
The Gulf of Papua:

Challenging industry perspectives of
prospectivity with evolving geophysical
technology

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Searcher

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Introduction

The offshore Gulf of Papua is a significantly under-explored region of the world, with only 32 offshore wells drilled in an area covering over 180,000 km². These wells are constrained to the shallow (<500 m) waters of the Fly River Platform and Aure Trough, with the deep-water regions historically unexplored and frontier. Legacy interpretation, likely driven by lack of data over the region, interpreted the deep-water Gulf of Papua as a dramatically thinned section of sediments

underlain by oceanic crust associated with the opening of the Coral Sea in the Early Tertiary. A comprehensive exploration campaign spanning twenty years has turned legacy interpretations on their head, including 2D seismic in an 8x8 km down to 1x1 km grid across the Gulf which unveiled preserved depocenters beneath the Coral Sea Breakup Unconformity (CSBU), an Airborne Gravity Gradiometry & Magnetics Survey along the Transition Zone which highlighted the structural tie to the onshore and a regional Geochemical Survey, which challenged the perceived crustal models at the time (Figure 1).

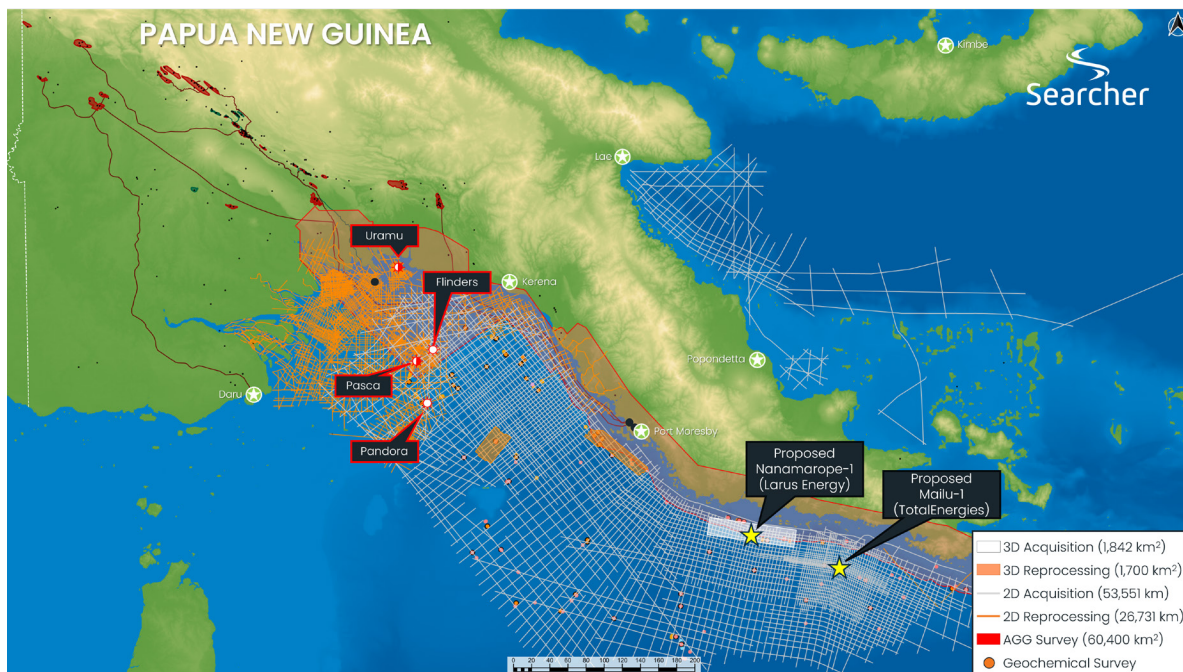


Figure 1: Geotechnical Database Utilised across the offshore Gulf of Papua

Unveiling Unseen Depocenters

In decades past, offshore interpretation has been focused on the Fly River Platform, the shallow water region at the mouth of the Fly River. In the shallow-water region, a thick succession of Mesozoic to Cenozoic sediments over basement is well-established, as discussed in numerous publications such as Jablonski et al., (2006) and Bulois et al., (2017), but outboard has historically been interpreted to thin rapidly with only a thin sequence of post-breakup Tertiary sediments remaining. This is largely data-driven, with very little subsurface information available over the deep water Gulf of Papua, limited to a handful of noisy and bland seismic lines.

