THE STRATIGRAPHIC ARCHITECTURE, DISTRIBUTION AND HYDROCARBON POTENTIAL OF THE ORGANIC RICH KYALLA AND VELKERRI SHALES OF THE UPPER ROPER GROUP (MCARTHUR BASIN)

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SUMMARY

Recent exploration studies on the stratigraphic framework, depositional environment and tectonic setting of the Mesoproterozoic Roper Group in the McArthur Basin, have led to an improved understanding of the highly prospective organic-rich shales of the Velkerri and Kyalla Formations. From a review of open file drill core and well logs, several major regressive-transgressive (R-T) cycles have been identified within the Roper Group. The R-T cycles show sedimentary features typical of deposition within a clastic dominated marine deltaic setting and show marked lateral variation in facies and thicknesses. The lateral thickness variations are particularly noticeable across regional 2D seismic lines. Seismic interpretation and well correlation confirm the extensive and relatively undeformed nature of the Velkerri and Kyalla Formations in the subsurface, they appear thickest in the southeast of the Greater Beetaloo Basin.

Key words: McArthur Basin, Roper Group, Kyalla Formation, Velkerri Formation.

INTRODUCTION

The Palaeo to Mesoproterozoic McArthur Basin is exposed over an area of approximately 180 000km^2 in the north eastern Northern Territory (Ahmad et al., 2013). The basin contains a series of prominent sub-basins with inverted margins that are preserved beneath a regional base Cambrian unconformity. The stratigraphy consists of Palaeoproterzoic carbonate packages of the McArthur and Nathan Groups capped by Mesoproterozoic silicilastics of the Roper Group (Figure 1). The Roper Group is made up of several major regressive-transgressive (R-T) cycles each ca 500-1000m thick, consisting of sandier-upward cycles punctuated by mudstone rich formations. These stacked sedimentary cycles represent marine successions (Abbott & Sweet, 2000) that developed across an extensive sedimentary basin covering much of the North Australian Craton over a period of approximately 150m.yr (Ahmad et al., 2013).

Santos implemented regional studies across the McArthur Basin to better understand the depositional setting and hydrocarbon prospectivity of the organic-rich shales of the Velkerri and Kyalla Formations. The analysis utilises electronic log data, conventional core descriptions, seismic reviews and potential field data. Facies analysis focuses on the three youngest R-T sequences of the Roper Group, based on seven continuously cored wells. The R-T sequences are named after the dominant lithostratigraphic formations, in ascending stratigraphic order, (1) Corcoran – Bessie Creek, (2) Velkerri – Moroak and (3) Kyalla. The regional seismic review highlights the lateral continuity and thickness variations of these R-T cycles. The thickest sections are recognised in the southeast of the Greater Beetaloo Basin, progressively thinning towards the northwest and to the Maiwok sub-basin where a significant portion of the Roper Group is in outcrop. An improved review on the depositional model assists in understanding and predicting the distribution of the organic-rich shales and associated siliciclastic sequences across the basin.

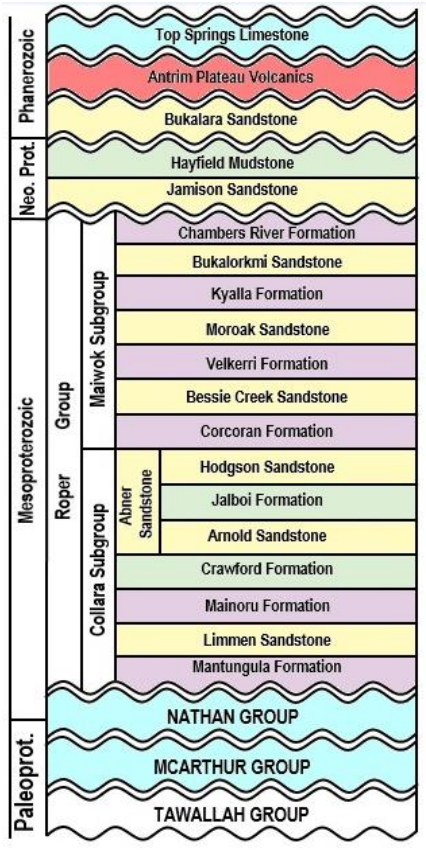

Figure 1- Stratigraphic column of the McArthur Basin.

