

PS Unlocking Potential Unconventional Petroleum Resources in the Frontier McArthur Basin, Northern Territory*

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Abstract

Significant potential for unconventional hydrocarbon resources exists in the vastly underexplored Proterozoic source rocks of the McArthur Basin, which is poorly exposed over a large proportion of the Northern Territory, Australia. Recent advances in technologies for liberating hydrocarbons from shale have now made exploration feasible in remote, frontier basins such as the McArthur Basin. For this reason, the Northern Territory has seen a significant increase in onshore exploration for unconventional resources over the last two years, with a focus in the McArthur Basin. The Northern Territory Geological Survey (NTGS) is currently assessing the McArthur Basin for its hidden potential for self-sourced continuous shale plays. New data has emerged from historical wells that were deemed unsuccessful for conventional oil and gas plays at the time of drilling. This data combined with the application of new analytical techniques, approaches and ideas to the understanding of the regional-scale geology and basin architecture could unlock a potential for unconventional plays that had been previously overlooked in the McArthur Basin. Recent and ongoing work by the NTGS is focusing on the Mesoproterozoic black shales of the Roper Group, within the Wilton Package of the McArthur Basin. The Roper Group comprises two prospective shale units, the Kyalla and the Velkerri formations. Both formations have proven potential as active source rocks, with oil shows being documented for each unit in a number of wells. The result of this assessment will be a compilation of data sets and 2D sub-surface maps using the geological evaluation standards for high shale gas production and accumulation areas. 2D subsurface maps will include total organic carbon (TOC), brittle and clay mineral content, shale maturity, kerogen typing, effective thickness, depth of formation, and fluid and gas content. Recent exploration has resulted in a number of technically successful wells intersecting the shales within these packages, which has paved the way for further innovative drilling across the basin. The next phase of the investigation will see the repetition of the shale evaluation throughout the Meso- to Palaeoproterozoic packages, and to form a basin-wide overview of the unconventional petroleum potential of the McArthur Basin.



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Introduction

The Northern Territory Geological Survey (NTGS) is investigating the shale intersections of the Mesoproterozoic Roper Group, McArthur Basin in the north of the Northern Territory, Australia (**Figure 1**). Historically, petroleum explorers targeted conventional petroleum reservoirs in this region with the organic-rich shales regarded solely as source rocks. Investigations targeting self-sourced continuous reservoirs for unconventional petroleum within the Roper Group (**Table 1**) began in the mid-2000s.

The Roper Group comprises a regionally extensive, cyclic succession of mainly alternating mudstones and sandstones, with minor lithologies of pedogenic sedimentary breccia, fluvial sandstone, micritic and intraclastic limestone, and ooidal ironstone (Ahmad *et al* 2013).

The Kyalla and Velkerri formations of the Roper Group are proven source rocks, with documented oil shows in a number of wells intersecting the units. Both formations are prospective self-sourced continuous (unconventional) petroleum reservoirs (**Figure 2**).

The 3D architecture of the base of the Roper Group (**Figure 3**) indicates sediment depths of up to 4 km with shale unit thicknesses of up to 800 m.

