



The Renaissance Tour:

A revival of frontier basins with
data-driven exploration

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Presented at the Petroleum Exploration Society of Australia (WA Branch) Lunch Series, June 2025

Introduction and using seismic data to de-risk petroleum systems elements

As the energy exploration landscape evolves, so too does the thinking around the basins being investigated. Advancing seismic acquisition and processing technologies in the last decade have allowed for explorers to take a fresh look on frontier and previously discarded basins, with the shifts in thinking and interpretation yielding billions of barrels of results.

In this world tour, four deep-water basins are investigated, including the Papuan Basin of Papua New Guinea (PNG), the Scotian Basin of Canada, the Namibian-South African Orange Basin and its Brazilian conjugate margin in the

Pelotas Basin. Seismic in the last ten years over each of these areas have allowed for updated thinking in crustal architecture, reservoir fairway modelling, and the identification of source rocks using angle stacks, made possible from long-offset acquisition and high-end processing workflows.

On a regional scale, the mapping of seismic datasets can be used to assist in understanding tectonostratigraphic evolution, sediment trends and depositional environment histories. On a more local scale, individual structures are mapped alongside direct hydrocarbon indicators (DHIs) and fluid escape features to identify and de-risk petroleum systems elements, all to build up prospects and leads portfolios. Using high-quality, modern seismic datasets boosts confidence in exploration on all scales.



Papua New Guinea: An updated crustal model

The offshore Gulf of Papua covers 180,000 km² yet until 2006, only had a handful of legacy seismic lines that extended beyond the shelf break into waters deeper than 500 m. These lines were very sparse, plagued with bland signal and noise, resulting in an interpretation of a limited basin extent and widespread thin oceanic crust associated with the opening of the Coral Sea in the latest Cretaceous to Early Tertiary. Long-offset broadband 2D acquisition campaigns in 2015 and 2016 covered the outboard frontier area in a regional grid of seismic that revealed a wealth of preserved depocenters beneath the Coral Sea breakup unconformity (green horizon, Figure 1), increasing the extents of the sedimentary basin, pushing observed sediment thicknesses kilometres deeper and opening up new play fairways analogous to proven plays

onshore and along northern Australia (Found et al., 2024; Found et al., 2025).

The full record length of the two broadband surveys acquired by Searcher in partnership with BGP were processed with a PSDM algorithm, achieving imaging down to 35 km and allowing for the interpretation of a likely Moho event (red horizon, Figure 1). When picked across the survey extents, crustal thicknesses of 10–15 km can be mapped in the far south close to the Coral Sea spreading centre, but averages 25 km across most of the deepwater Papuan Plateau and 35 km within the fully continental crust of the Fly River Platform. This challenged the geological model at the time and placed most of the basin in a continental crust setting, a model supported by supplementary geochemical sampling and heat flow modelling, with the updated crustal model and data having implications on geothermal gradients and maturity models (Davies, 2019; Found et al., 2025).

