

# Revision of the Neoproterozoic stratigraphic nomenclature of the Beetaloo Sub-basin, Northern Territory

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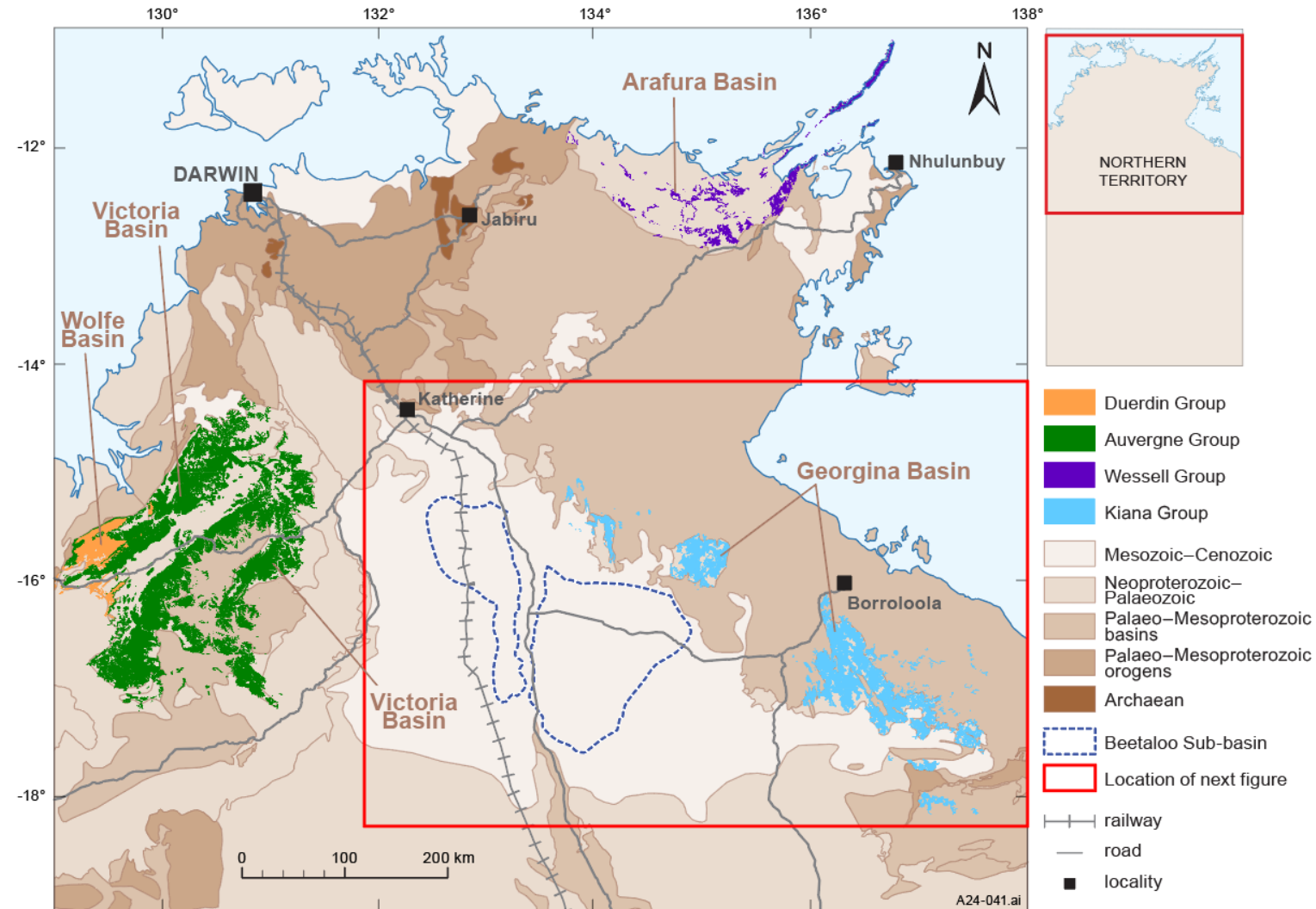
# Neoproterozoic stratigraphic issues in the Top End of the Northern Territory

## The problem

Considerable, historical and ongoing confusion in regards to the stratigraphic nomenclature, age, distribution and correlations of late Mesoproterozoic and Neoproterozoic formations in the central-northern NT, particularly in the sub-surface Beetaloo Sub-basin of the McArthur Basin, and adjacent areas.