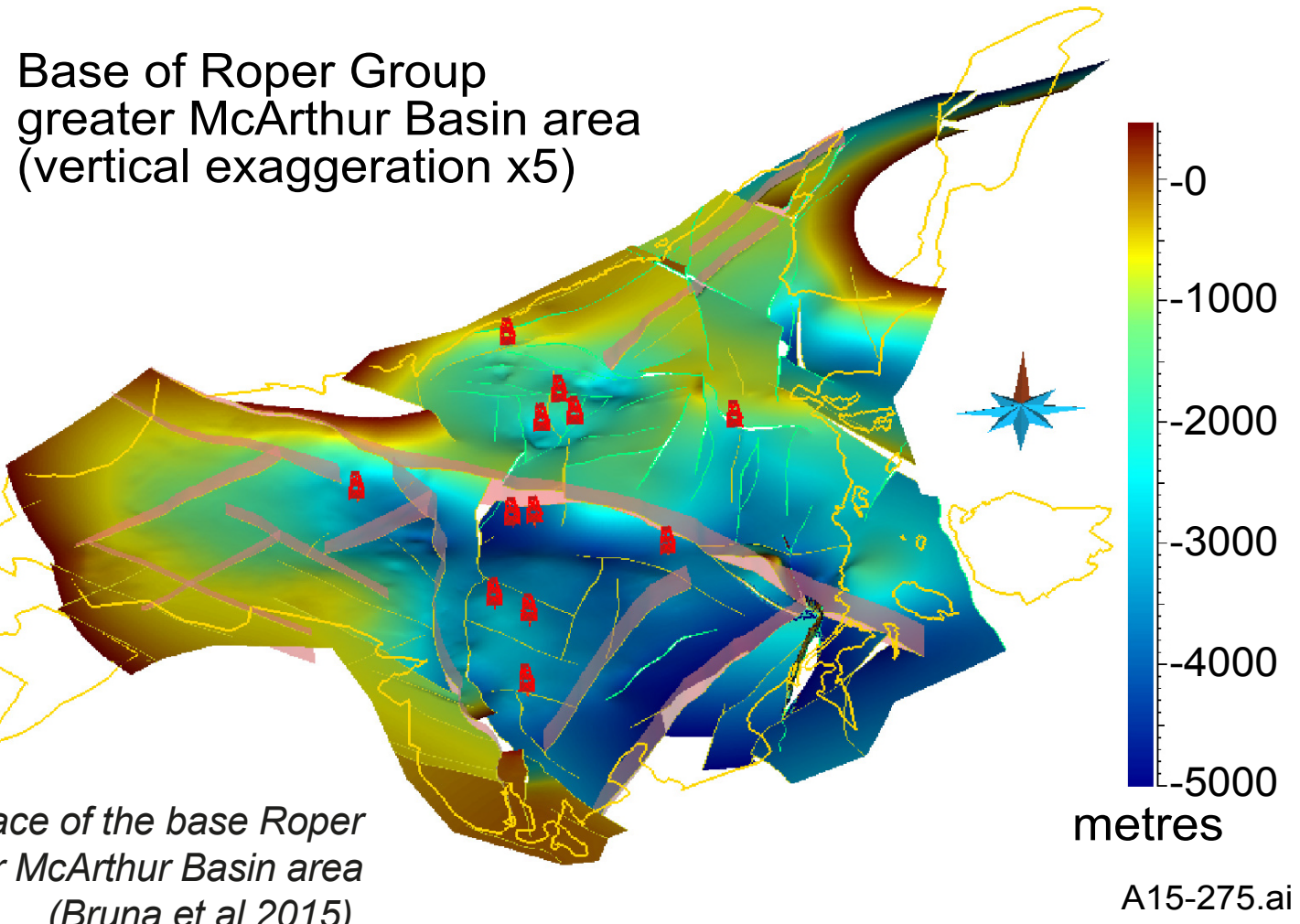


Figure 3. Surface of the base Roper Group in the greater McArthur Basin area (Bruna *et al* 2015).