WORKFLOW

Detailed sedimentological studies were initiated by Santos in 2013. The studies incorporated a sedimentological and stratigraphic review of ca. 3500m of open file drill core that has been acquired by oil and gas companies in the 1980's and 1990's. The core is currently available to the public at the Northern Territory Geological Survey core store. The continuous cores targeted the conventional sands of the Bessie Creek and Moroak Sandstones and in doing so have also preserved the finer grained parts of the sequence, including the organic-rich Velkerri and Kyalla Shales. In 2017 a seismic review of the Roper Group was completed across the basin, utilising open file 2D

seismic data ranging in vintages from 1983 – 2013. The interpretation workflow integrated surface geology maps, 1st derivative bouger gravity and 1st derivative reverse to pole magnetic data. The data set provides a rare opportunity to establish the facies relationships across the full spectrum of shallow water to deeper marine deposits, which is often prohibited due to the lack of data and/or surface exposure.

RESULTS & DISCUSSION

Facies Interpretation

The three youngest R-T sequences are characterised by two coastal-deltaic depositional environments: (1) sand-dominated fluvial to proximal delta front/coastal environments in mainly shallow water settings, with evidence of fluvial, tidal and wave/storm processes, and (2) mud-dominated distal delta front, prodelta and basinal environments in mainly deeper water settings with evidence of fluvial, storm and gravity flow processes, including periodic anoxic conditions. These sedimentological features appear in sandier upward coarsening cycles that accumulated in a mud-prone marine deltaic setting. The depositional model comprises the following features (Figure 2 & 3);

(a) Sandy, braided river dominated upper delta plain, which passes down-dip into a sandy, mixed fluvio tidal lower delta plain to delta front,
(b) Proximal delta front/subaqueous delta platform characterised by a mixed energy regime of tide, wave and storm processes,
(c) Distal delta front (above storm wave base)
(d) Prodelta to basin floor environment, (below storm wave base) that is characterised by dilute gravity flow processes and accumulations of reworked organic material.

Depositional environments (a) and (b) are typically observed in the sandier regressive units of the Roper Group, namely the Bessie Creek and Moroak Sandstone. The more distal delta environments ((c) and (d)) are represented by the finer grained transgressive shales of the Corcoran, Velkerri and Kyalla Formations, which contain organic-rich matter (total organic carbon 1-10%). The prominent facies characteristics of the transgressive sequences are as follows; (1) thin (mm-cm scale) turbidites with minor slumps and debrites, (2) an absence of wave reworked storm events beds and (3) gradational vertical facies relationships with distal delta front pro delta facies. The gross stratigraphic architecture resulted from northward-directed, coastal-deltaic progradation and aggradational episodes, separated by mud prone transgressive sequences, probably in a shallow epicontinental sea.

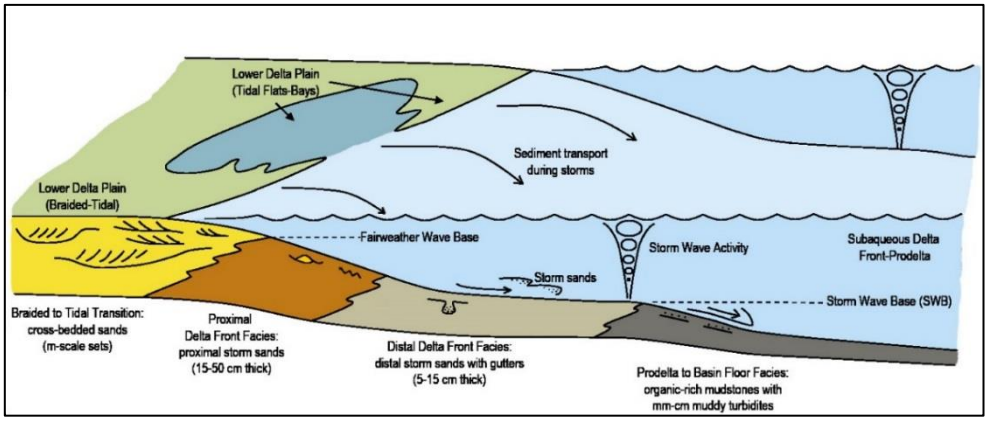

Figure 2: Schematic section illustrating conceptual depositional environments and sedimentary facies in a Mesoproterozoic upper Roper Group delta.

