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Middle Proterozoic Biostratigraphy and Log Correlations of the Kyalla and Chambers River Formations Beetaloo Sub-basin, Northern Territory, Australia

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Mesoproterozoic biostratigraphy of the Beetaloo Sub-basin, Northern Territory, Australia

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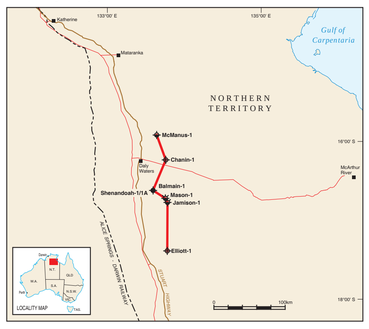
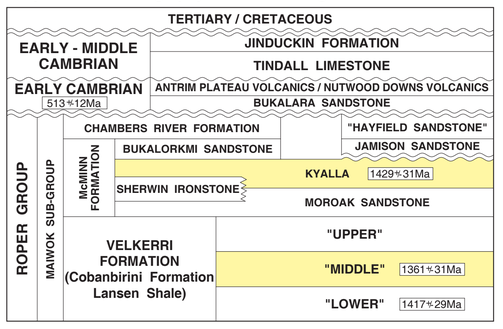
The Beetaloo Sub-basin, McArthur Basin, Northern Territory hosts some of the oldest proven hydrocarbon source rocks in Australia in the Mesoproterozoic Roper Group. Oil has been typed to organic matter from the Velkerri Formation, and the younger Kyalla Formation also boasts organic-rich intervals. Core and cuttings samples taken from a suite of petroleum exploration wells over a more than 200 km north to south transect were analysed using modified palynological techniques following previously reported recoveries of microfossils mainly from the Velkerri Formation and older rocks of the McArthur Basin. We report the occurrence of reproducible palynological assemblages from wells that confirm wireline log correlations. Microfossils recovered from the Velkerri, Kyalla and Chambers River formations show considerable promise for biostratigraphic correlation, but require further documentation of distributions patterns, as well as systematic description. Many previously undescribed species appear to be present. In particular, the Chambers River Formation is characterized by abundant clusters of small, tightly packed spheres (cf. *Symplassosphaeridium*). Leiospheres, filaments (especially *Synsphaeridium* spp.) and clusters of larger spheres are more common in the Kyalla Formation. So far, no specimens of *Tappania plana*, previously recorded by Javaux et al. (2001) from the older Corcoran and Jalboi formations, have been found. Circumstantial lithological evidence suggests the possibility of a glacial imprint in the Mesoproterozoic depositional environment of the Beetaloo Sub-basin.

