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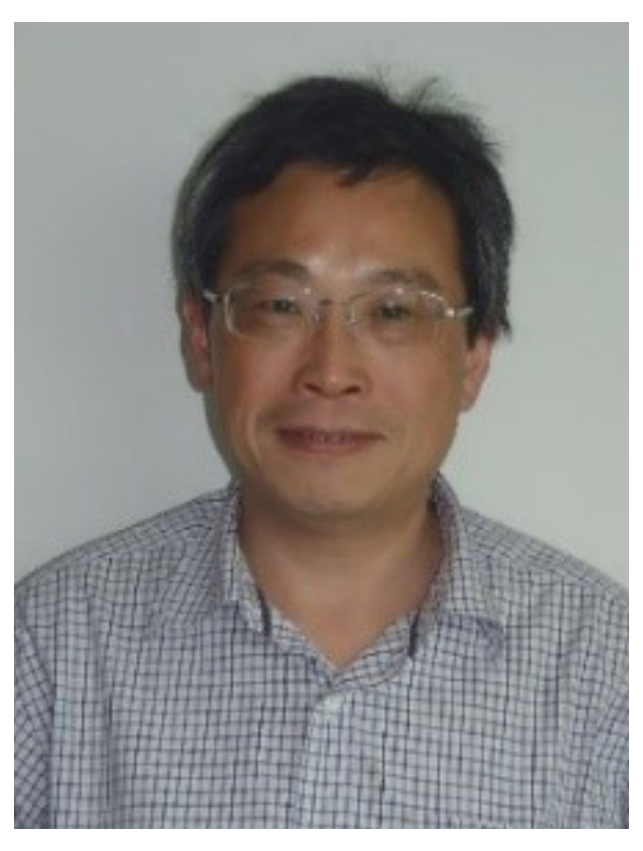
Unconventional hydrocarbon prospectivity of the Paleoproterozoic Fraynes Formation in Manbulloo S1, Northern Territory



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Exploring for the Future

Unconventional hydrocarbon prospectivity of the Paleoproterozoic Fraynes Formation in Manbulloo S1, Northern Territory

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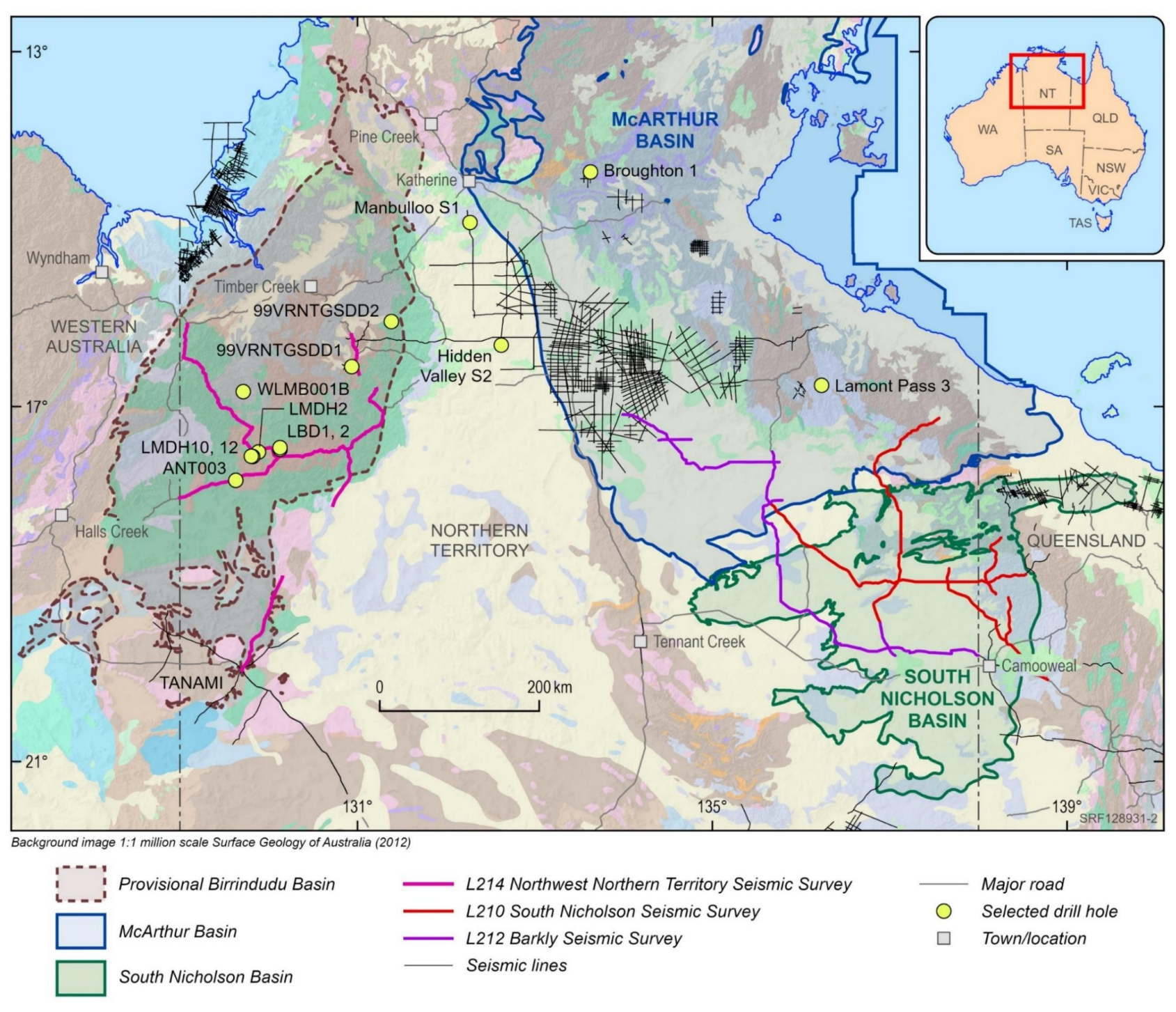
Introduction