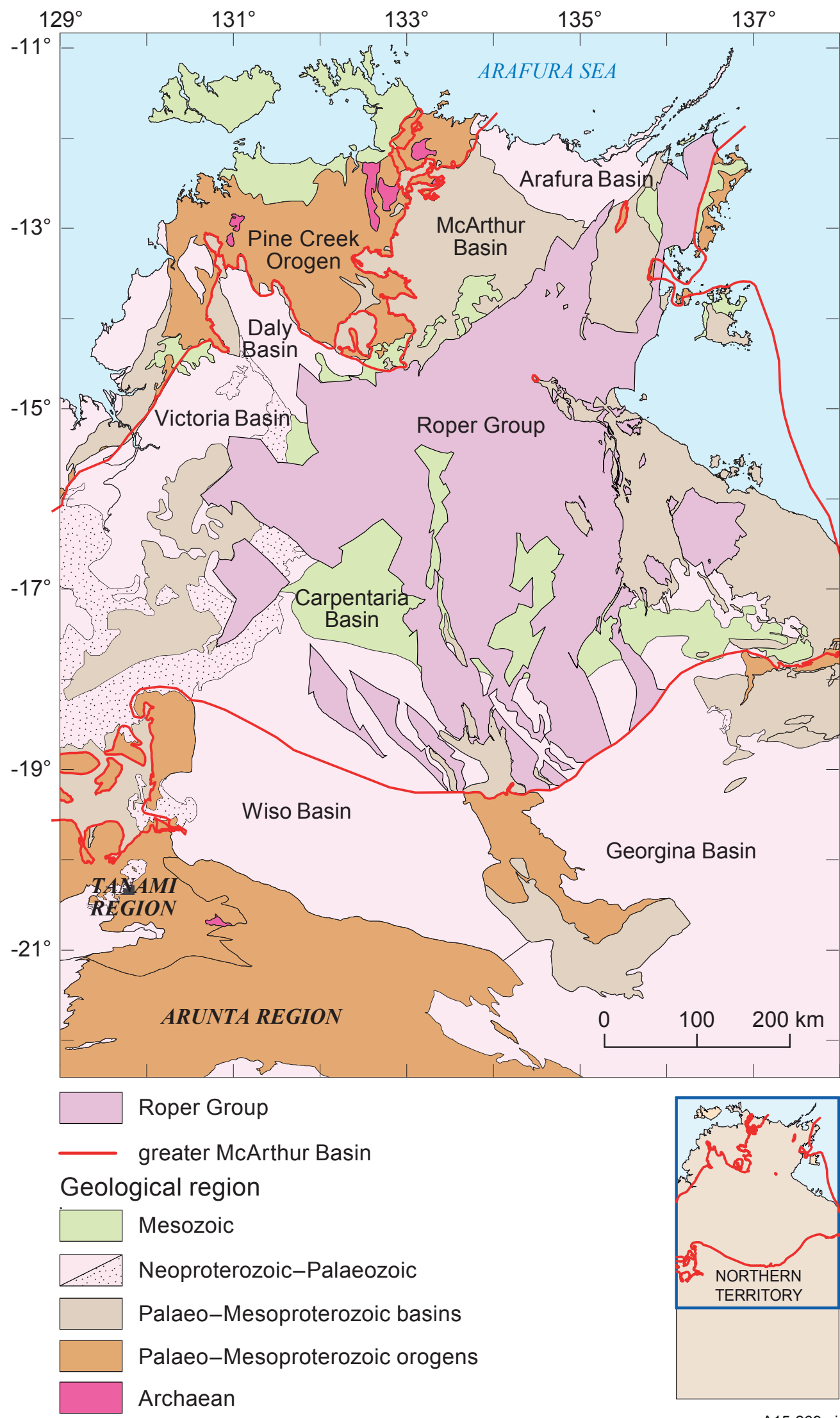


Figure 1. Location of the greater McArthur Basin, NT, Australia. Roper Group is highlighted in pink.

ERA	DEPOSITIONAL PACKAGE (Rawlings, 1999)	GROUPINGS	Chronometric subdivision (Ahmad & Scrimgeour, 2006)
Mesoproterozoic	Wilton Package	Roper Group	P 9 (1000–1500 Ma)
	Favenc Package	Mount Rigg and Nathan groups	P 8 (1500–1600 Ma)
Palaeoproterozoic	Glyde Package	McArthur, Vizard, Balma and Habgood groups	P 7 (1600–1700 Ma)
	Goyder Package	Parsons Range, upper Spencer Creek groups	P 7 (1600–1700 Ma)
	Redbank Package	Katherine River, Tawallah, Donydji, lower Spencer Creek groups	P 6 & P 5 (1700–1850 Ma)

Table 1. Groupings and chronometric subdivisions of the McArthur Basin, adapted from Rawlings (1999), Ahmad & Scrimgeour (2006)