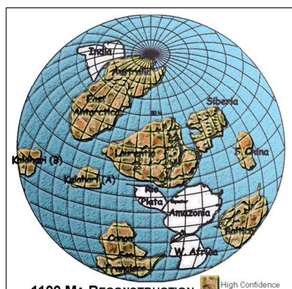
Locality Map



Simplified Lithostratigraphy and Absolute Age



Possible Palaeogeography

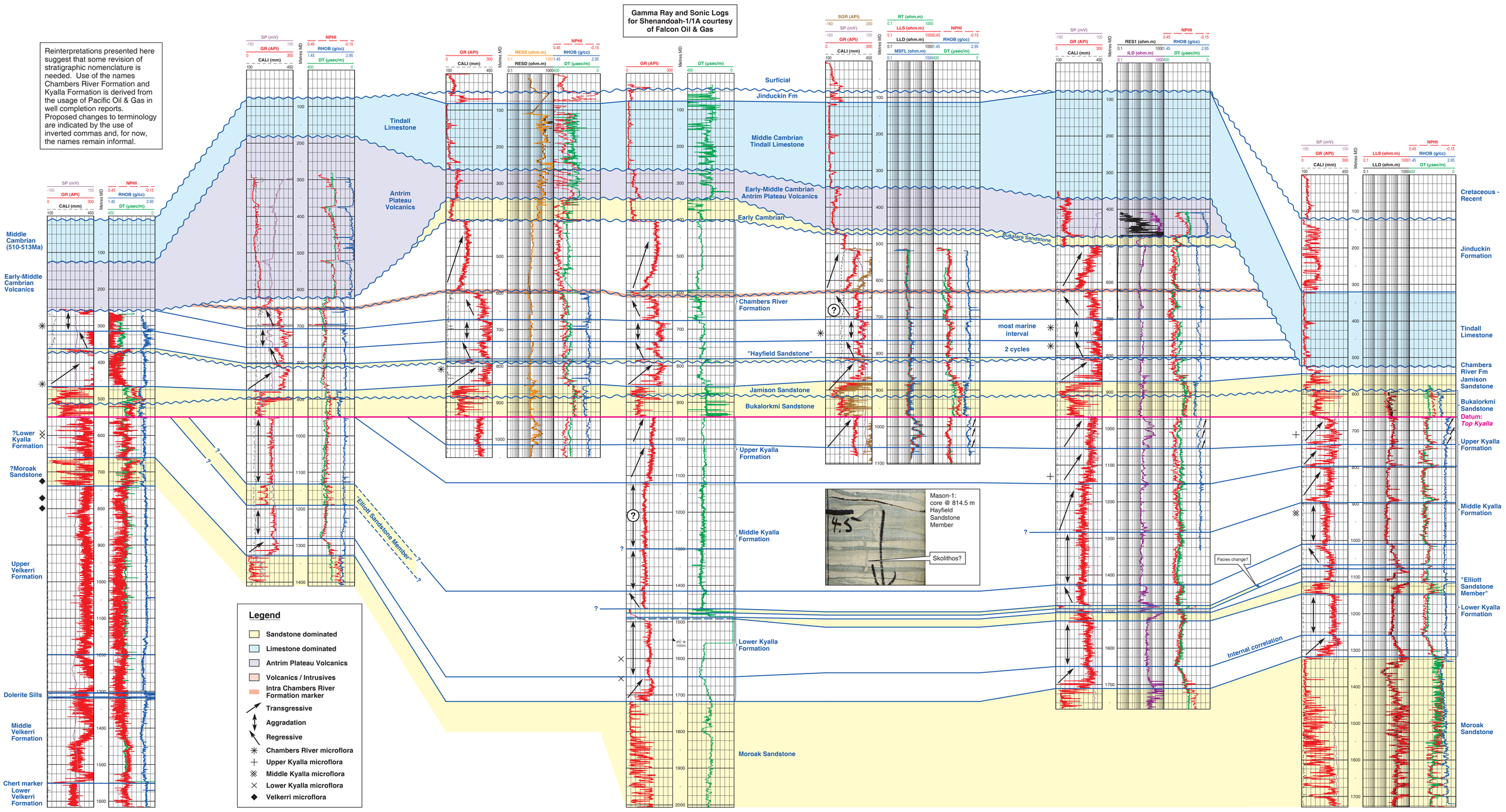


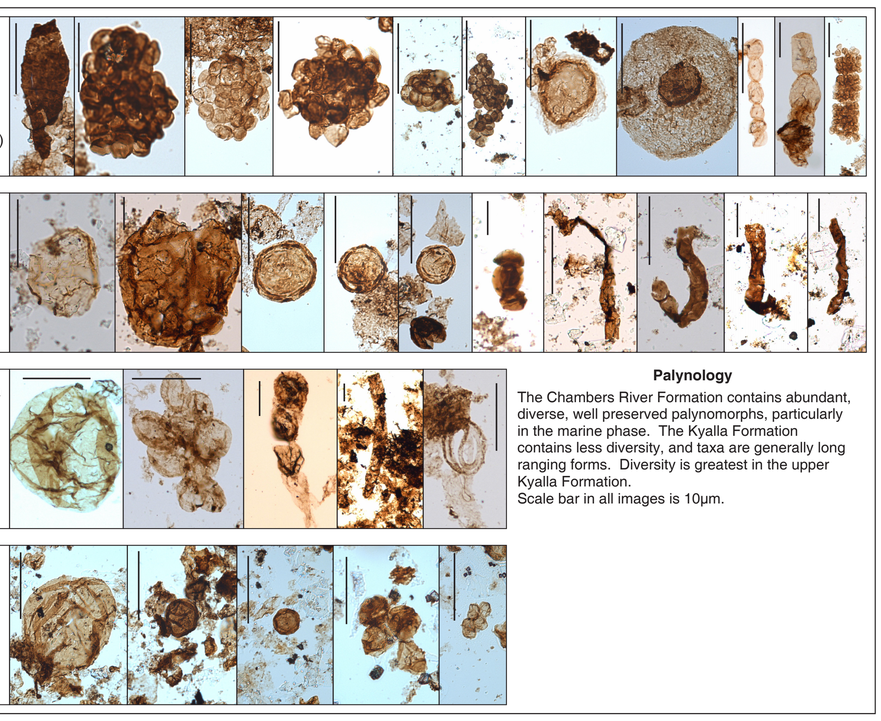
According to this palaeogeographic reconstruction at 1,100 Ma, northern Australia including the Beetaloo area, was located in near polar regions (no carbonates) whereas the São Francisco area was situated about 25 degrees from the equator (tillites inter-bedded with carbonates).