The Greater McArthur Basin encompasses the McArthur Basin, the Birrindudu Basin, and the Tomkinson Province in Northern Australia (Close 2014), with evidence suggesting subsurface connection between the McArthur and Birrindudu basins. While the McArthur Basin has been extensively studied, the region to the west including the Birrindudu Basin remains underexplored despite hosting rocks of similar age, such as the Fraynes Formation. The Fraynes Formation is the equivalent to the prospective Barney Creek Formation, which is one of the primary source rocks of the McArthur Basin, prompting interest in the source potential of the Fraynes Formation. This study aims to assess the hydrocarbon generating potential and shale gas prospectivity of the Fraynes Formation in the exploration drillhole Manbulloo S1 through the reconstruction of the original source-rock characteristics and well log interpretation.



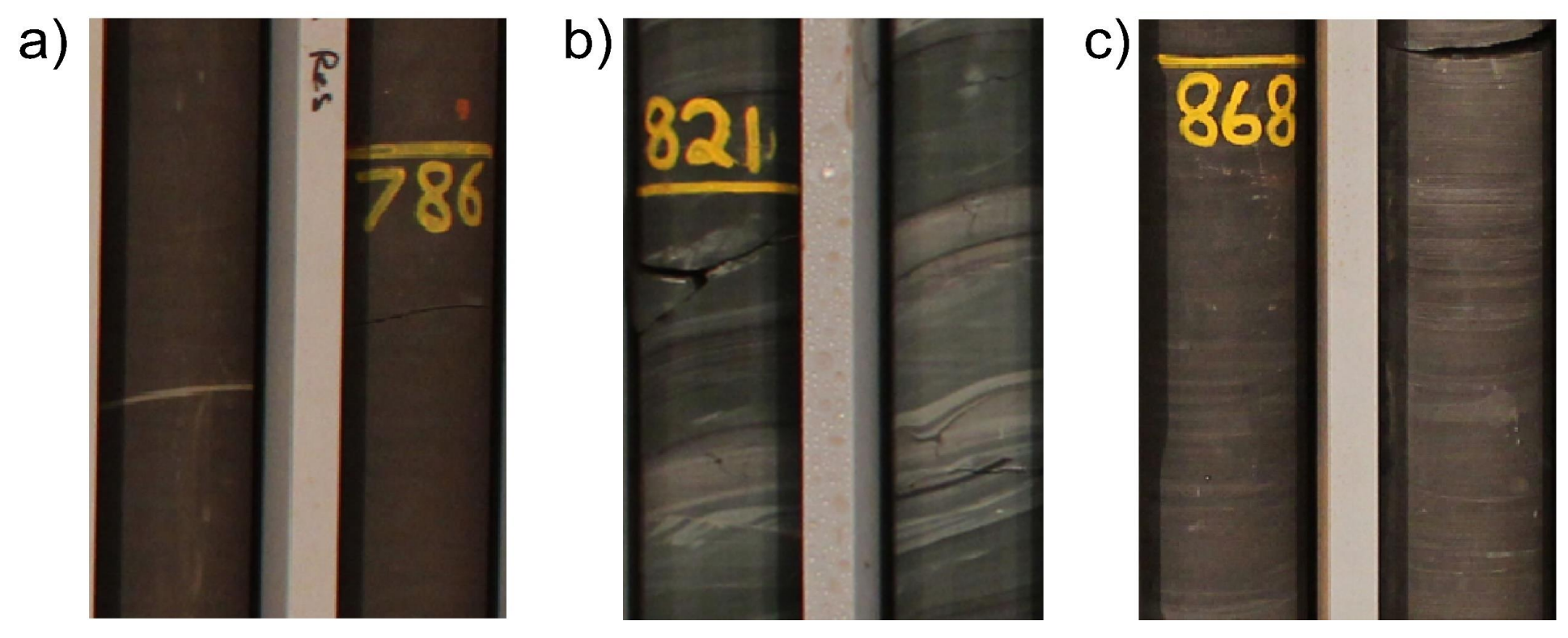
Regional map of the Birrindudu, McArthur and South Nicholson basins showing key seismic surveys and selected drill holes.