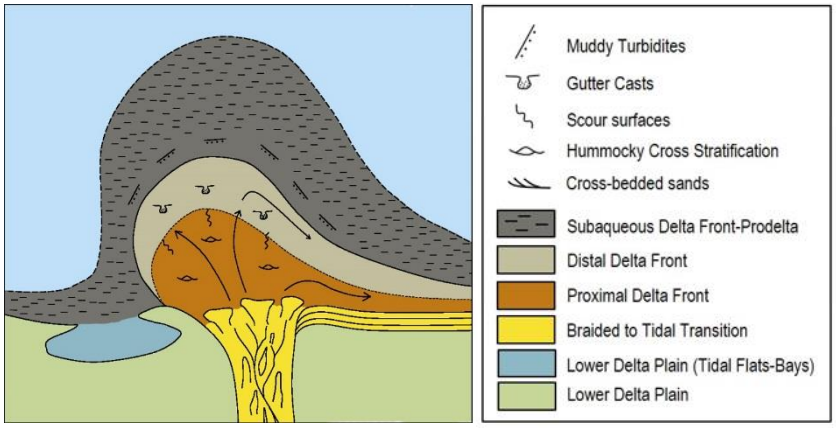

Figure 3: Plan view of Mesoproterozoic upper Roper Group delta.

Seismic Interpretation

Seismic data reveals an overall northward thinning wedge-shaped, epicontinental ramp-style setting which controlled accommodation space and the distribution and thickness of organic-rich mudstones. Seismic sections show high (up to ca. 350km) lateral continuity of the fine grained Velkerri and Kyalla Formations across the McArthur Basin (Figure 4). The southeast of the Greater Beetaloo Basin hosts the thickest sections of the Velkerri and Kyalla Formations (Velkerri ca. 1700m, Kyalla ca. 930m), which progressively thin towards the northwest (Velkerri ca. 300m, Kyalla ca. 50m). The thickened successions correspond to basin depo-centres and the attenuated sections are influenced and controlled by tectonically positive areas of relative uplift. Seismic data displays evidence of intense structuration along the sub-basin margins, which form relatively narrow zones resulting from tectonic reactivation, inversion and uplift. Younger stratigraphic sequences are often not preserved at these margins. The deformation at these margins has effectively shielded the remnant basin from deformation, resulting in exceptionally preserved 'layer cake'-type stratigraphy in the sub-basins.