McMANUS-1 — Pacific Oil & Gas, 1989 — North — 37.1km — **CHANIN-1** — Pacific Oil & Gas, 1993 — 46.4km — **BALMAIN-1** — Pacific Oil & Gas, 1992 — 270m — **SHENANDOAH-1/1A** — Sweetpea Petroleum, 2007; Falcon Oil & Gas, 2009 — 20.5km — **MASON-1** — Pacific Oil & Gas, 1991 — 6.5km — **JAMISON-1** — Pacific Oil & Gas, 1990 — 67.9km — **ELLIOTT-1** — Pacific Oil & Gas, 1991 — South

Gamma Ray and Sonic Logs for Shenandoah-1/1A courtesy of Falcon Oil & Gas

Reinterpretations presented here suggest that some revision of stratigraphic nomenclature is needed. Use of the names Chambers River Formation and Kyalla Formation is derived from the usage of Pacific Oil & Gas in well completion reports. Proposed changes to terminology are indicated by the use of inverted commas and, for now, the names remain informal.

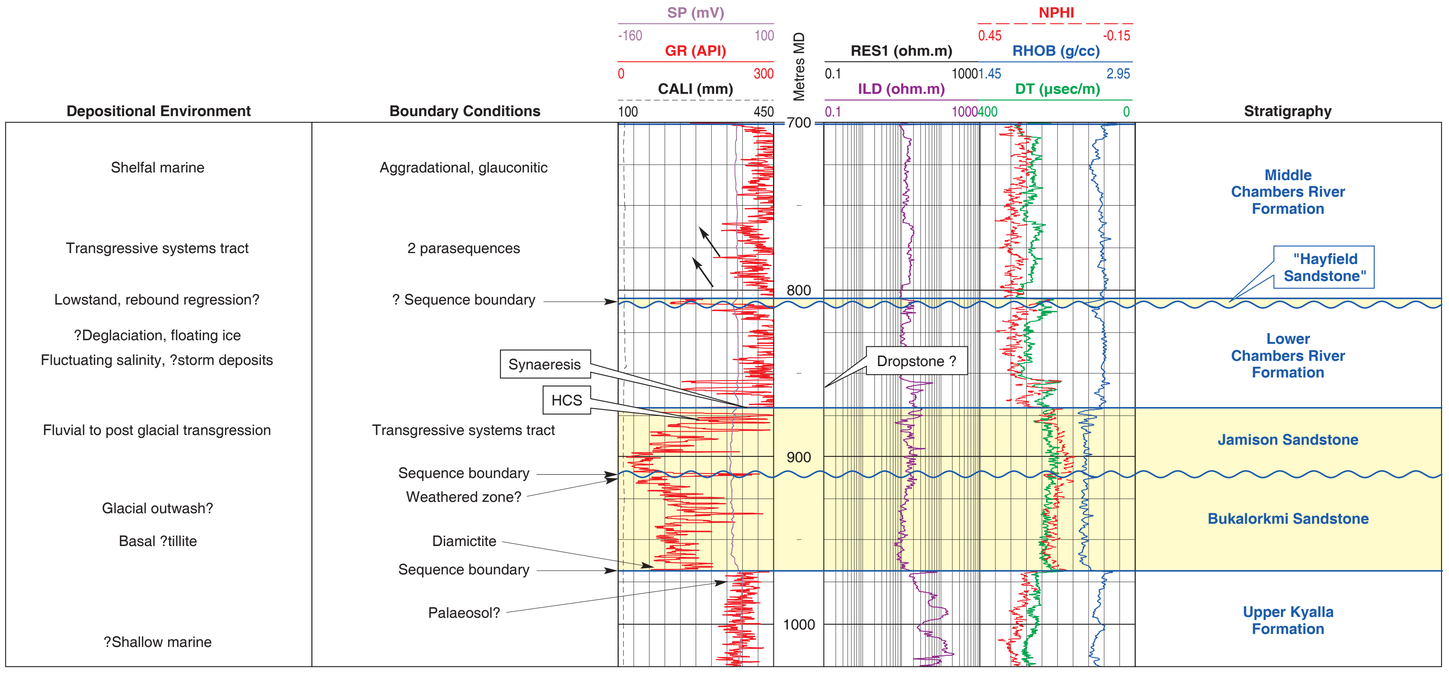




Palynology

The Chambers River Formation contains abundant, diverse, well preserved palynomorphs, particularly in the marine phase. The Kyalla Formation contains less diversity, and taxa are generally long ranging forms. Diversity is greatest in the upper Kyalla Formation.
Scale bar in all images is 10µm.

Jamison-1, Stratigraphy and Interpretive Depositional Environments



Lithological Note

The Bukalorkmi Sandstone, which lies between the shale and siltstone-dominated Chambers River Formation and the similarly fine-grained facies of the underlying Kyalla Formation, comprises two, regionally correlatable lithofacies. The lower, more radioactive sandstone-dominated interval with a thin, characteristic basal conglomerate sharply overlies the Kyalla Formation. The basal conglomerate is described in Jamison-1 well.

