

Depositional setting and stratigraphic architecture of the Roper Group (McArthur Basin): insights from a sedimentological analysis of core and well data

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Recent exploration activity in the McArthur Basin has confirmed the Mesoproterozoic Velkerri and Kyalla organic-rich shales of the Roper Group as probably the most prospective shale gas play in Australia. The Velkerri and Kyalla shales occur within a thick, predominantly marine, clastic succession containing well-developed, mostly conformable, regressive and transgressive sequences.

In 2011, Santos implemented regional studies to provide a better understanding of the tectonic and depositional setting of the Roper Group and to help frame the shale gas prospectivity of the basin. These regional studies initially focussed on the tectonic setting of the McArthur Basin and the geometry of the basin-fill (Johns *et al* 2015).

Subsequent studies, initiated in 2013, were directed at establishing genetic stratigraphic and depositional models of the Roper Group, building on previous models of clastic-dominated, epicontinental shelfal successions. This involved a sedimentological and stratigraphic review of ca 3500 m of open file drill core that was acquired in the basin by oil and gas exploration companies in the 1980s and 1990s and is now publically available in the Northern Territory Geological Survey core store. The continuous cores not only sampled the initial exploration targets (the Bessie Creek and Moroak sandstones) but also the well-preserved, fine-grained parts of the sequence, including well-developed organic-rich shales.

This dataset provides a rare opportunity to establish the facies relationships across the full spectrum of shallow water to deeper marine deposits; this is often prohibited through lack of data and/or exposure in most subsurface and outcrop situations. The core data were integrated with other available data, including wireline logs, enabling the construction of a genetically-based regional correlation

framework of the main stratal units of the Roper Group throughout the study area. The studies also provided new insight into sedimentary processes and depositional environments that were active during the deposition of the Roper Group. This included an assessment of the physical processes responsible for deposition of organic-rich shales; these processes are counter to conventional models that often invoke condensation of hemipelagic-dominated deposition for such deposits.

The Roper Group succession comprises approximately six major regressive-transgressive (R-T) sequences, each ca 500–1000 m thick (total thickness ca 3–6 km) that are interpreted to be the result of deposition in a clastic-dominated coastal-deltaic setting. Facies analysis focused on the three youngest R-T sequences, based on seven continuously cored wells across the McArthur Basin. These three R-T sequences of the Roper Group are named after the dominant lithostratigraphic formations and are, from oldest to youngest: (1) Corcoran-Bessie Creek, (2) Velkerri-Moroak, and (3) Kyalla.

The depositional setting of all three R-T sequences was similar and is characterised by two coastal-deltaic depositional environments: (1) sand-dominated fluvial to proximal delta front/coastal environments in mainly shallower water settings, with evidence of mixed 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 and including periodic anoxic conditions. The resulting conceptual depositional model (Figures 1, 2) comprises the following features:

- a) sandy, braided river-dominated upper delta plain, which passed down-dip into a sandy, mixed fluvio-tidal-dominated lower delta plain to delta front (fluvial- to tide-dominated processes, extending down to fairweather wave base)