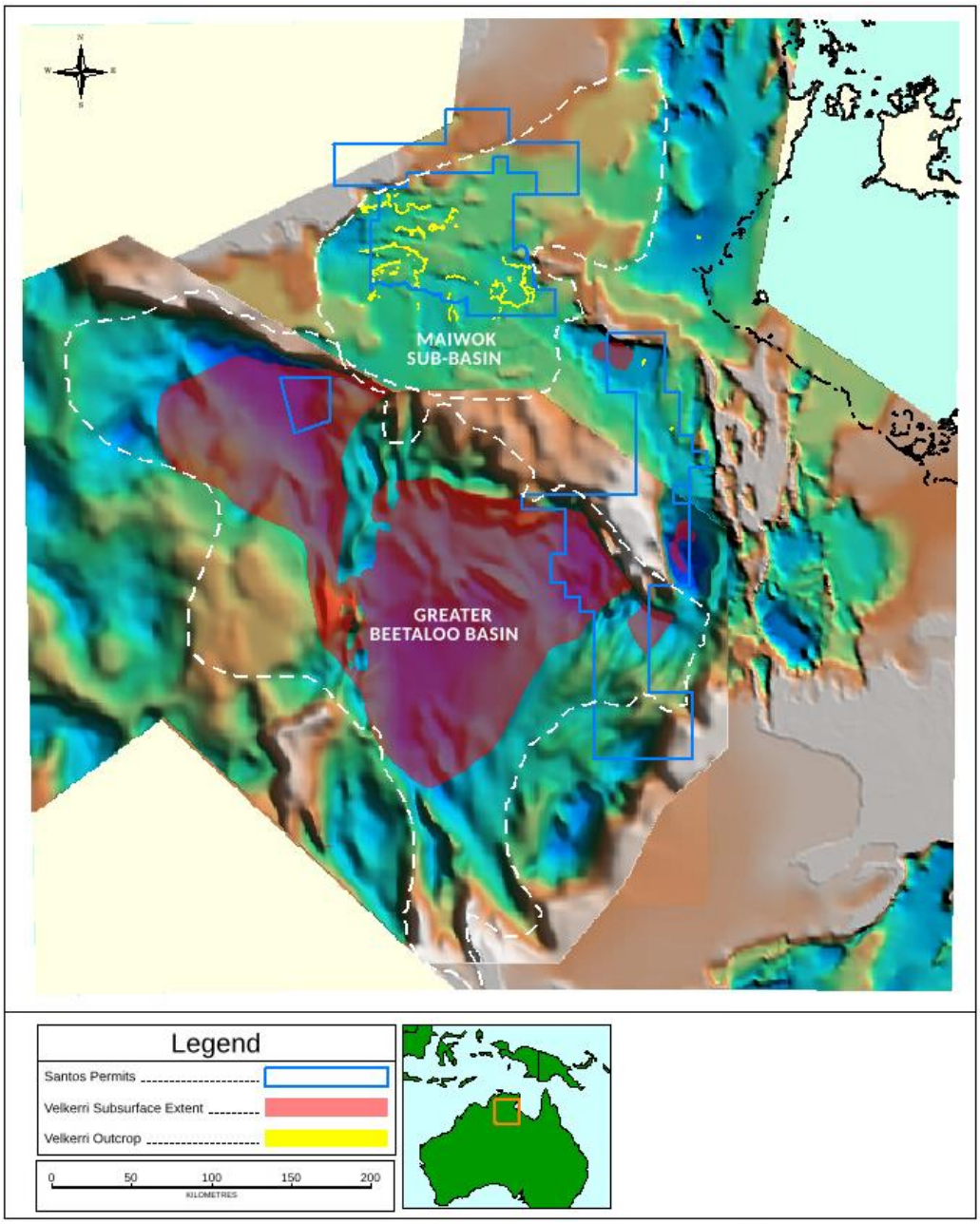

Figure 4: Lateral extent of the Velkerri Formation in the subsurface, overlaid on SEEBASE™ depth to basement image (after FrOG Tech., 2011, 2014): yellow-brown tones depict Proterozoic basement highs, blue-green tones are represented as depocentres.

CONCLUSIONS

From a review of continuous drill core, well data, seismic sections and potential field data, a regional stratigraphic framework of the organic-rich shales in the Velkerri and Kyalla Formations of the upper Roper Group across the McArthur Basin has been developed. The gross depositional environments comprised a northward-prograding coastal-deltaic depositional setting. The organic-rich mudstones of the Velkerri and Kyalla Formations accumulated in the most distal parts of this laterally-connected deltaic source-to-sink sediment transport system. Deposition in the most basinal areas was dominated by dilute, small-scale, and probably laterally extensive gravity flows. These flows were rich in reworked organic material, which accumulated in anoxic sea-bed conditions. The gravity flows were driven mainly by variations in clastic input through river mouths and from the delta front, and may have been triggered by up-dip storm and flood events. It is anticipated that the inferred relatively benign sea floor topography did not interfere, to any great extent, to the dispersal of fine-grained gravity flows. Consequently, the Velkerri and Kyalla Formations are laterally continuous, relatively undeformed and thermally mature shale reservoirs hosting potentially large volumes of retained hydrocarbon.

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