The upper interval commences with a basal conglomerate in several wells, but this conglomerate manifests with different log responses in different wells. In some wells the basal conglomerate has elevated gamma ray values, indicating the presence of radioactive material, in others the basal conglomerate, as in Jamison-1, is reflected in a density log peak, indicative of the presence of dense rocks within the conglomerate. The beds overlying the conglomerates are generally of low gamma ray facies indicative of clean sandstones. The gamma ray logs then reflect the upward transition into the lower Chambers River Formation suggestive of a fining upward sequence and a transgressive depositional regime.

The clearly defined change in lithofacies, accompanied by the basal conglomeratic unit at the base of the upper sedimentary package suggests that there is a change in the depositional conditions and the possible presence of an unconformity between the two units of the Bukalorkmi Sandstone. Future stratigraphic revision may need to reflect this regional lithofacies change by restricting the name Bukalorkmi Sandstone to the lower unit, and redefining the name Jamison Sandstone to include the upper upward fining unit. The break between the two units may be a Type I sequence boundary, reflecting either a change in depositional condition, or tectonism.

The base of the redefined Bukalorkmi Sandstone, i.e. the lower unit, would be a Type I sequence boundary, with a basal conglomerate and an erosional contact with the underlying Kyalla Formation, as suggested by the well log correlations north of the Balmain-1 well, where the upper Kyalla Formation is increasingly truncated below the Bukalorkmi Sandstone in Chanin-1 and McManus-1. Above the Jamison Sandstone, the gamma ray logs show that the fining upwards transition continues up into the shale-dominated Lower Chambers River Formation. This shaly package is abruptly replaced by a thin sandstone unit, here referred to informally as the "Hayfield Sandstone". It is currently unclear whether this is a direct equivalent of the formally defined Hayfield Mudstone.