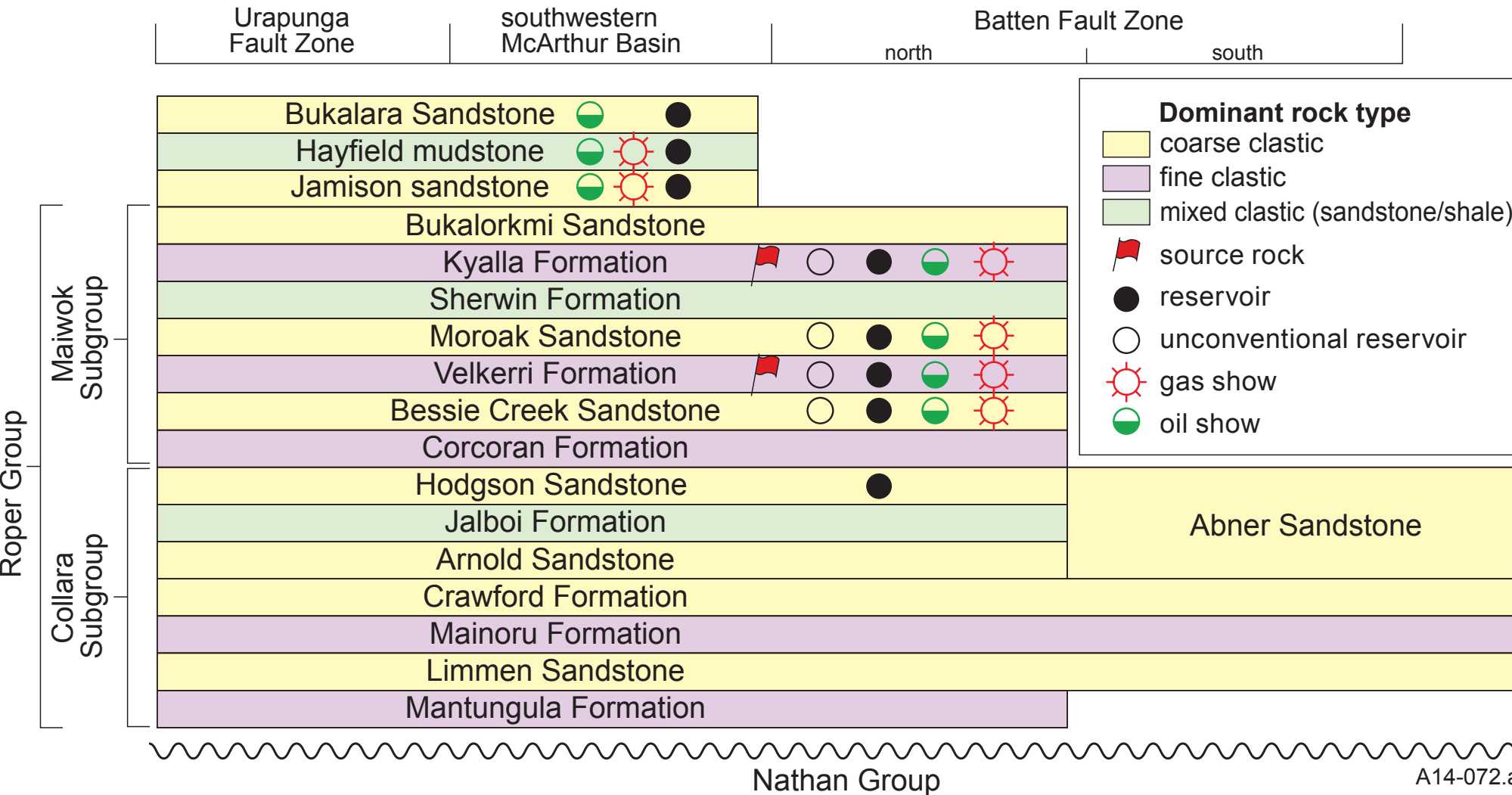


Figure 2. Stratigraphic column representing the Roper Group sedimentary sequence. Adapted from Munson (2014).

McArthur Basin Data Package DIP012-015 available at Australia Petroleum booth
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Organic geochemistry and structure of the Roper Group

Total Organic Carbon (TOC) content analysis of the Kyalla and Velkerri formations show that both formations contain very-good (>2 wt% TOC) to excellent (>4 wt% TOC) organic-rich intervals (**Figure 4**). The Velkerri Formation middle shales are laterally extensive and relatively undisturbed, with organic-rich components (**Figure 5**).