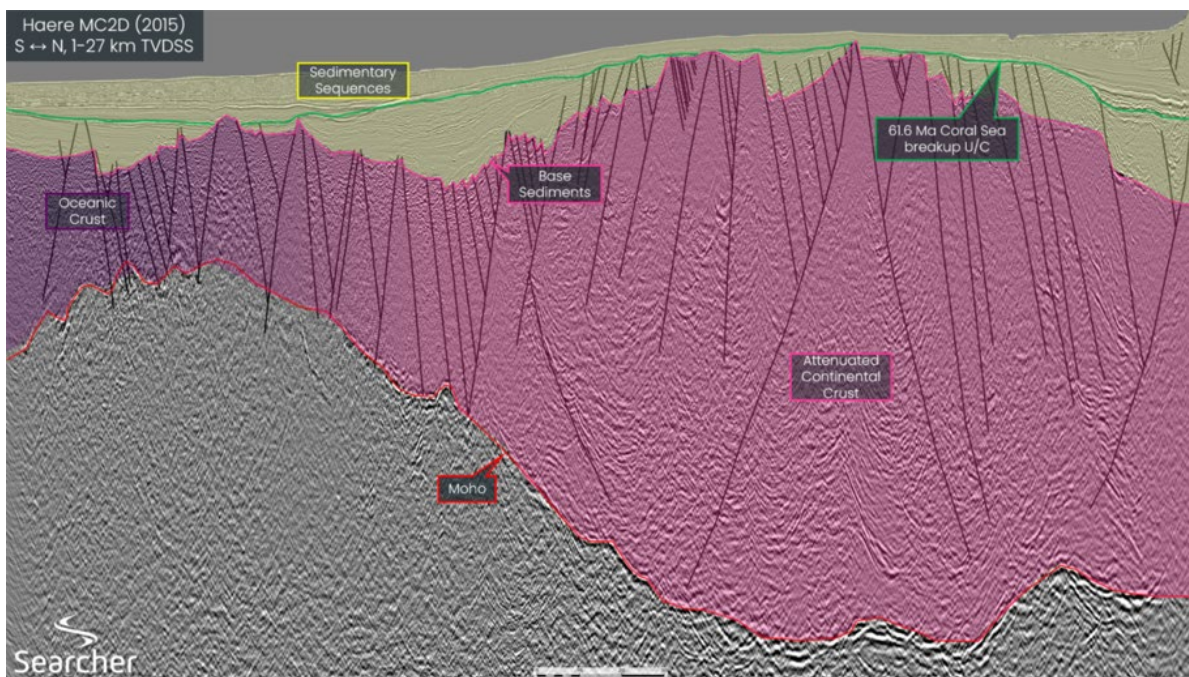


Figure 1: A regional southwest-northeast line from Searcher's Haere MC2D Seismic Survey, where long-offset cables and PSDM processing of the full record length resulted in imaging down to 35 km TVDSS. This allowed for interpretation of a likely Moho event, which could be mapped across the entire survey.

A Bottom Simulating Reflector (BSR), which is a Direct Hydrocarbon Indicator (DHI) in seismic data that is indicative of the base of a gas hydrate, can be mapped across several tectonostratigraphic provinces within the Papuan Basin, appearing as a cross-cutting reflector parallel to the seafloor but of opposite polarity (Figure 2). In frontier basins with little to no well control, it can also be used to approximate the geothermal gradient, as the thickness of the gas hydrate stability zone, and hence the BSR, is temperature-dependent (Vohat et al., 2003; Rodriguez et al., 2022). When BSR thickness is mapped and utilised to calculate the geothermal gradient, spatial variations tied to tectonostratigraphic province can be observed (Figure 2). Towards the Fly River Platform, which contains a large

carbonate bank and thick overburden of Plio-Pleistocene prograding deltas, the calculated geothermal gradient averages 35°C/km, which is comparable to temperature profiles calculated in wells in the region (Davies, 2019). The gradient cools considerably in proximity to the carbonate pinnacle reefs that are emergent at seafloor, and warms to an average of 42°C/km in the Aure Fold & Thrust Belt region, possibly due to the uplift of buried and warmer rocks. This places the top of the oil window for generative source rocks at approximately 2.4 km below mud line in the warmer regions, allowing for Paleogene deepwater carbonates and Mesozoic clastics to be within present-day generative windows, extending proven onshore plays into the frontier offshore.