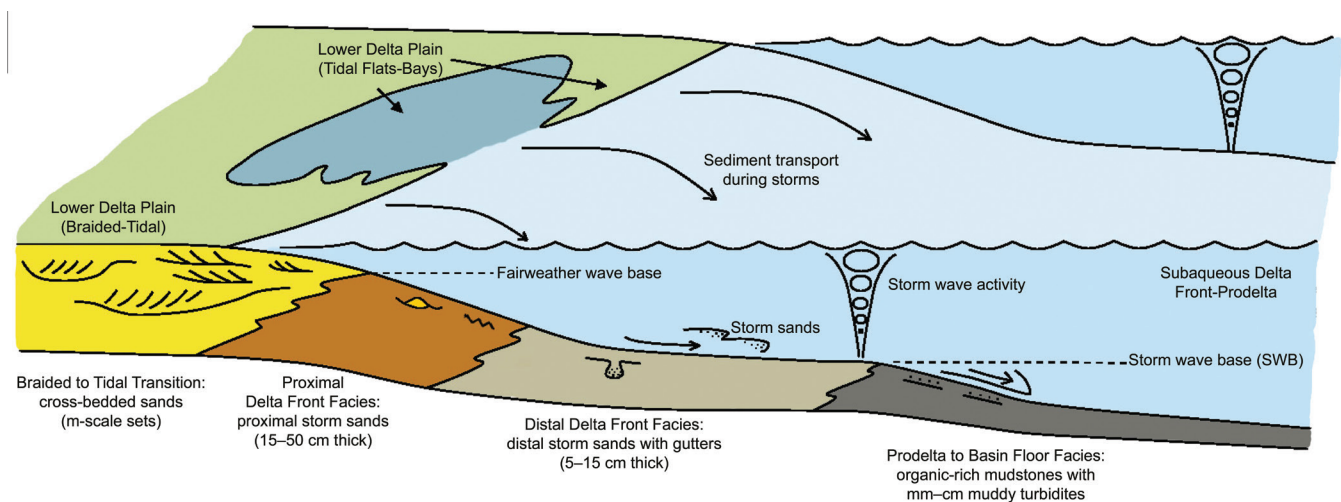


Figure 1. Schematic section illustrating conceptual depositional environments and sedimentary facies in a Mesoproterozoic upper Roper Group delta.

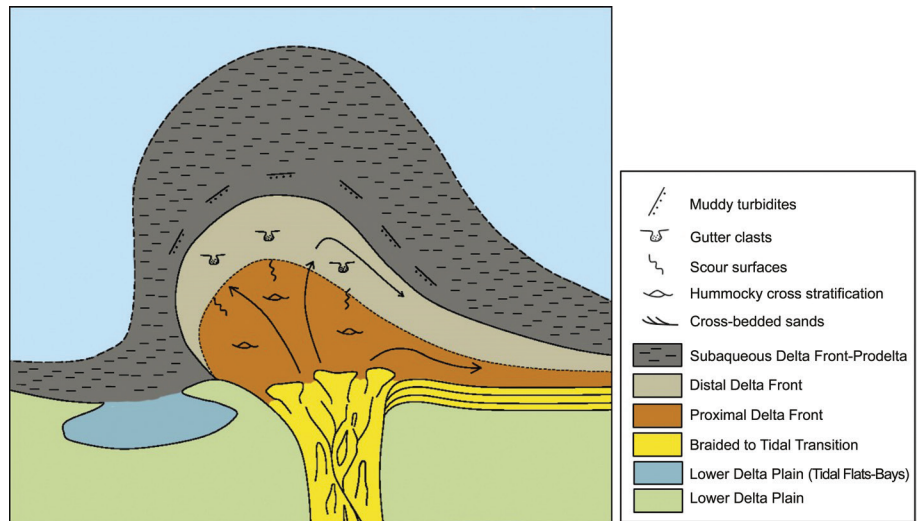


Figure 2. Plan view of Mesoproterozoic upper Roper Group delta.

- b) proximal delta front/subaqueous delta platform characterised by a mixed energy regime of tide-, wave- and storm-reworked mouth bars
- c) distal delta front (dominated by storm processes)
- d) prodelta to basin floor (depositional below storm wave base) characterised by dilute gravity flow processes and accumulation of reworked organic material.

Lateral facies relationships (eg in the Velkerri-Moroak R-T sequence) supports northward coastal-deltaic progradation.

These R-T cyclical successions resulted from continuous sedimentation in a subsiding basin with episodes of northwards-directed deltaic progradation when shallow water coarse clastics were deposited in progradational and aggradational sequences, separated by transgressive episodes. The latter resulted in deposition of deeper water marine muds, and fine sand and silts in an offshore prodelta setting. The organic-rich mudstones within the Velkerri-Moroak R-T sequence occur at the turnaround between transgressive and regressive periods.

The mudstone-dominated parts of the successions (Velkerri and Kyalla formations) host laterally continuous, organic-rich intervals (total organic carbon 1–10%) with the following facies characteristics: (1) thin (mm-/cm-scale) turbidites and minor slumps and debrites, (2) an absence of wave-reworked storm events beds, and (3) gradual vertical facies relationships with distal delta front and prodelta facies. It is concluded that the organic-rich mudstones accumulated in the most distal part of the deltaic source-to-sink sediment transport system, below storm-wave-base; deposition was dominated by numerous, small, dilute gravity flows. The environments of deposition of the distal delta front to prodelta facies were laterally contiguous

with shallower water, delta front equivalents. Organic-rich mudstone deposition was more energetic than previously considered and not typical of condensed ‘hemipelagic’ sequences.

The primary origin of the carbonaceous material appears to have been internally sourced, possibly reworked from a zone extending from the intertidal areas to the distal delta front-prodelta. This model envisages the relatively rapid accumulation of organic-rich muds under anoxic sea-bed conditions within a sub-storm wave base setting. The lateral continuity of the shale horizons across the basin reflects relative sea level fluctuations and variation in clastic input, as well as a relatively benign sea floor topography that did not hinder, to any great extent, the dispersal of fine-grained sediment gravity flows.

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References

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