This legacy interpretation was challenged in 2006 with the acquisition of the Lahara MC2D Seismic Survey (alongside project partner Fugro, now TGS), which extended beyond the shelf break into the deep-water, and revealed previously unseen preserved depocenters of sediment beneath the major breakup unconformity associated

with the opening of the Coral Sea in the Early Tertiary (Figure 2). The original acquisition had imaging challenges associated with the complex overburden, composed of a carbonate platform, mass transport complexes and a high-energy Plio-Pleistocene prograding delta, all of which pushed the limits of PSTM imaging at the time. Subsequent reprocessing of the dataset in 2014 with a PSDM algorithm allowed for increased confidence in imaging the deeper section, and pushed the base of the sedimentary section beyond the record length of 8,100 ms.

These revelations helped shaped the design of the following Haere and Hahonua MC2D seismic acquisition campaigns, carried out in 2015 and 2016, respectively with project partner BGP.. Streamers of 10,050 m were utilised to increase the record length, increased from 7,200 m from the Lahara MC2D acquisition. The result from the three surveys was a Gulf-wide grid of broadband seismic (white lines; Figure 1), which revealed a complex network of preserved Mesozoic grabens and half-grabens extending across the Papuan Plateau, reaching up to 90 km in width.

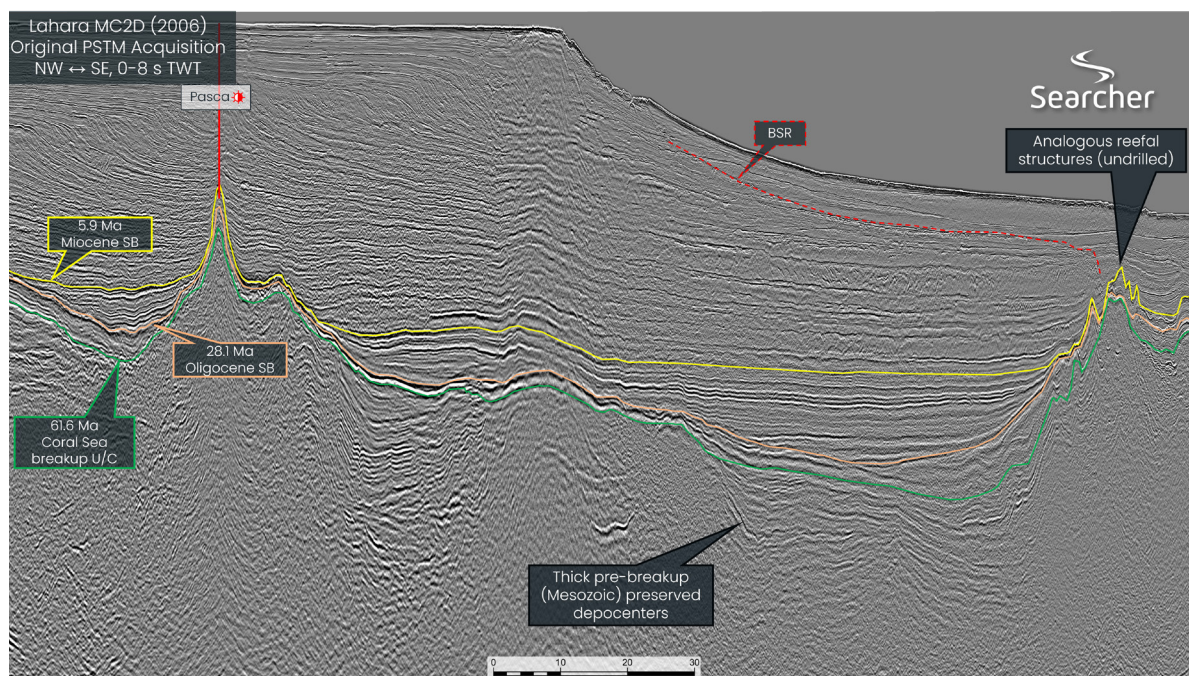


Figure 2: An example from the Lahara MC2D Original PSTM Seismic Survey (2006), highlighting the presence of preserved depocenters beneath the Coral Sea breakup unconformity beyond the Fly River Platform and in the deep-water regions of the Gulf of Papua

Crustal Nature and Structure

To extend onshore interpretations and proven petroleum system trends into the offshore, the Roho Airborne Gravity Gradiometry (AGG) and Magnetics survey was acquired along the Transition Zone in 2016, where seismic data is logistically challenging and prohibitively expensive. Flown in a 1 x 10 km grid in the Fly River region and a 2 x 10 km grid along the coastline, to cover an area over 60,400 km² (Figure 1), the survey ties to the onshore surveys as well as shipborne gravity surveys acquired alongside the Haere MC2D seismic survey.