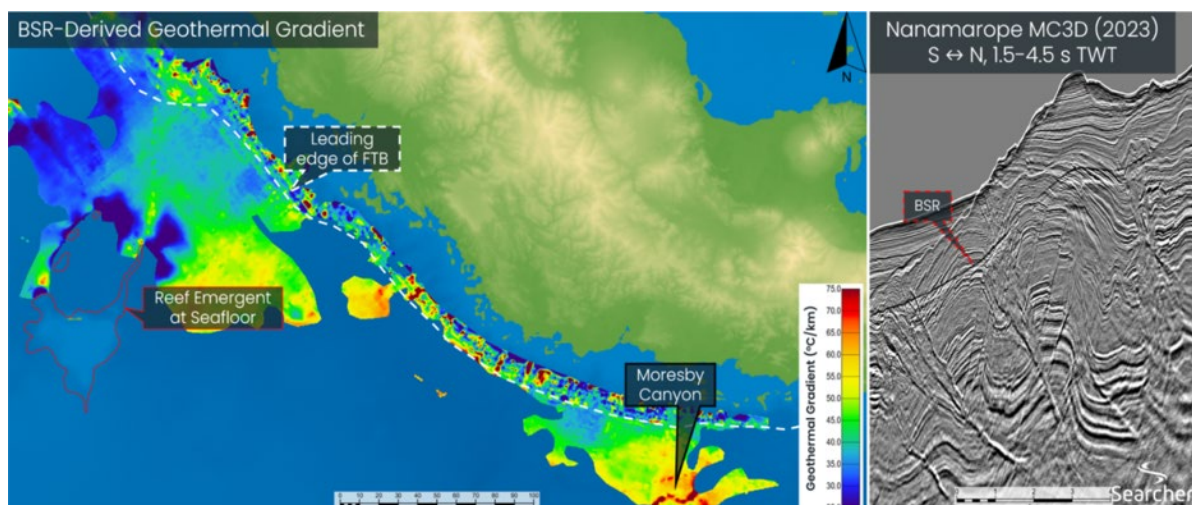


Figure 2: (left) The approximate geothermal gradient derived from Bottom Simulating Reflector (BSR) mapping across the Gulf of Papua, highlighting the warm setting that allows for organic-rich marls and clastics to sit within oil and gas generative windows across large regions of the Gulf (Found et al., 2024). (right) An example of the BSR within the Aure Fold & Thrust Belt on the Nanamarope MC3D Seismic Survey (Note: SEG -ve polarity).

Nova Scotia: A tale of two halves

The Scotian Basin, located off the coast of Nova Scotia, Canada, has a proven shelf, with exploration and development around Sable Island producing hydrocarbons since the 1960s. However, beneath the deepwater slope and basin floor lies a salt basin with emerging play fairways that have only been lightly explored, with four wells drilled in the last ten years. Of those four, none encountered thick reservoir-

quality sands, and only one (Aspy-D11) recorded hydrocarbon shows, leading to uncertainties around source rock presence, maturity and sediment fairways around and beneath the salt. Modern multi-azimuth seismic data has been acquired in a bid to de-risk these uncertainties, including the Tangier WAZ 3D, acquired in 2013 by bp and reprocessed in 2017 by CGG. The survey crosses multiple domains loosely defined on salt morphology, including the eastern salt canopies and central-western salt diapirs (Figure 3).