## Aim of this study

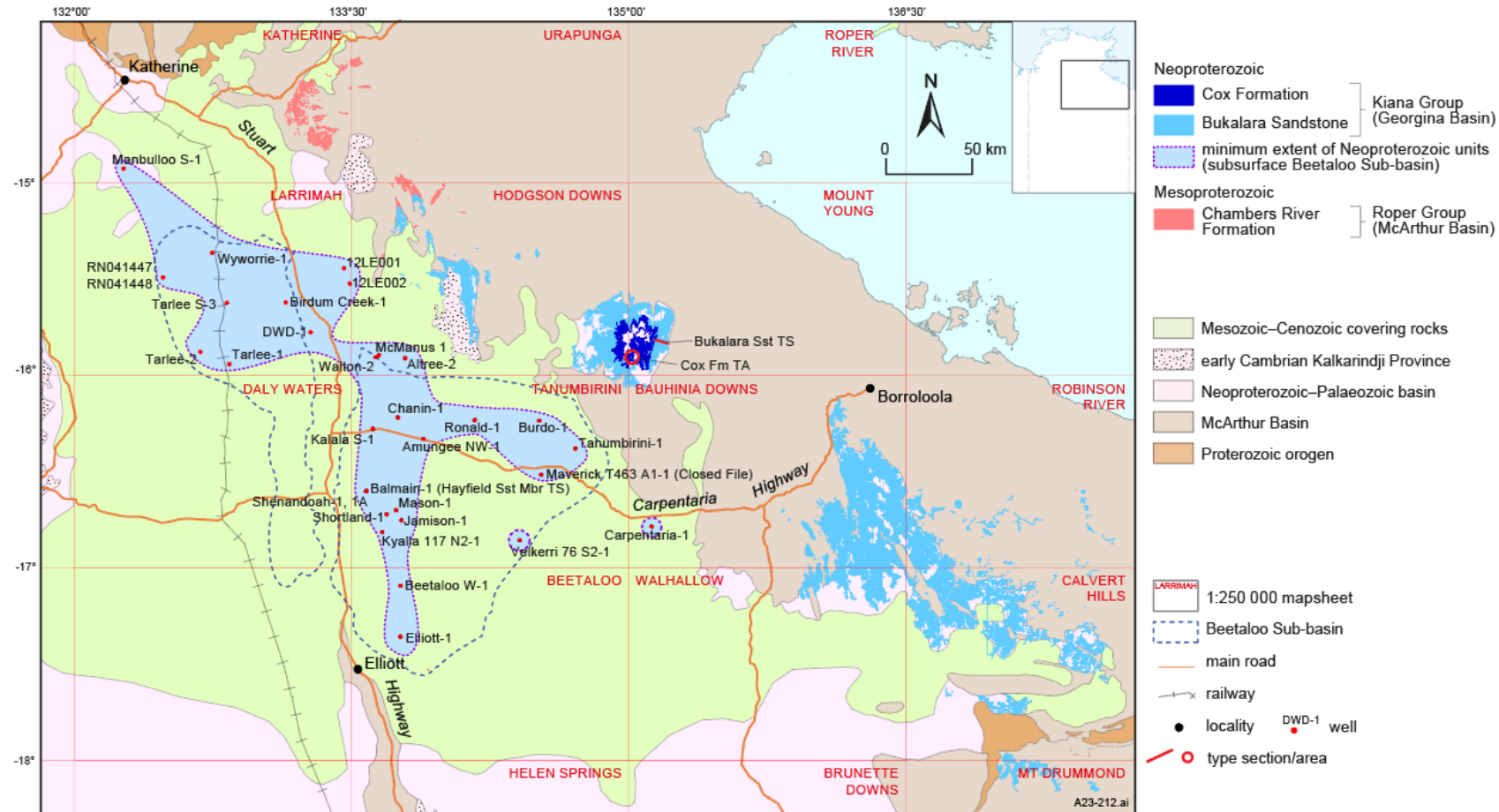
To identify and document the distinguishing characteristics of these late Mesoproterozoic and Neoproterozoic formations in order to better resolve their stratigraphic relationships.