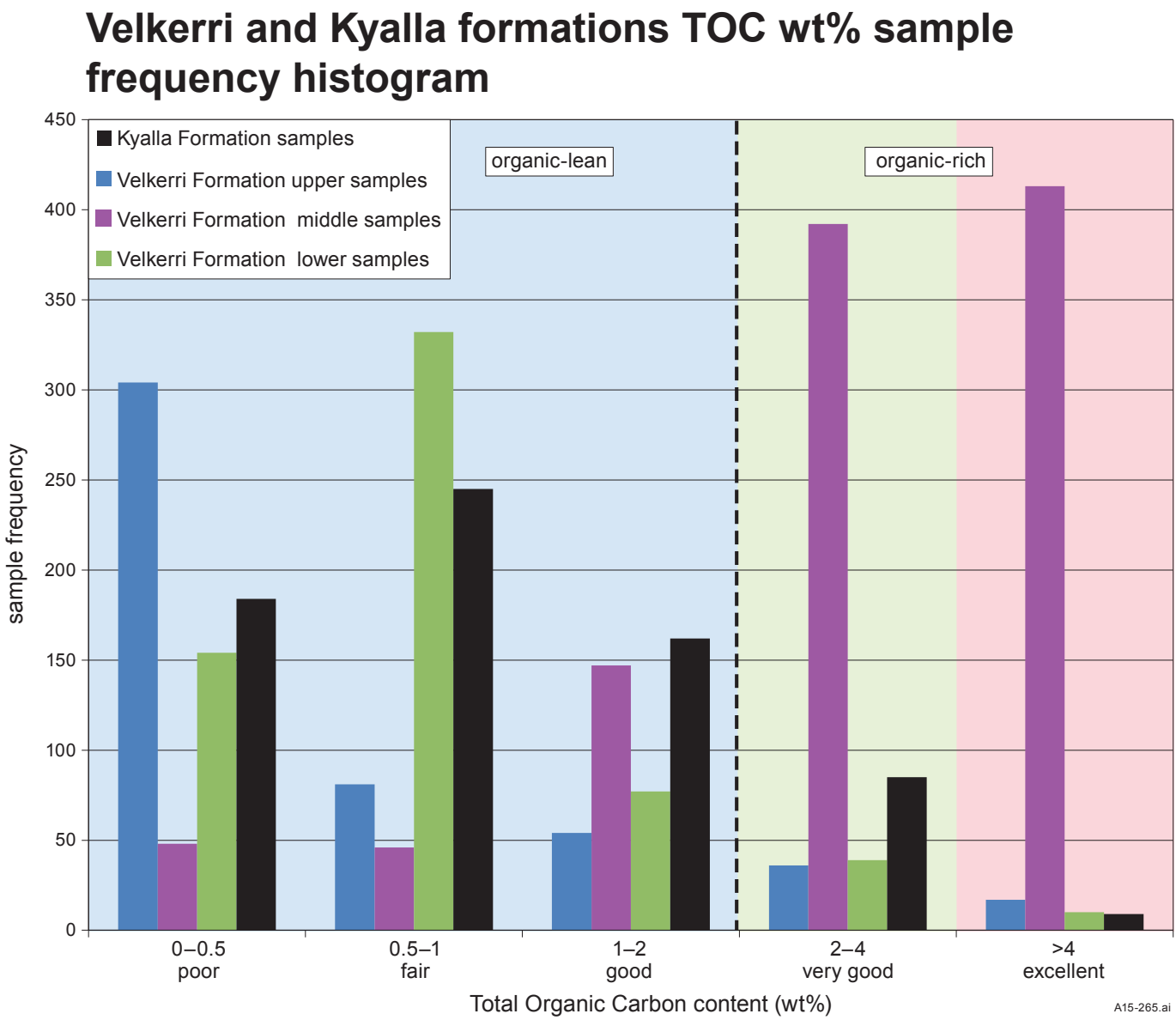
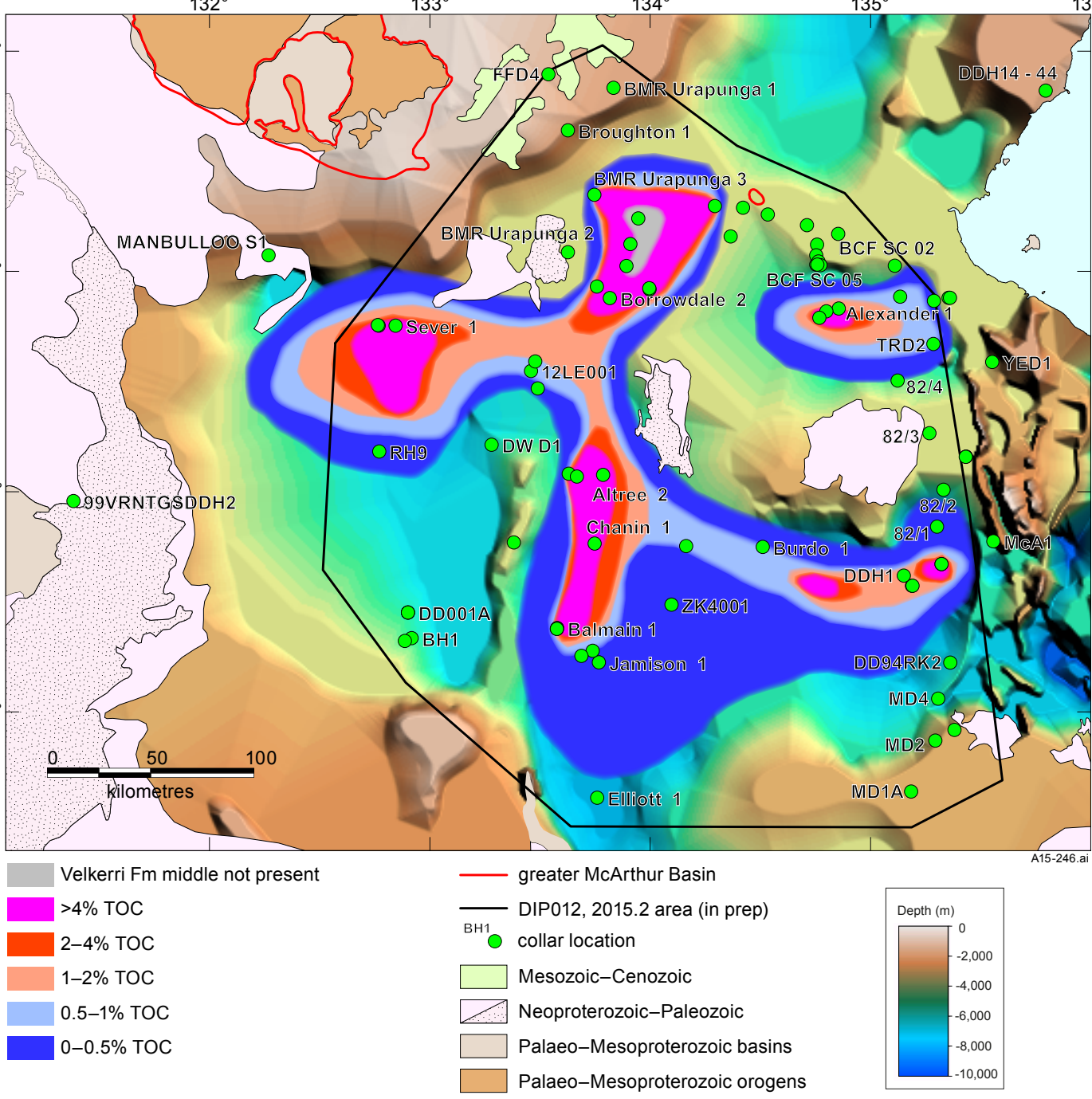


Figure 4. Sampling frequency histogram for TOC wt% content of the Velkerri and Kyalla formations.