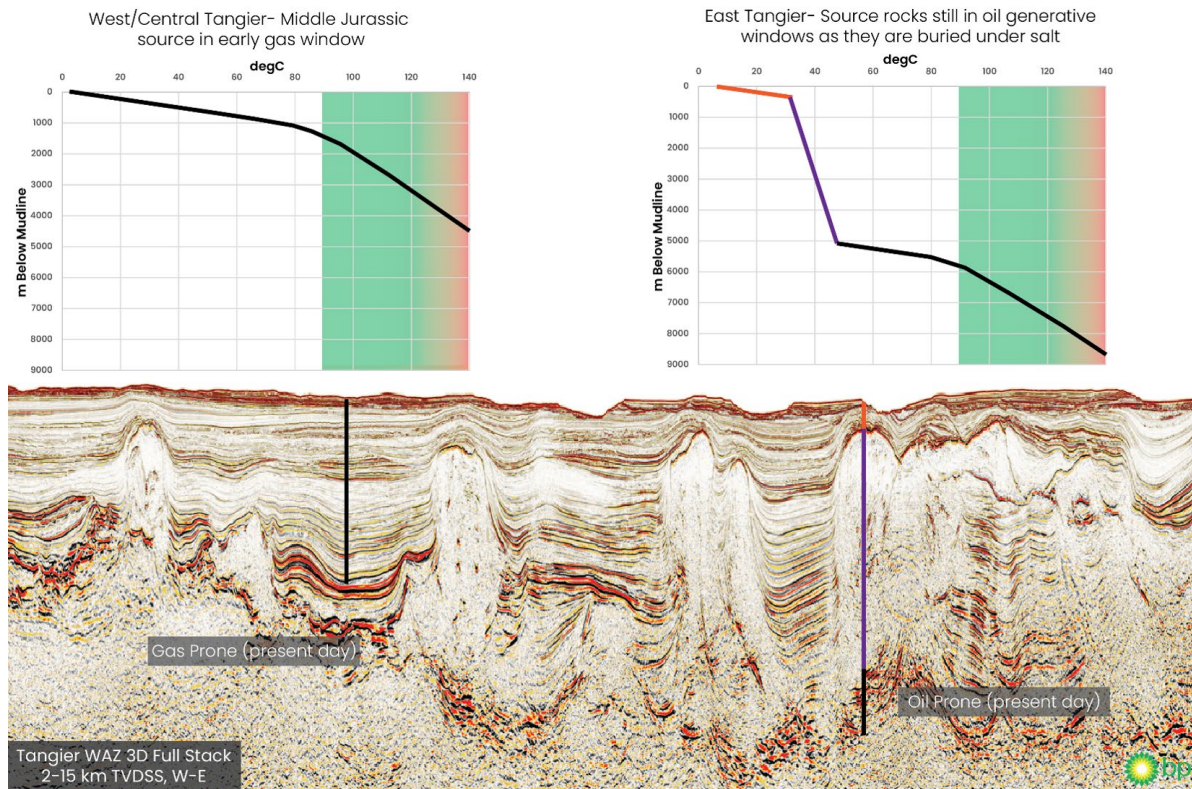


Figure 3: Geothermal gradients derived from BSR mapping on the Shelburne and Torbrook 3D surveys, offshore Nova Scotia, Canada, plotted on the Tangier 3D survey. The thick salt canopy in the eastern extent of the survey allows for source rocks to be oil generative at much deeper depths relative to the western/central diapir domain. The varying gradients due to the salt presence allows for multiple source rocks to be in generative windows, allowing for significant stack potential. (Note: SEG +ve polarity). Seismic courtesy BP/Hess.

Whilst a BSR is not widespread within the Tangier survey, one can be mapped on the adjacent Torbrook and Shelburne 3Ds, and similarly to mapping offshore Papua New Guinea, thickness variations can be observed in different settings, even those that lie immediately adjacent to one another. In proximity to salt diapirs and canopies, the BSR thickness decreases rapidly, indicating an increased geothermal gradient thickening once more moving away from the salt features. Utilising a rule-of-thumb equation (Formula 1, after Vohat et al., (2003) & Rodriguez et al., (2022)), geothermal gradients around 35°C/km are calculated away from the salt, increasing to 58°C/km in closest proximity to the diapirs.

$$\text{Geothermal Gradient} \approx \frac{8.538 \ln(\text{Depth to BSR}) + 7.523}{(\text{Hydrate Thickness})}$$

Formula 1: Rule-of-thumb approximation for calculating geothermal gradient in °C/km from Bottom Simulating Reflector thickness, where Depth to BSR and Hydrate Thickness are both in kilometres.

Utilising these calculated values, the 110°C isotherm, well within the oil-generative window, lies between 1.8 to 4 km below mud line, within the western/central salt diapir domain of the Tangier 3D survey, allowing for multiple units to be in varying stages of maturity across the

basin depending on their proximity to the salt, which also allows for the potential of stacked plays from different sources, including the Mid to Late Jurassic units that act as the source for the Sable Island fields. Evidence of mature Jurassic source rocks is also supported by the 2018 Scotian Slope Coring Program, which analysed seabed cores acquired near seabed seeps and pockmarks, and determined "...a pre-Cretaceous age" geochemical signature that "...suggests the source rock is at least in the middle of the oil window" (Keppie et al., 2023). Further to the east of the survey, the presence and thickness of the salt diapirs and canopies results in oil-generative windows as much as 8 km below mud line (Figure 3).