The continuous tie supports the interpretation of large-scale extensional fault blocks in a broadly northwest-southeast orientation, a trend observable with onshore mapping as well as on the offshore seismic datasets. When compared to overlapping seismic data, the gravity data is influenced by both basement morphology and the presence of carbonate reefal structures. Both

were taken into account when modelling, with the carbonate features often in the northeast-southwest orientation, along trend to the known Pasca and Pandora discoveries offshore.

The Roho survey also maps the observed 'hinge point' where the paleo-extension and modern-day compressional tectonic settings meet, as the Aure Fold and Thrust Belt continues from the onshore Eastern Highlands along the coastline into the offshore, an active thrust zone in response to the spreading of the Woodlark tectonic plate in the northern waters of Papua New Guinea.

With the revised sedimentary succession and structural interpretation tying the onshore and offshore Papuan Basin in more detail, the nature of the underlying crust was challenged. The Haere and Hahonua MC2D surveys were acquired with long-offset broadband cables and their entire record length was processed, imaging down to 35 km was achieved. This allowed for a likely Moho event to be interpreted (red horizon; Figure 3), which indicates a geophysical crust-upper mantle boundary (Lovering, 1958).

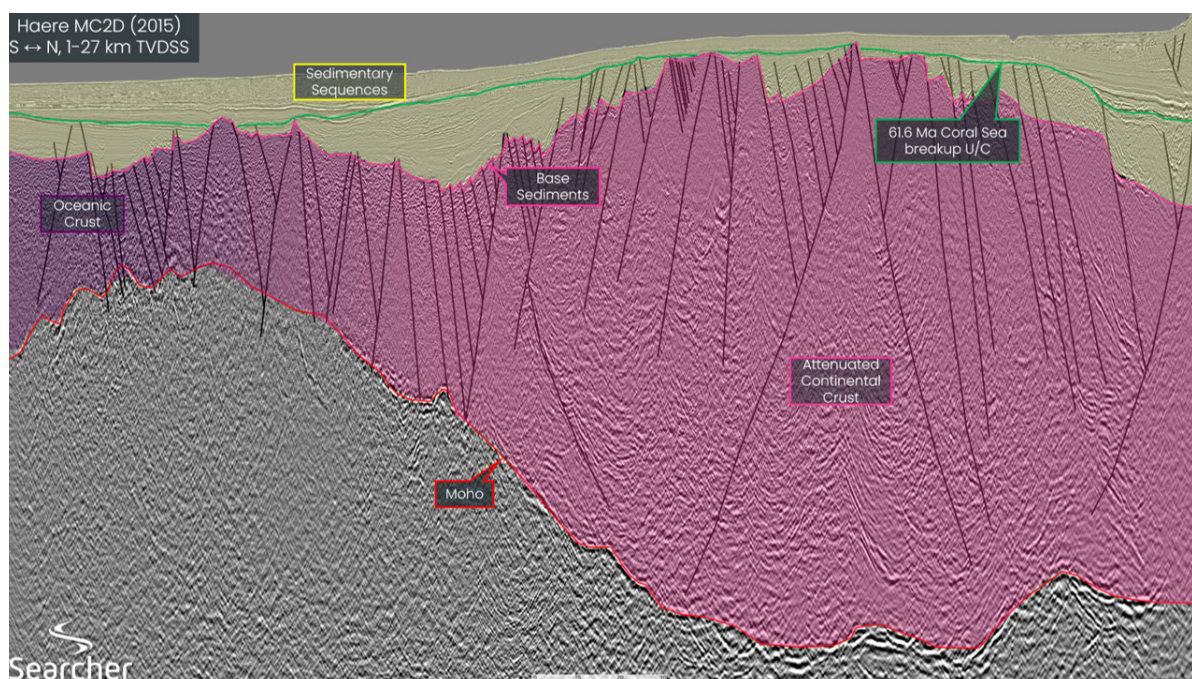


Figure 3: An example from the Haere MC2D Seismic Survey (2015), where the long-offset cables and full-length PSDM processing resulting in imaging down to 35 km TVDSS, allowing for the interpretation of a likely Moho event to investigate the crustal nature underlying the sedimentary sequences in the Gulf of Papua.

