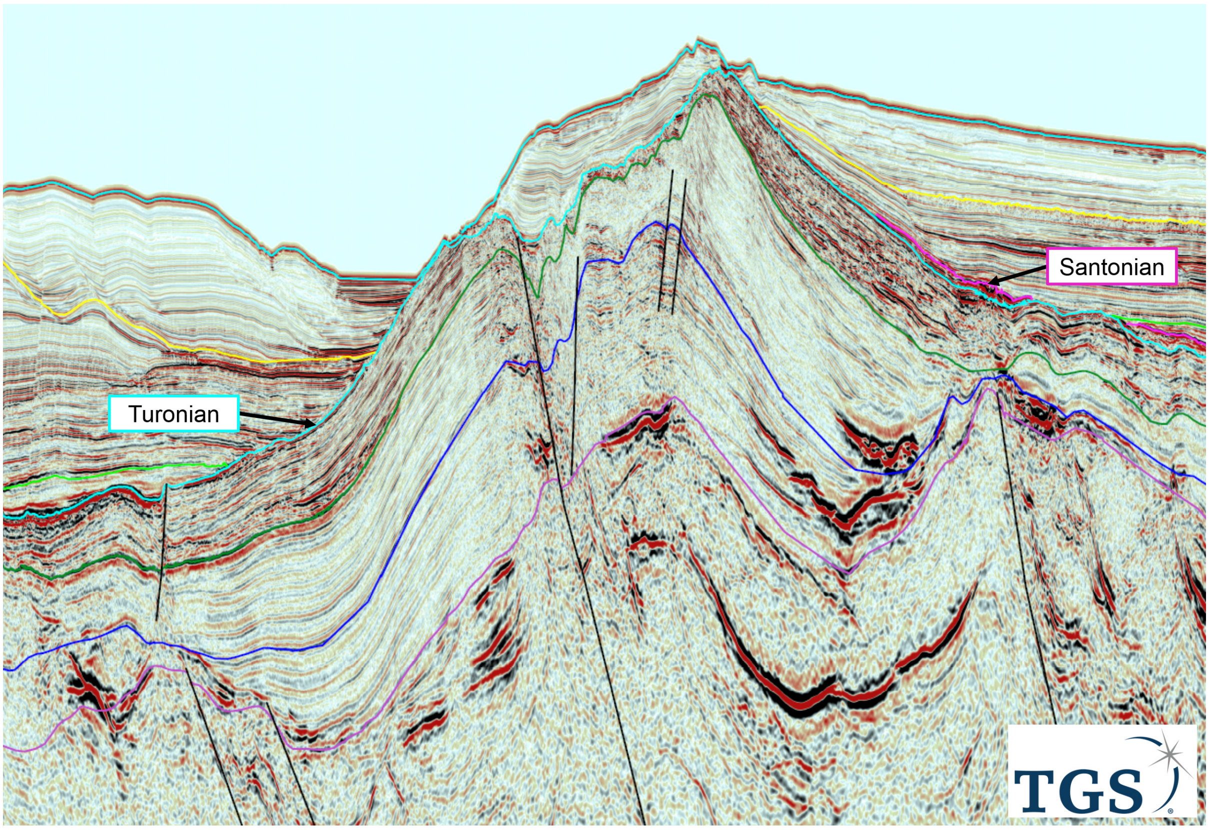

Figure 2 *Seismic line showing the inverted Mesozoic sediments in the Davie Fracture Zone (DFZ).*

Extended Deep Water Potential in Majunga

Break-up related uplift and tilting of eastern Madagascar resulted in increased erosion and focused deposition of sediments into the Majunga Basin. New seismic lines extending into the basin reveal large fan complexes with pinch outs against the slope. Potential source rocks are present in both the syn-rift sections and, although currently unproven, thick Cretaceous sedimentary sequence.

Furthermore, the seismic data reveals many different structural styles and related traps in the Majunga Basin resulting from two phases of extension; local compression, halokinesis and passive margin drifting. Structures due to salt movement are evident and create anticlinal four-way dip closures and salt flank pinchouts that provide interesting exploration targets (Figure 3).