Additionally to de-risking source rock presence and maturity, the new 3D surveys are invaluable tools for identifying reservoir fairways, with the multi-azimuth configurations allowing for imaging in close proximity to and beneath the salt, where legacy imaging has always proven challenging. Discussed further in Rodriguez et al., (2025), a network of Early Cretaceous sand fairways were identified and mapped, with the Aspy-D11 well drilled in 2018 clipping the very edge of one of these in the interval with observed hydrocarbon shows, and these sand fairways remain yet to be tested.

The Orange–Plotas Conjugate Margin: A big beast with a big point

The Orange Basin is one of the industry's diamonds at the moment, with the prospectivity story revolutionised in the last five years with the discovery of Venus, Mopane and Graff (among others) opening three new mixed turbidite-contourite play fairways offshore Namibia and South Africa. These billion-barrel discoveries have led to a flurry of exploration activities, with massive amounts of 3D seismic acquired, including Searcher's 9,100 km² of data in South Africa, and 12,400 km² in Namibia in a joint venture with project partner Shearwater, all acquired and processed between 2022 and 2025. The new 3D data is allowing for more reliable analysis to de-risk source and reservoir, with increased offsets during acquisition from longer cables and robust

processing algorithms allowing for angle stacks as far as 45 degrees and beyond to be utilised reliably.

As discussed in Davison et al., (2018), source rocks can be readily identified on seismic data by a widespread high-amplitude 'soft' reflector and an associated large Type IV Amplitude Vs Offset (AVO) effect, driven by the low compressional velocity and low density associated with high kerogen content. This stands out in contrast to a reservoir, which is associated with Type II/III AVO effects. Within the Orange Basin, both source and reservoir can readily be identified (Figure 4), with the UltraFar angle stack, which in the example in Figure 4 comes from the Bridge MC3D survey over the Capricornus discovery (Rhino Resources, 2025) and covers the 33-44 degree range, brightening over both the Aptian source rocks and reservoir intervals, but causing opposite AVO anomalies, allowing for easy distinguishing between source and reservoir.

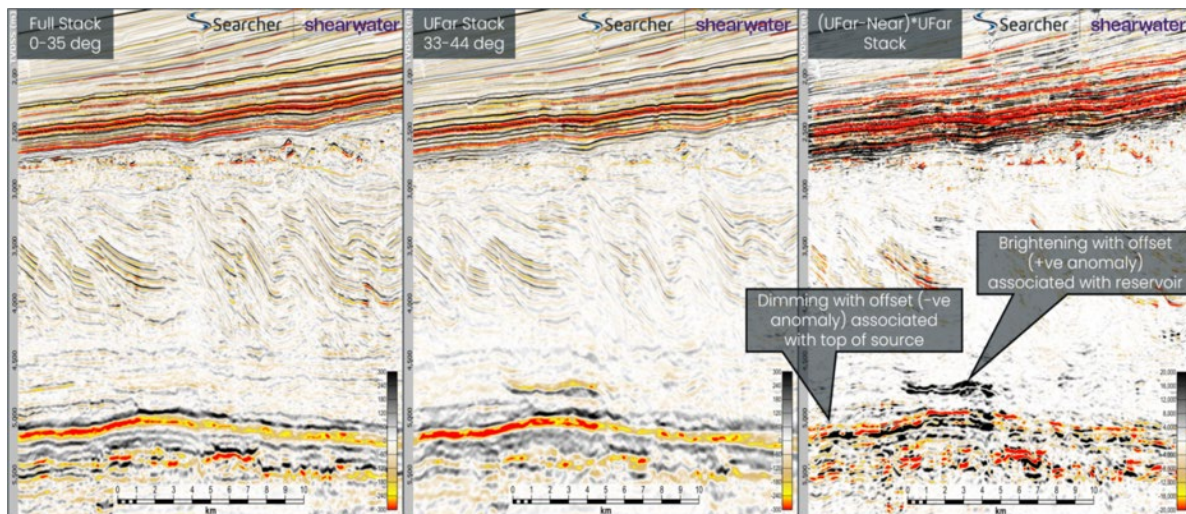


Figure 4: Examples of how Angle Stacks can be used to identify hydrocarbon accumulations in the Orange Basin, with the Bridge MC3D survey showing the 2025 discovery drilled by Capricornus-IX by Rhino Resources. (Left) The Full Angle Stack, covering the angle range of 0-35 degrees (Centre) The Ultrafar Angle Stack, covering the angle range of 33-44 degrees (Right) The (UFar-Near)*UFar AVO Stack, which highlights the Type III anomaly associated with the Capricornus discovery, and the Type IV anomaly associated with the top of the Aptian Kudu Shale equivalent source rock (Note: SEG +ve polarity).