Hydrocarbon generating potential

- Fifteen cutting samples were used to measure bitumen reflectance (BRo, %) (Pangaea 2015), and the measured BRo (%) was converted to an equivalent vitrinite reflectance (EqVR, %). The EqVR values indicate that the Fraynes source rocks are within the gas window.
- Total organic carbon content and Rock Eval Pyrolysis testings were conducted on 99 samples from Manbulloo S1 (Pangaea 2015). Source rocks in the Fraynes Formation have median and maximum TOC contents of 0.83% and 4.98%, respectively.
- Internal units were defined according to sedimentary facies (Crombez *et al*. 2023).
- Three cases of kerogen types (Case 1: 100 % Type I; Case 2: mix of 50–50 % Type I-II; and Case 3: 100 % Type II) were assumed for computing the original hydrogen index.
- The original TOC content was derived from the present-day TOC content, transformation ratio, and residual carbon factor.
- The generative potentials for both oil and gas were estimated using the original TOC content, original hydrogen index and thermal maturity data (Ruble *et al*. 2016)

Sedimentary facies, hydrocarbon generating potential and petrophysical properties of the organic-rich shales (TOC content ≥1 wt%) in the Fraynes Formation in Manbulloo S1.

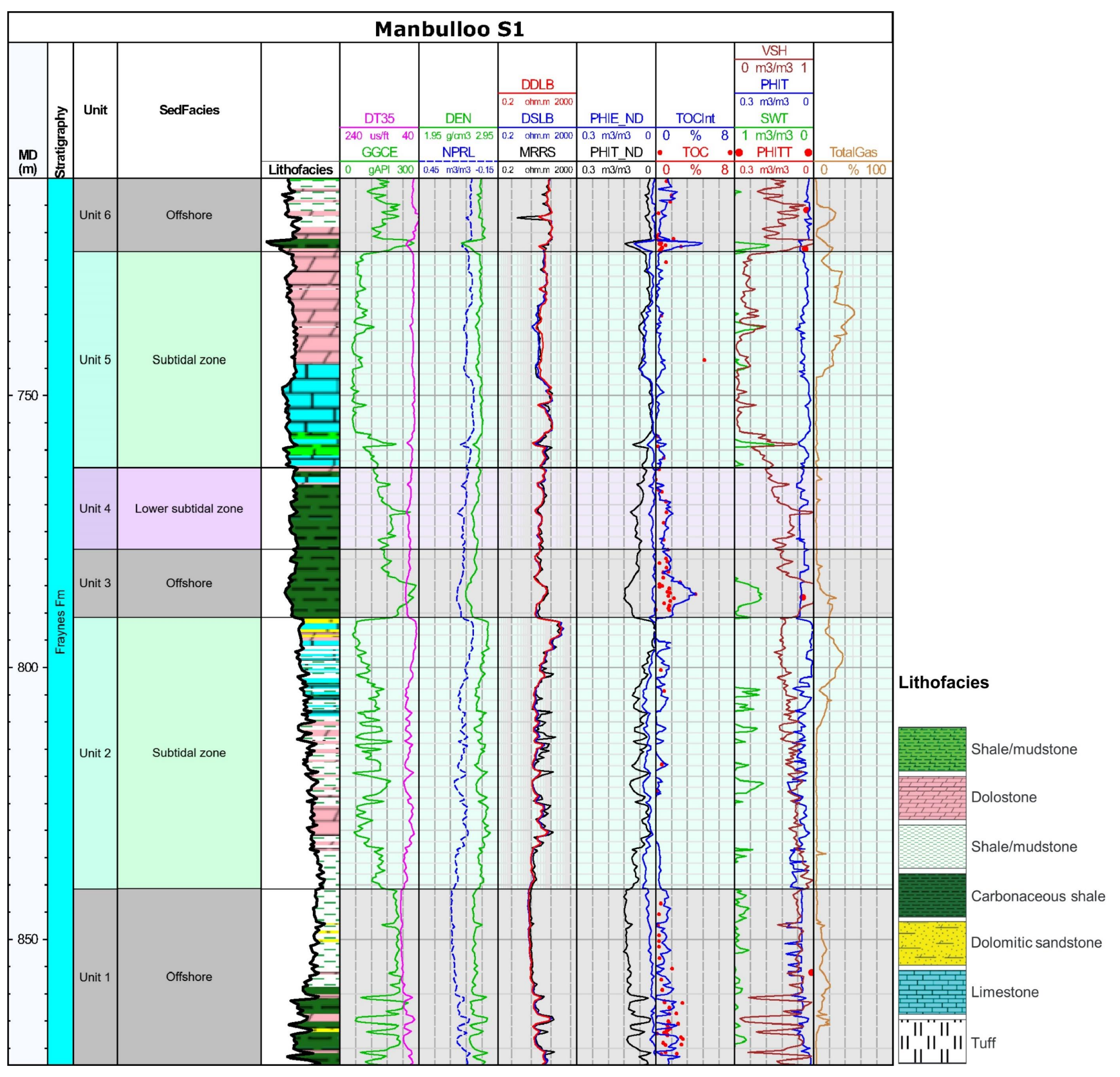
Unit (depth, m)	Net shale thickness (m)	Present day TOC (wt%)	Kerogen Type case	Generated Oil (bbl/a-ft)	Generated gas (Mcf/a-ft)
		Average/ maximum		Average/maximum	Average/maximum
Unit 6 (709.5–723.5) Offshore	7.3	1.62/2.59	1	163/259	1294/2171
			2	111/179	882/1501
			3	76/124	598/1035
Unit 5 (723.5–763.2) Subtidal	0.9	3.03/4.98	1	273/433	2463/3969
			2	190/302	1713/2769
			3	131/209	1183/1912
Unit 4 (763.2–778.3) Lower subtidal	4.7	1.08/1.1	1	99/101	1027/1053
			2	68/69	703.35/722
			3	47/48	482/496
Unit 3 (778.3–790.8) Offshore	11.7	1.58/4.05	1	124/329	1373/3666
			2	83/230	924/2565
			3	55/161	611/1790
Unit 2 (790.8–833.8) Subtidal	3.8	No organic-rich samples were tested.			
Unit 1 (833.8–873.2) Offshore	20.1	1.65/2.78	1	99/177	1630/2904
			2	67/123	1101/2026
			3	45/86	734/1417
Fraynes Formation	48.5	1.64/4.98	1	122/433	1511/3969
			2	83/302	1023/2769
			3	56/209	684/1912