When mapped across the region, crustal thicknesses of 10–15 km, commonly associated with oceanic crust, were constrained to the very southern reaches of the dataset, which correlates to the Coral Sea Basin and the spreading zone. The vast majority of the Gulf had mappable crustal thicknesses of 22–30 km, with over 35 km observed beneath the Fly River Platform. This led to the interpretation of the crustal nature of the Gulf being attenuated continental, rather than the oceanic nature traditionally presented in literature.

The reinterpretation of the crustal model has significant, far-reaching implications for hydrocarbon prospectivity, including (but not limited to) heat flow, sediment burial, maturity and preservation. To derisk these elements, high-resolution seismic acquisition and reprocessing were completed, as well as a basin-wide geochemical survey.

Derisking Petroleum Systems

In a frontier basin with little supporting data, the Bottom Simulating Reflector (BSR) can be utilised to approximate the geothermal gradient (Vohat et al., 2003; Rodriguez, 2022). As a BSR can be observed on multiple seismic datasets across the Gulf of Papua (Figure 4; right), it was mapped and the approximate geothermal gradient was calculated across the region (Figure 4; left). An average of 42°C/km was calculated, varying laterally with cooler geotherms observed in proximity to the heat sink carbonate reefs, and warmer values observed closer to the fold and thrust belt, as hot buried rocks are uplifted (Found et al., 2024). These results place the oil generative window approximately 2.4 km below mudline, which puts the Early Tertiary carbonates and Mesozoic clastics within generative windows for both oil and gas.

To support the proxy calculations and updated models, the Davaria Geochemical Survey was acquired in 2017, consisting of satellite slick and seep analysis, drop cores, heat flow measurements, seabed dredges and multi-beam bathymetry. The heat flow measurements

supported the attenuated crustal setting, with an average value of 64 mW/m², and geochemical sampling and biomarker analysis of the drop cores indicate the presence of thermogenic hydrocarbons with similar organic compound signatures to the Mesozoic mixed-source oils within the onshore Papuan Fold Belt.

The results of mapping and the Davaria Geochemical Survey were integrated into basin-wide 1D modelling, which indicated that a Mesozoic source rock complex has the potential to reach maturity in the Early Cretaceous, followed by a hiatus associated with the Coral Sea breakup uplift and erosion, before burial to maximum depth and resumed expulsion through to present day.

Multiple structural and stratigraphic play styles were identified on the regional seismic data across each of the recognised tectonostratigraphic provinces (Figure 5), with the reprocessing of vintage 3D and acquisition of modern 3D seismic data in 2023 allowing for the scaling of regional evaluation to prospect-level, where intense processing workflows has allowed for the clearest imaging to date, allowing for reliable attribute and Amplitude vs Offset (AVO) analysis to derisk prospects and leads in detail.