The reliable angle stacks, and AVO stack that can be generated utilising these products (Figure 4; right), the area can quickly be screened for further prospectivity and to de-risk identified leads across each of the newly- defined Inner Basin, Slope and Outer Basin turbidite-contourite plays.

Following the successes of the Orange Basin, the Searcher-Shearwater joint venture investigated its conjugate margin, the Pelotas Basin of southernmost Brazil and northern Uruguay. This has culminated in the acquisition of a 3D survey, with 9,700 km² acquired as of the time of writing. As observed in Figure 5, when compared on identical vertical and horizontal scales to the Orange Basin datasets, the conjugate nature can be readily identified, with similar crustal nature

and relatively simple geological nature revealed. However, there are notable differences between the two basins, with the Pelotas Basin lacking the gravity-driven fold and thrust belt and thick mass transport sequences of the Orange Basin, consequently resulting in a much thicker section of stacked contourite-turbidite channels and fans.

Whilst only Fast-Track, post-stack migrated data in the time domain was available at the time of writing, similar morphologies to the Venus-style Outer Basin play of the Orange Basin can be observed (Figure 5), with AVO responses similar to those seen over the source and reservoirs, improving confidence of similar play fairways and potential across the Atlantic in the Pelotas.

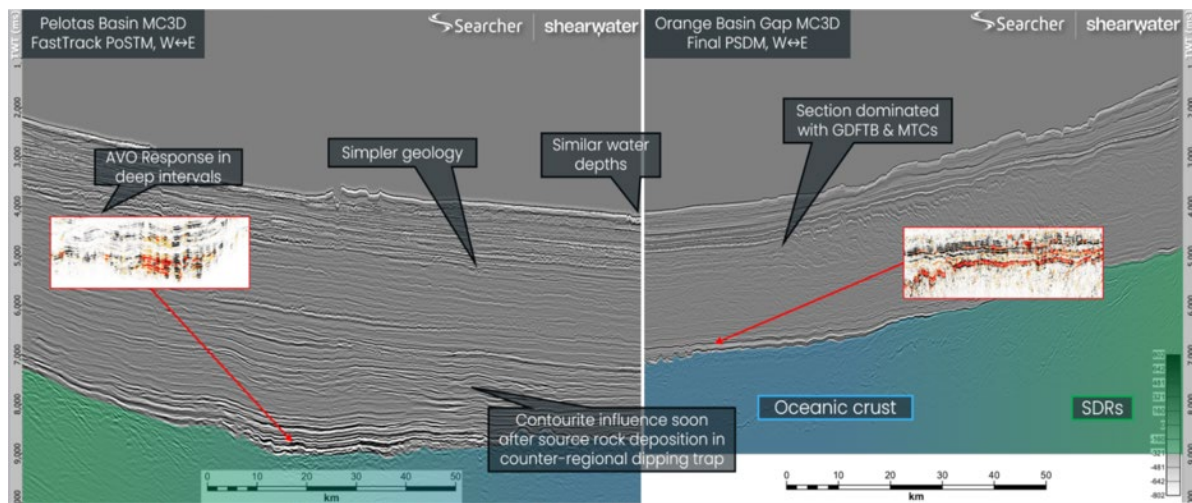


Figure 5: Correlation of the Namibian-South African Orange Basin (right) to the conjugate Pelotas Basin in southernmost Brazil (left) when compared on identical scales. Both basins lie in similar water depths and have a setting over oceanic to transitional crust characterised by seaward dipping reflectors (SDRs) and display Type III and Type IV AVO anomalies in the deeper intervals. The Pelotas Basin, which is mostly unexplored, contains a thicker sedimentary section and less complex overburden, with the gravity-driven fold & thrust belt absent (Note: SEG +ve polarity).