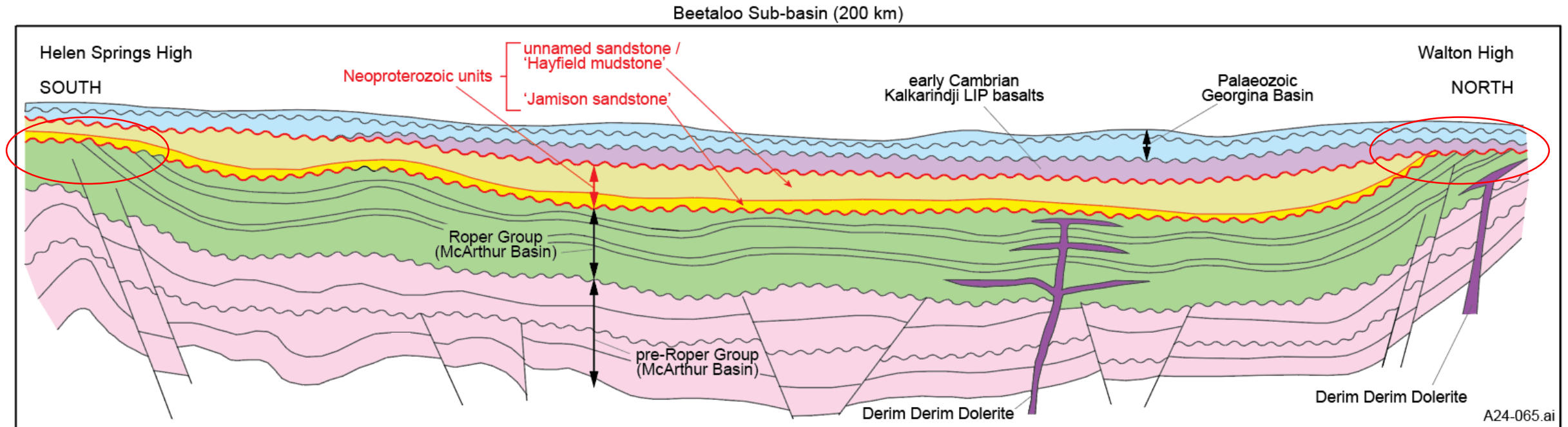
Distribution of outcropping Neoproterozoic rocks across the northern NT.

## Stratigraphic units included in this study

Geological region	Group	Formation
early Cambrian		
Kalkarindji Province	Kalkarindji Suite	
Neoproterozoic		
Georgina Basin	Kiana Group	Cox Formation
		Bukalara Sandstone
Beetaloo Sub-basin	ungrouped	Unnamed sandstone ('Inacumba unit')
		'Hayfield mudstone' including 'Hayfield sandstone member'
		'Jamison sandstone'
Mesoproterozoic		
Maiwok Sub-basin	Roper Group	Chambers River Formation
Derim Derim-Galiwinku LIP		Derim Derim Dolerite
Beetaloo Sub-basin	Roper Group	upper Roper Group (includes Kyalla and Velkerri formations)

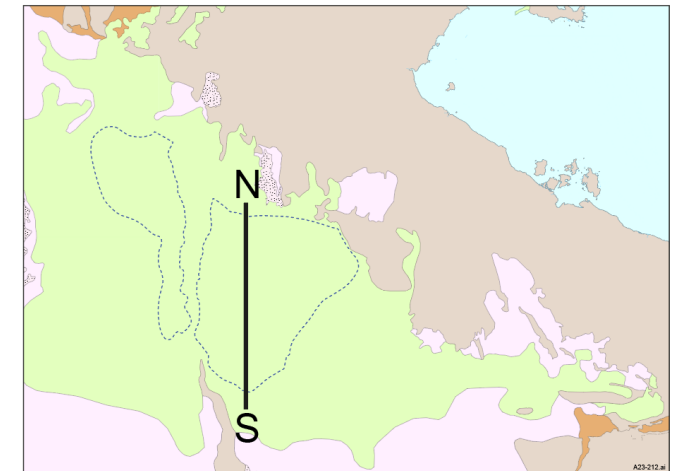


## Architecture of Beetaloo Sub-basin



South–north cross-section across sub-basin showing unconformable and intrusion relationships (modified from Silverman *et al* 2007).