Fraynes Formation shales: a) offshore shales (unit 3); b) subtidal shales (unit 4); c) offshore shales (unit 1). The numbers on the images are the driller's depth (m).

Petrophysical characterisation

- Total organic carbon (TOC) content was interpreted from porosity and resistivity logs. The organic-rich shale was identified where TOC content is ≥1 wt% in the interpreted TOC content profiles.
- Volume fraction of shale, porosity and water saturation were interpreted using gamma ray, neutron-density crossplot and dual-water model in Techlog^{TM}.
- Organic porosity was interpreted using a mass balance model (Wang *et al*. 2023).
- The total shale density porosity was interpreted after removing the effect of organic matter, adding the organic porosity (Wang *et al*. 2023).
- Total water saturation was re-interpreted using the total density porosity and dual-water model.



Well data in Manbulloo S1. From left to right, track 1: measured depth (m); track 2: stratigraphy (Pangaea 2015a); track 3: internal units; track 4: sedimentary facies (SedFacies, Crombez *et al.* 2023); track 5: lithofacies; track 6: gamma ray (GGCE, gAPI) and compressional wave slowness (DT35, $\mu s/ft$); track 7: bulk density (DEN, g/cm^3) and neutron porosity (m^3/m^3); track 8: deep (DDLB, Ωm) and shallow (DSLB, Ωm), and micro-resistivity (MRRS, Ωm); track 9: total (PHIT_ND, m^3/m^3) and effective porosity (PHIT_ND, m^3/m^3) interpreted from neutron-density crossplot; track10: laboratory measured (TOC, wt%) and interpreted TOC content (TOCint, wt%); track 11: interpreted volume fraction of shale (VSH, m^3/m^3), total porosity (PHIT, m^3/m^3) and and total water saturation (SWT, m^3/m^3), and laboratory measured total porosity (PHITT, m^3/m^3); track 12: total gas from mudlog, 1 unit = 1% of methane in air.

Conclusions

Thermal maturity data indicate that the Fraynes Formation shales are within the gas window. The maximum generated gas in the Fraynes Formation source rocks could be up to 2769 Mcf/a-ft when assuming the kerogen compositions are a mix of 50-50% Type I and II where the offshore shales have higher generating potential than subtidal shales. Petrophysical interpretation for the organic-rich shales show that net shale thickness is 48.5 m in the Fraynes Formation in Manbulloo S1, and the organic-rich shales have favourable shale gas prospectivity including both free and adsorbed gas contents.

Key references

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