This figure also illustrates the log character of the lower-most part of the middle Chambers River Formation above the Hayfield Sandstone, where two upward-coarsening cycles can be clearly defined on the gamma ray log in Jamison-1. These two cycles are correlatable across the well log section wherever the Chambers River Formation is preserved. The overlying higher gamma ray log unit is also correlatable across the well transect, and in Jamison-1 at 724.4 m contains up to 2% glauconite, indicative of a probable shallow shelf depositional environment. It is in this marine interval that abundant, diverse, well preserved palynomorphs are found, indicating that these organisms lived in shallow shelfal marine environments. Similar organisms are also found in the elevated gamma ray section in the basal Chambers River Formation at 808.2 m in Balmain-1, suggesting that this shaly section is also of shallow marine depositional origin.

Speculations on Depositional Environment

Re-Os system dating from the Middle Velkerri Formation of 1361 +/- 21 Ma indicates that the overlying Kyalla and Chambers River formations are younger. In the São Francisco area of Brazil, the Vazate Group contains two glacial horizons interbedded with carbonates deposited in the time frame 1353 +/- 69 Ma and 1063 +/- 190 Ma indicating mid to late Mesoproterozoic glaciation at palaeolatitudes of 25-30 degrees of the equator at least at 1100 Ma, and probably earlier. The Beetaloo Basin on this same reconstruction was located close to the pole, compatible with a lack of carbonates within the Kyalla and Chambers River formations.

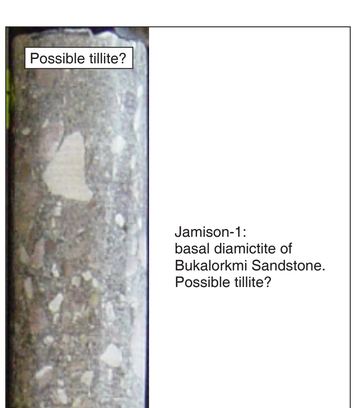
Circumstantial evidence suggests the possibility of a glacial imprint in the Mesoproterozoic depositional environment of the Beetaloo Sub-basin. Assuming the absolute age of the upper Velkerri is 1361 +/- 21 Ma, the age of the Kyalla-Chambers River interval is younger. Palaeogeographic maps show that the Beetaloo Sub-basin probably lay adjacent to a pole at about 1100 Ma. Within the Kyalla - Chambers River interval, the strata are mostly fine grained siliciclastics with long distance persistence of stratigraphic units suggestive of quiet depositional conditions. Near the top of the Kyalla Formation in Jamison-1, carbonate nodules with squared crystal terminations, probably formed before substantial compaction, are possibly glendonites, the presence of which indicates host-sediment accumulation under near freezing, highly alkaline, phosphate-rich bottom water conditions.

The Bukalorkmi Sandstone (as redefined here in Jamison-1) is a conglomeratic poorly sorted unit. The widespread basal conglomerate of the Bukalorkmi Sandstone lies unconformably upon shallow marine siliciclastics of the Kyalla Formation, with some evidence of an underlying palaeosol. The basal diamictite is thin, perhaps representing a glacially transported deposit.

The top of the Bukalorkmi Sandstone is regionally abrupt with another possible palaeosol development, and overlain by clean, well-sorted sandstones of possible fluvial deposition of the Jamison Sandstone (as defined here in Jamison-1). The Jamison Sandstone fines upward in a transgressive systems tract, with the presence of hummocky cross-bedding interpreted in some wells and synaeresis cracks attesting to storm deposition and fluctuating salinities, perhaps related to seasonal run-off changes.

A possible shale dropstone in rhythmically bedded shale and siltstones in the basal Chambers River Formation at McManus-1 suggests the potential for floating ice. The overlying Chambers River Formation contains up to 2% glauconite in Jamison-1 indicative of a shallow shelfal depositional environment in this part of the Chambers River Formation suggesting continued transgression.

A major global glacial episode need not be proposed, but the rising of a mountain chain may have allowed the development of a localised ice cap in proximity to a pole.



Jamison-1:
basal diamictite of Bukalorkmi Sandstone.
Possible tillite?

Jamison-1:
top of core, near top Jamison Sandstone reservoir
Synaeresis cracks indicative of fluctuating salinity?

McManus-1:
~451 m
Lower Chambers River Formation

Possible dropstone, or rafted frozen 'pebble' of muddy sand into ?varves

Bibliography

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Drafting by Shane McGilligan

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