- Derim Derim Dolerite (ca 1330–1295 Ma) intrudes all upper Roper Group formations in Beetaloo Sub-basin, but not Neoproterozoic units.
- Roper Group is gently folded; overlying units are not.
- Unconformities occur below and above Neoproterozoic units.





# Outcropping Neoproterozoic units of Georgina Basin (Kiana Group)

## Kiana Group

- Unconformable on Meso- to Palaeoproterozoic rocks of McArthur and South Nicholson basins.
- Unconformably overlain by early Cambrian (ca 513 Ma) Kalkarindji Suite of the Kalkarindji Large Igneous Province.
- Flat-lying – not deformed by late Mesoproterozoic post-Roper Group deformation (ca 1300–1050 Ma: Betts *et al* 2015).
- Not intruded by ca 1330–1295 Ma Derim Derim Dolerite.

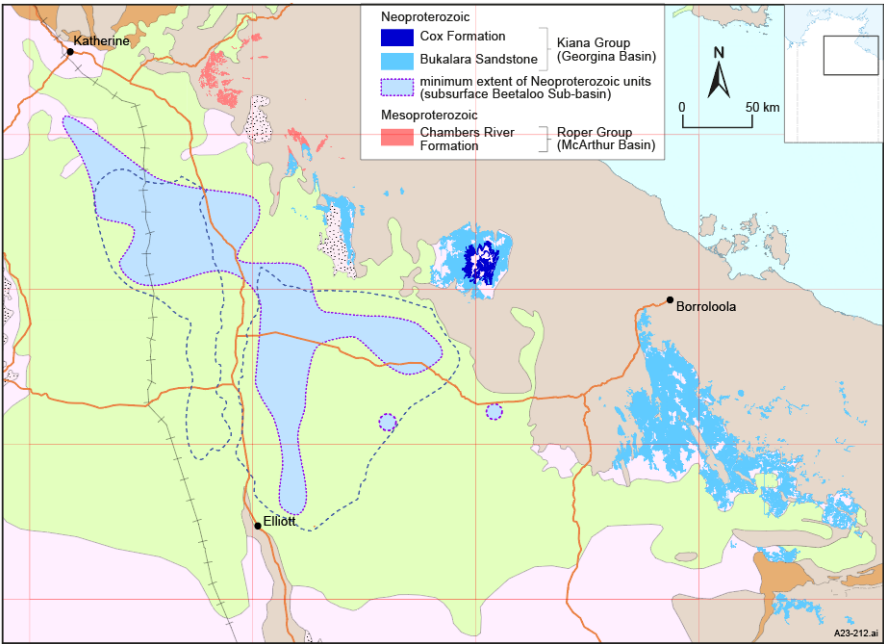
A24-067.ai	early Cambrian	
	Kalkarindji Suite	
	Neoproterozoic	
	Kiana Gp	Cox Formation
		Bukalara Sandstone
	Unnamed sandstone ('Inacumba unit')	
	'Hayfield mudstone'	
	'Jamison sandstone'	
	Mesoproterozoic	
	Chambers River Formation	
	Derim Derim Dolerite	
	upper Roper Group	

## Cox Formation

- Conformable on Bukalara Sandstone.
- Mudrock-dominated unit; minor sandstone.
- 50 m thick (top removed by erosion).

## Bukalara Sandstone

- Fine- to coarse-grained sandstone, minor conglomerate and mudrock.
- Up to 300 m thick.



Cross-bedded and ripple marked, generally flat-lying bedsets of Bukalara Sandstone.