Figure 5. map showing Velkerri Formation middle shale contoured TOC wt% relative to Proterozoic SEEBASE™ basement surface (adapted from Pryer and Louit 2005).



Citations

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Rawlings D, 1999. Stratigraphic resolution of a multiphase intracratonic basin system: the McArthur Basin, northern Australia. Australian Journal of Earth Sciences 46, 703-723.
Revie D, 2015. Shale resource data from the greater McArthur Basin (June 2015). Northern Territory Geological Survey, Digital Information Package DIP-014.

The presence of Kerogen Type I and some Type II (**Figure 6**) together with sedimentological evidence, indicates a restricted marine

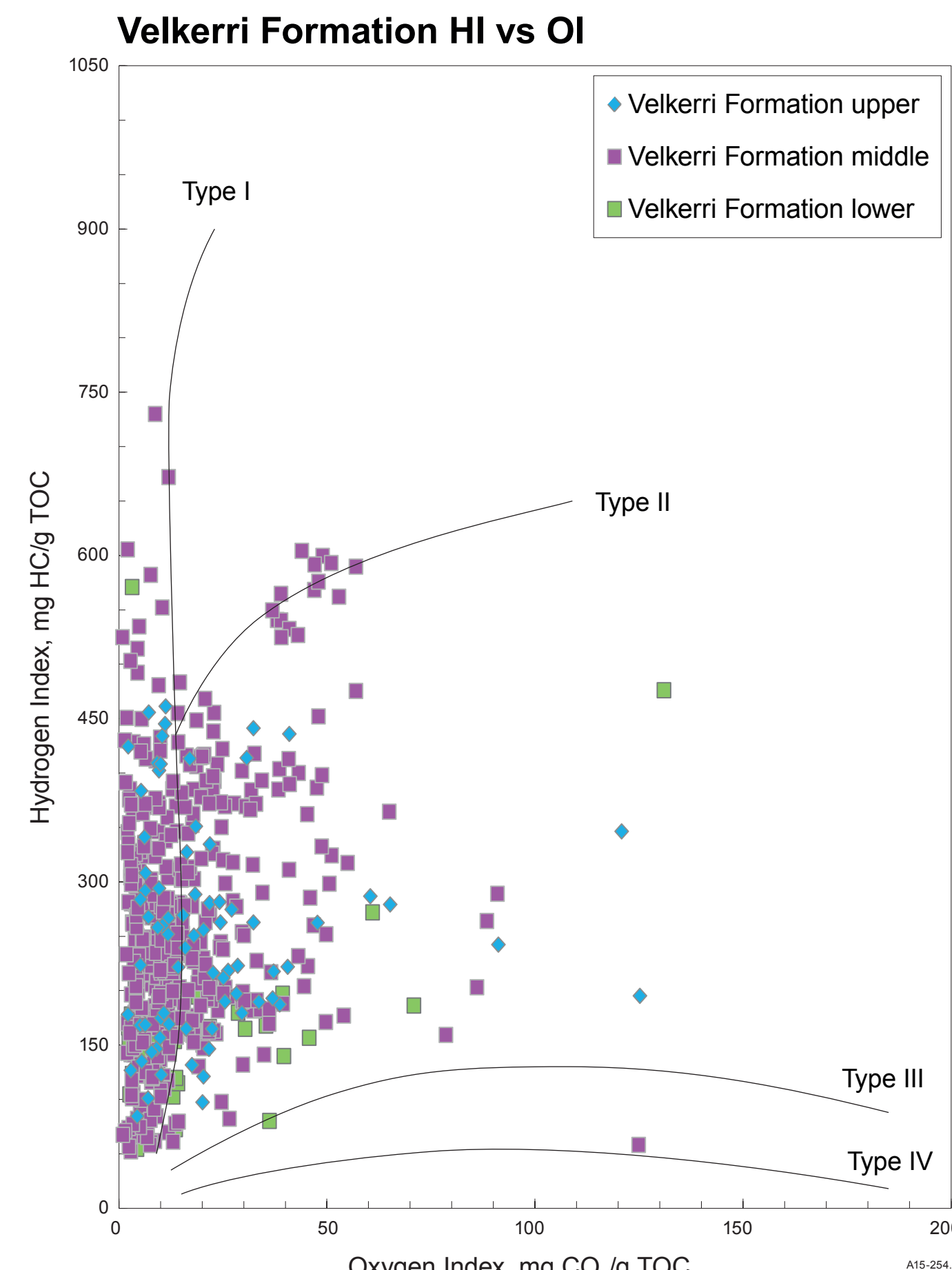


Figure 6. HI v OI plot for Velkerri Formation.

environment with long quiescent periods during which fine-grained sediments were deposited.