Conclusion

Modern broadband, long-offset seismic data is allowing for more insights than ever into the subsurface and the geological potential within basins previously underexplored or overlooked due to traditional imaging challenges or perspectives. By utilising the data and its attributes, perspectives can be challenged at a regional crustal scale, and prospectivity can be de-risked on a local scale.

References and Bibliography

- Davies, K., 2019, Seismic to Seep: An observation-based approach to defining the petroleum systems of the offshore Gulf of Papua: Presented at the PESA Lunch series, Perth
- Davison, I., Rodriguez, K. & Eastwell, D., 2018, Seismic detection of source rocks: *GeoExPro*, Vol 15(6), pp. 20-23
- Decalf, C., Bondurant, C. & P. Bunting, 2018, Salt sediment interaction in the Central Basin of the Nova Scotia Passive Margin, Offshore Eastern Canada: Presented at the Conjugate Margin Conference, Halifax
- Deptuck, M.E. & K.L. Kendell, 2022, Geology of the central Scotian Shelf and Slope- Call for Bids NS22-1: CNSOPB Geoscience Open File Reports
- Found, L., Crellin, S. & H. Debenham, 2025, The Gulf of Papua; Challenging industry perspectives of prospectivity with evolving geophysical technology: Presented at SEAPEX Exploration Conference, Singapore
- Found, L., Hodgson, N., Rodriguez, K. & H. Debenham, 2024, Exploration of the Papuan Plateau: How revolutionary geophysical technology reveals new seismic insights: *GEOExPro*, 2024 Volume 4
- Galp, 2025, Mopane-3X well confirming new exploration discovery: Galp Investor Announcements, <https://www.galp.com/corp/en/investors/publications-and-announcements/investor-announcements/investor-announcement/id/1591/mopane-3x-well-confirming-new-exploration-discovery>
- Holm, R.J., Rosenbaum, G. & S.W. Richards, 2016, Post 8 Ma reconstruction of Papua New Guinea and Solomon Islands: Microplate tectonics in a convergent plate boundary setting: *Earth-Science Reviews*, 156(2016), p. 66-81, <http://dx.doi.org/10.1016/j.earscirev.2016.03.005>
- Keppie, F., MacAdam, N., Sangster, C., MacDonald, A., Doane, K., Luheshi, M., Weston, J., Macrae, A., Bishop, A., Richards, B., Fowler, M., Dmytriw, R., Deptuck, M., Kendell, K., Makrides, C., Bimont, C., Breda-Dupin, I., Cuilhe, L., Doublet, S., Jermannaud, P., Machault, V., Mouchot, N., Prevost, J. & D. Thomas, 2023, Scotian Basin Integration Atlas 2023: Nova Scotia Department of Natural Resources and Renewables
- Marshak, S., 2021, *Earth- Portrait of a Planet* Seventh Edition: W.W. Norton, ISBN 978-0-393-88307-7
- Rhino Resources, 2025, Capricornus 1-X successfully tests light-oil discovery: Rhino Resources News Announcements, <https://www.rhinorsc.com/capricornus-1-x-light-oil-discovery/>
- Rodriguez, K., Found, L., Kovacic, G., & N. Hodgson, 2025, Super Nova Scotia: It's time for an old sun to reignite: *First Break*, Vol 43, pp. 69-72
- Rodriguez, K., 2022, The Bottom Simulating Reflectors Black Swan Effect: Presented at the EAGE London Chapter
- Vohat, P., Sain, K. & N.K. Thakur, 2003, Heat flow and geothermal gradient from a bottom simulating reflector: A case study: *Current Science*, Vol. 85, No. 9 (10 November 2003), pp. 1263-1265
- Winter, F., Intawong, A. & J. Robinson, 2022, The Orange Basin- An underexplored oil giant?: *GeoExPro*, Vol 19(3), pp. 40-42

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