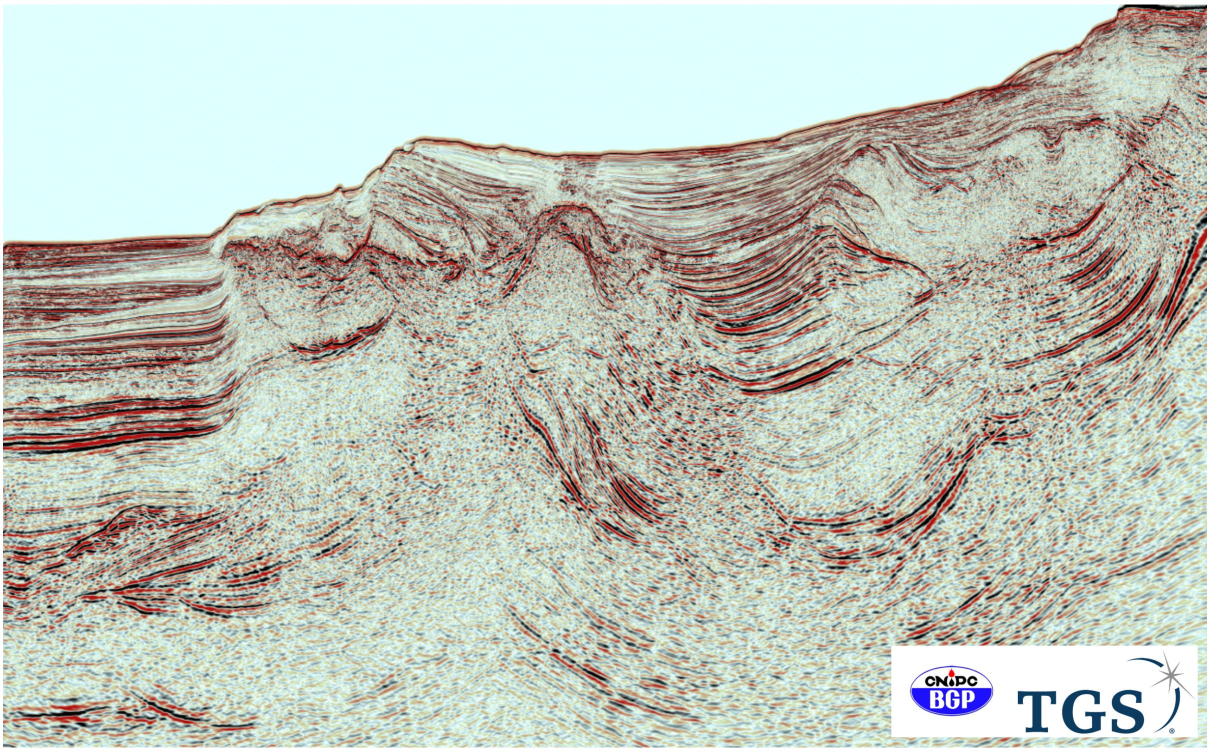

Figure 3 *Seismic line showing anticlines and salt flank pinchouts as a result of salt movement in the Majunga Basin.*

New Exploration Targets in Ambilobe Basin

Newly acquired seismic data extends the Ambilobe Basin interpretation to the NE of Madagascar and identifies exploration targets and plays. Seismic interpretation integrated with gravity and thermal modelling supports the presence of rifted Karoo and Jurassic sediments within tilted fault blocks. Thus providing potential source and trap geometries within the same sedimentary interval (Figure 4).

Acknowledgements

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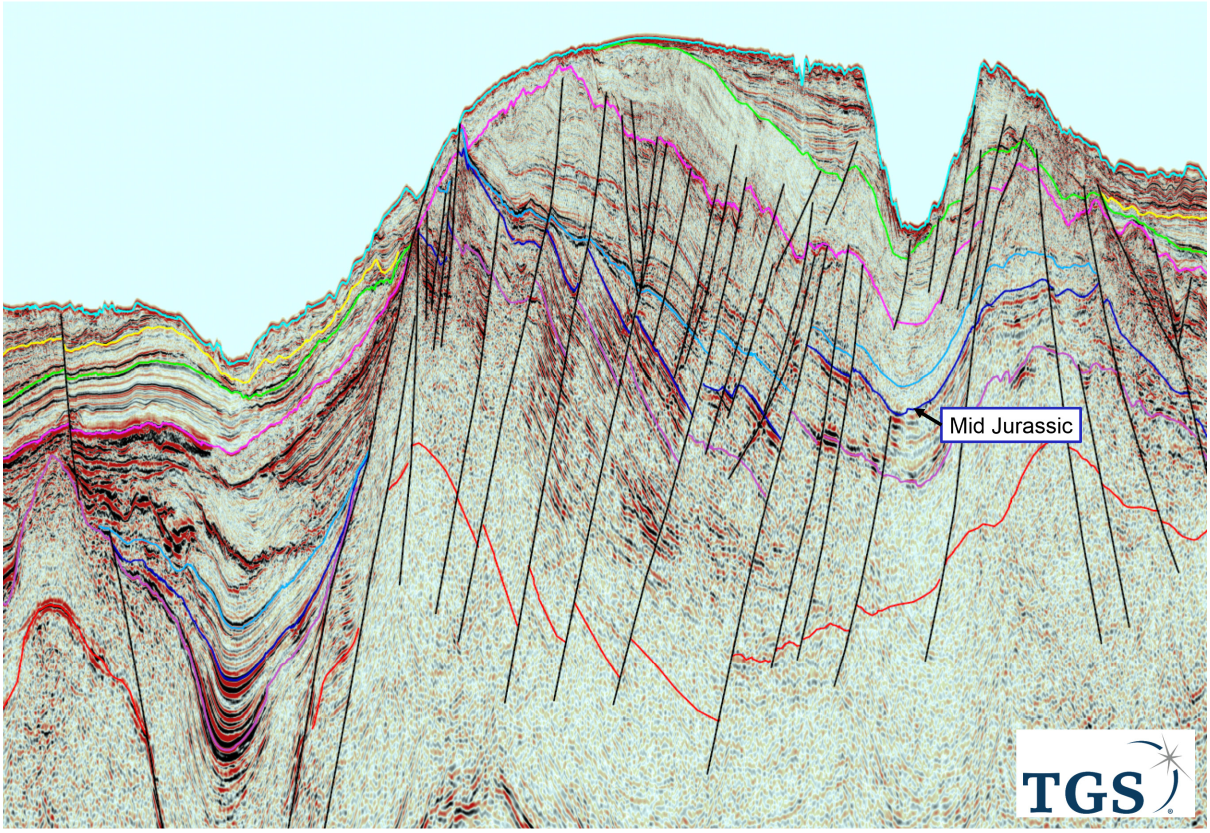

Figure 4 *Seismic line showing the tilted fault blocks consisting of Karoo and Jurassic syn-rift sediments in the Ambilobe Basin.*

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