Thermal maturity levels of the Kyalla and Velkerri formations range from immature to dry-gas mature (**Figure 7**) as indicated from organic petrography, bitumen/lamalginitite reflectance, elemental ratios, and hydrogen/oxygen indices (**Figure 8**).

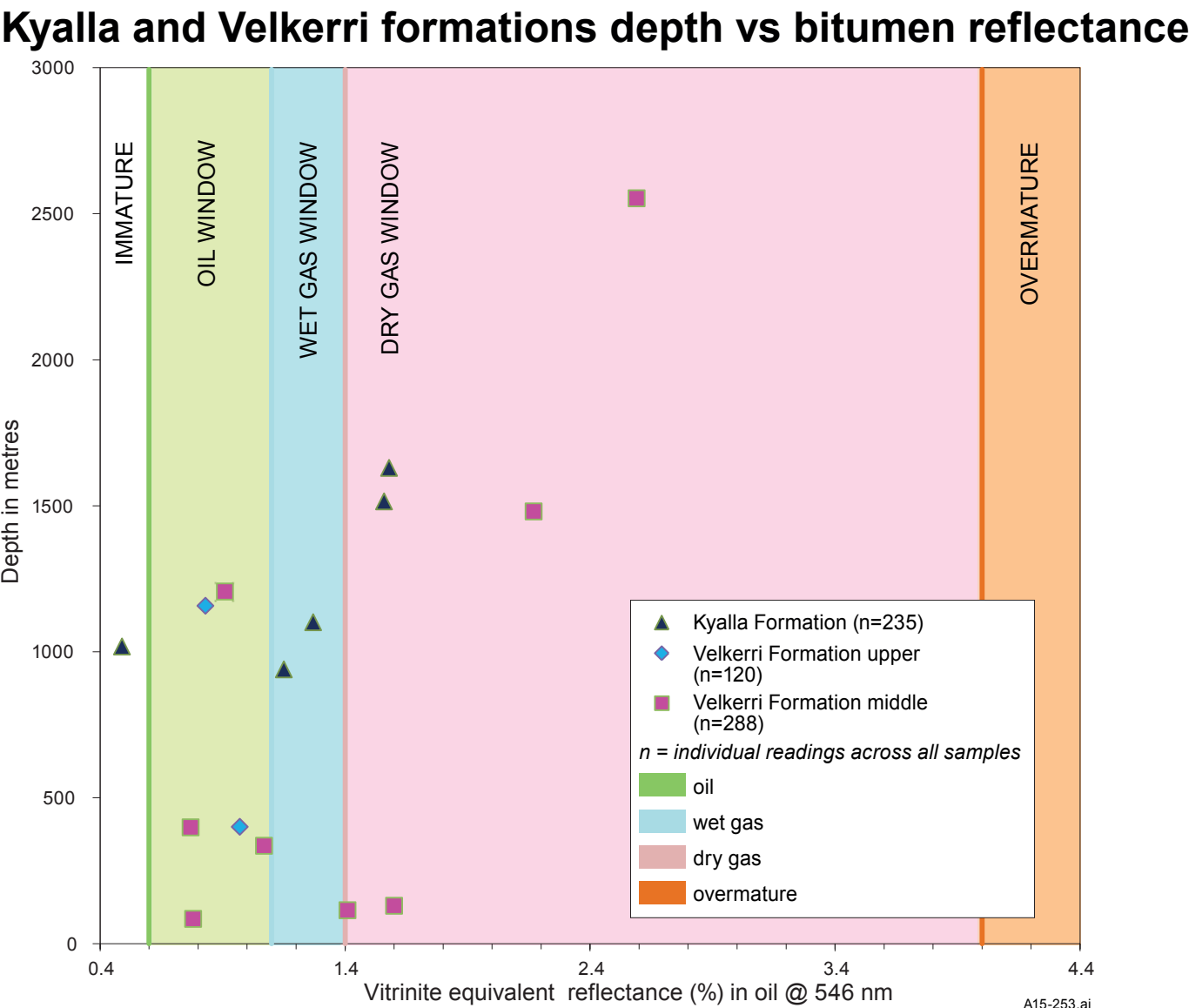


Figure 7. Organic reflectance values versus depth of the Kyalla and Velkerri formations. [Data from DIP014, Revie (2015)].