# Subsurface Neoproterozoic units of Beetaloo Sub-basin

- Unconformable on Mesoproterozoic Roper Group.
- Unconformably overlain by early Cambrian Kalkarindji Suite (ca 513 Ma).
- Flat-lying – not deformed by late Mesoproterozoic post-Roper Group deformation.
- Not intruded by ca 1330–1295 Ma Derim Derim Dolerite.

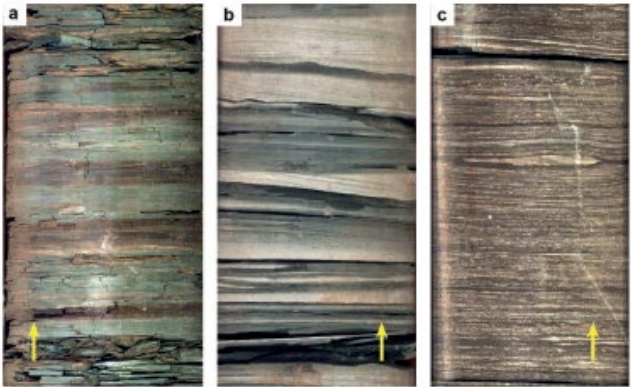
Unnamed sandstone formation in drill core: massive, medium-grained.



## Unnamed sandstone formation (= ‘Inacumba unit’).

- Unconformable on ‘Hayfield mudstone’
- Medium- to coarse-grained sandstone.
- 60–380 m thick.

Kiana Gp	early Cambrian
	Kalkarindji Suite
	Neoproterozoic
	Cox Formation
	Bukalara Sandstone
A24-067.ai	Unnamed sandstone ('Inacumba unit')
	'Hayfield mudstone'
	'Jamison sandstone'
	Mesoproterozoic
	Chambers River Formation
	Derim Derim Dolerite
	upper Roper Group



‘Hayfield mudstone’ in drill core: laminated mudrock; note cross-lamination and normal grading (centre).

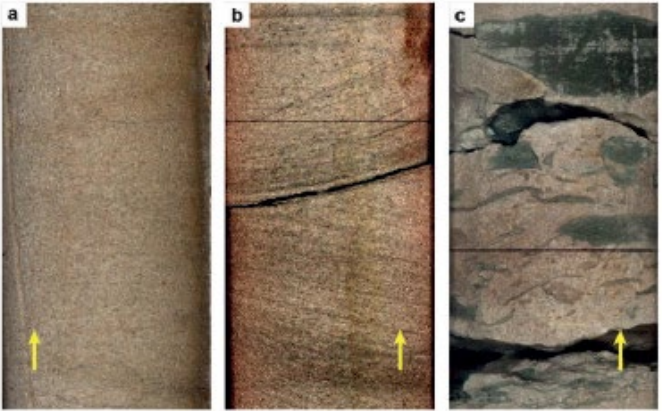
## ‘Hayfield mudstone’ (original informal name)

- Conformable on ‘Jamison sandstone’.
- Mudrock-dominated unit; minor sandstone.
- Includes 10–15 m-thick Hayfield Sandstone Member.
- <100–570 m thick.

## ‘Jamison sandstone’ (original informal name)

- Very fine- to coarse-grained sandstone, minor conglomerate and mudrock.
- 80–160 m thick.

‘Jamison sandstone’ in drill core: massive (left); cross-bedded (centre); with deformed mudclasts (right).





# Chambers River Formation

- Youngest formation of Roper Group.
- Outcrops to north of Mallapunyah Fault Zone (dashed line) in 'Maiwok Sub-basin'. Not present in subsurface Beetaloo Sub-basin.
- Correlated / equated with 'Hayfield mudstone' in some previous publications.
- Recessive mudrock and lesser resistant fine sandstone.
- 2000 m thick.