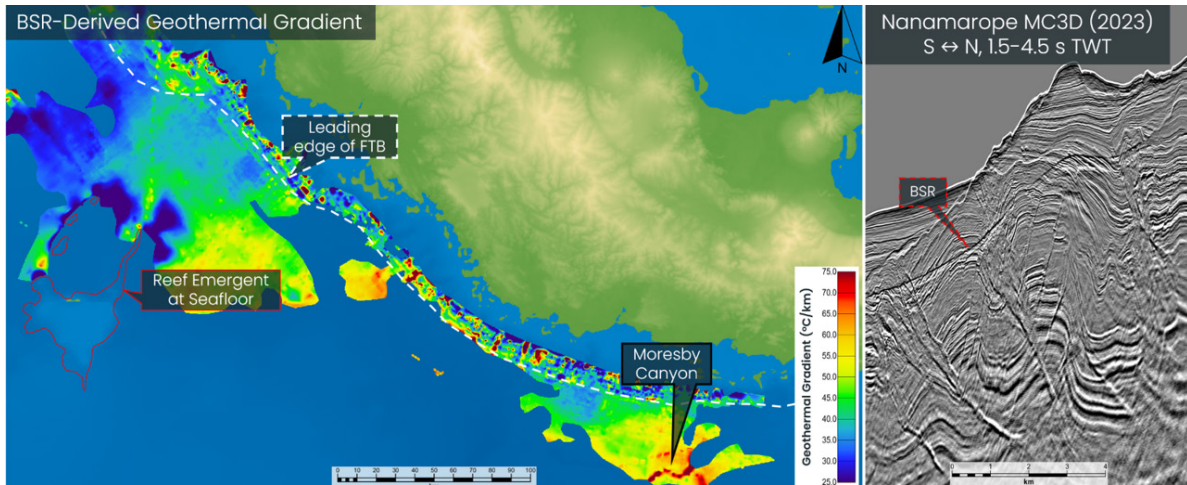


Figure 4: (left) The approximate geothermal gradient derived from Bottom Simulating Reflector mapping across the Gulf of Papua (Found et al., 2024). (right) An example of the Bottom Simulating Reflector within the Aure fold & Thrust Belt on the Nanamarope MC3D Seismic Survey (2023)

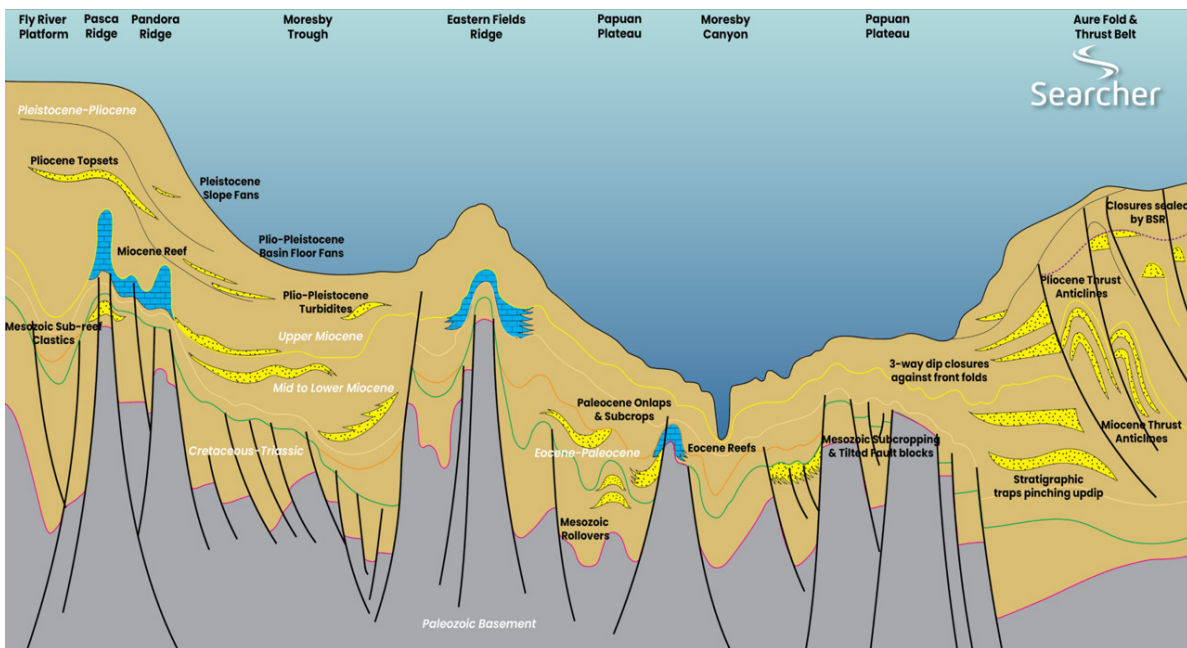


Figure 5: Play Diagram for the offshore Gulf of Papua

Conclusions

The offshore Gulf of Papua is a frontier region largely unexplored to date due to previously held concerns over the crustal nature and perceived lack of hydrocarbon prospectivity. In the twelve years since the last exploration well was drilled, which was ultimately successful proving a new Basin Floor Fan play, geophysical imaging has extended from the Fly River Platform to cover the entire Gulf of Papua.

Long-offset broadband 2D seismic allowed for imaging beneath the complex overburden and regional breakup unconformity, revealing preserved Mesozoic section and imaging to the Moho and beyond, supporting an underlying continental crust. This was supported by a Transition Zone AGG survey along the southern coast, and a Gulf-wide Geochemical survey, which lean further weight into the reinterpretation of the offshore Papuan Basin into a warm basin that is highly prospective for hydrocarbon generation, maturation and preservation.

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