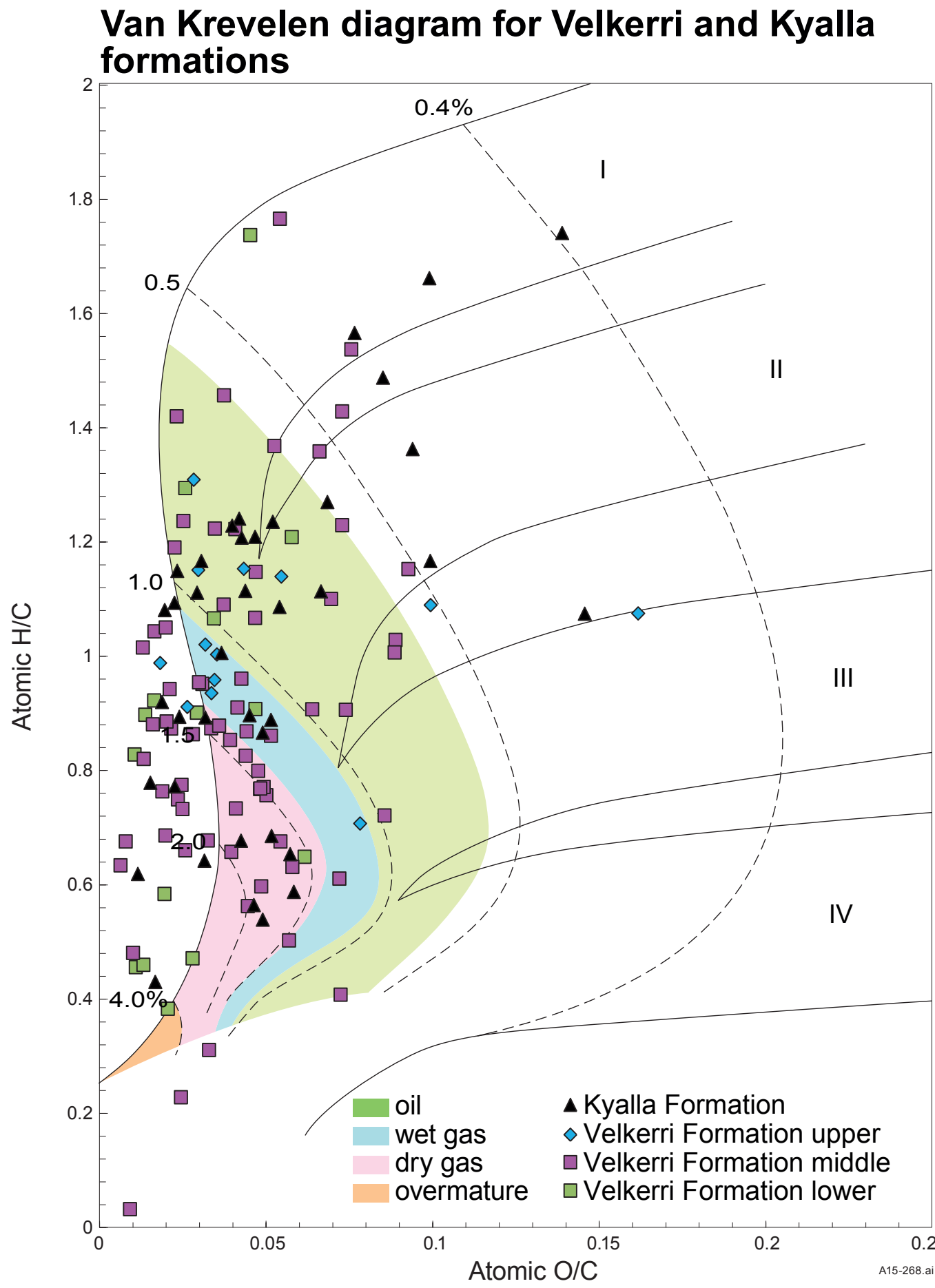


Figure 8. Van Krevelen diagram showing kerogen types of the Velkerri and Kyalla formations at different maturity levels. Dashed lines are isorank lines based on vitrinite reflectance, %Ro.

Shale mineralogy

X-Ray diffraction results from selected samples through the Kyalla and Velkerri formations indicate the shales have a variable mineralogy. The mineralogy of Velkerri Formation middle (<30% clay mineral content, >40% brittle mineral content) is favourable for enhanced hydrocarbon recovery techniques such as hydraulic fracturing (**Figure 9**).

Conclusions

- The Roper Group contains thick, fine-grained shales with a high frequency of very-good to excellent TOC content, thermally mature for oil to dry gas generation, laterally extensive and relatively undisturbed geology, favourable for potentially hosting self-sourced continuous (unconventional) petroleum plays.
- Multiple petroleum shows within the Roper Group stratigraphy indicate the presence of working petroleum system/s.
- Organic geochemistry indicates the Kyalla and Velkerri formations contain predominantly Type I and some Type II oil-prone kerogen, with high atomic H/C ratios and relatively low atomic O/C ratios.
- The environment of deposition for the Kyalla and Velkerri formations may have been a restricted barred bay with continental water influence which was partly or wholly closed off from open oceans at various stages of development.
- Presence of favourable mineralogy for large scale fracturing.

Figure 9. Ternary plot of clay, quartz and carbonate/other mineral content from selected XRD analysis of the Kyalla and Velkerri formations. Pink zone represents favourable mineralogy for enhanced recovery techniques.