Kiana Gp	early Cambrian
	Kalkarindji Suite
	Neoproterozoic
	Cox Formation
	Bukalara Sandstone
A24-067	Unnamed sandstone ('Inacumba unit')
	'Hayfield mudstone'
	'Jamison sandstone'
	Mesoproterozoic
A18-005a	Chambers River Formation
	Derim Derim Dolerite
	upper Roper Group



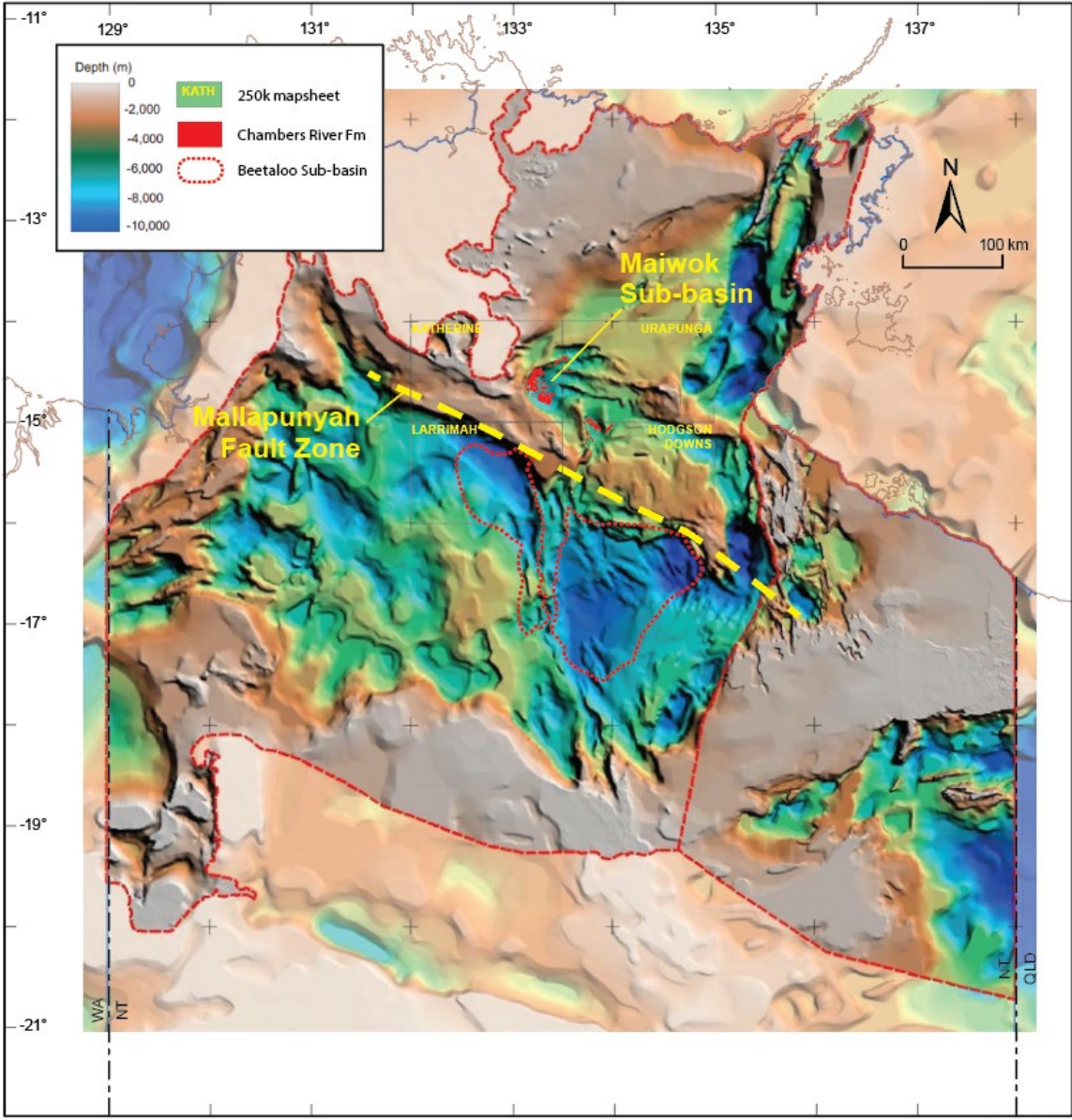
Type section: moderately dipping sandstone bedsets.



Interference ripples.



Typical recessive mudrock float.



SEEBASE™ depth-to-basement map of northern NT



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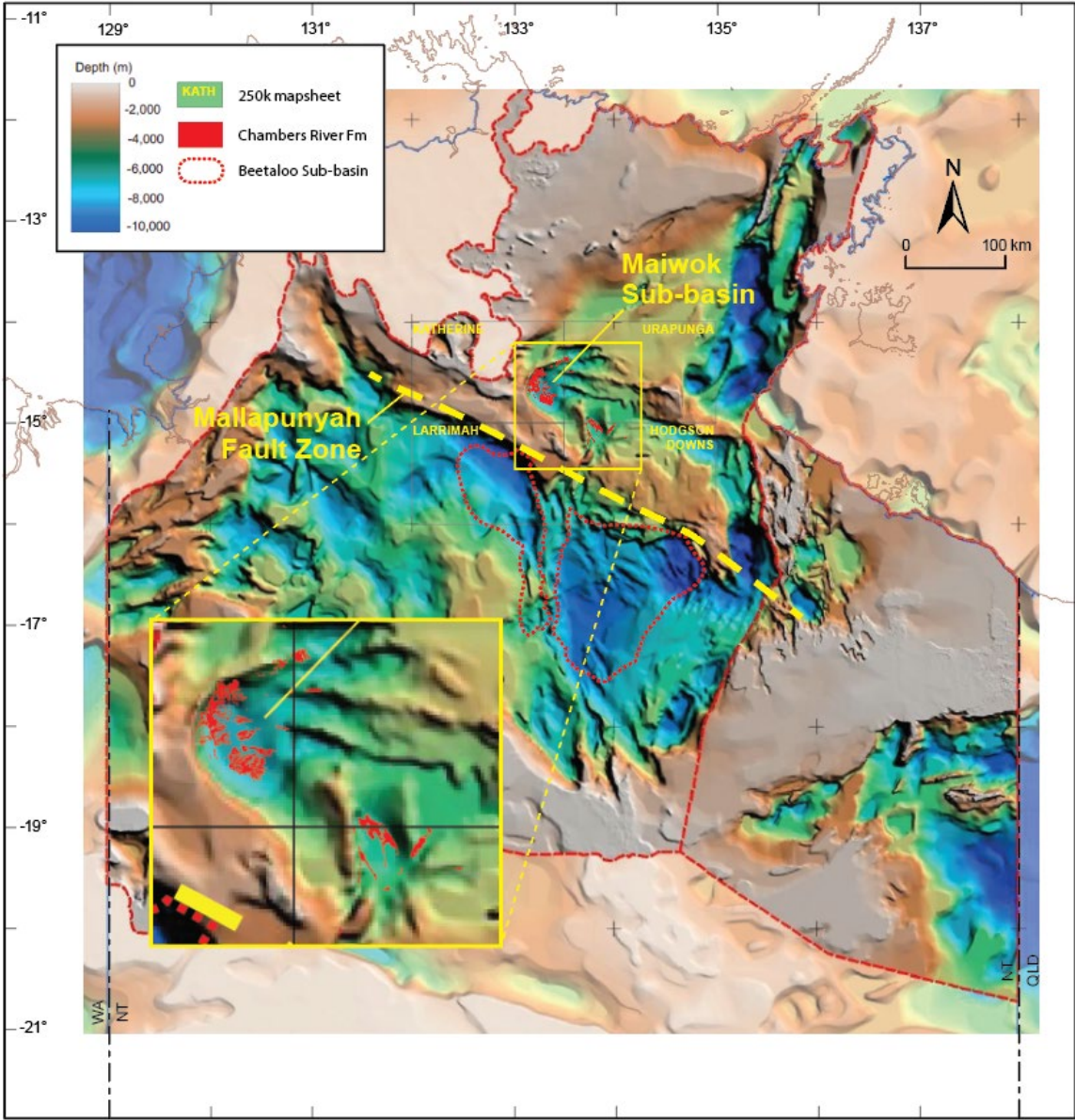
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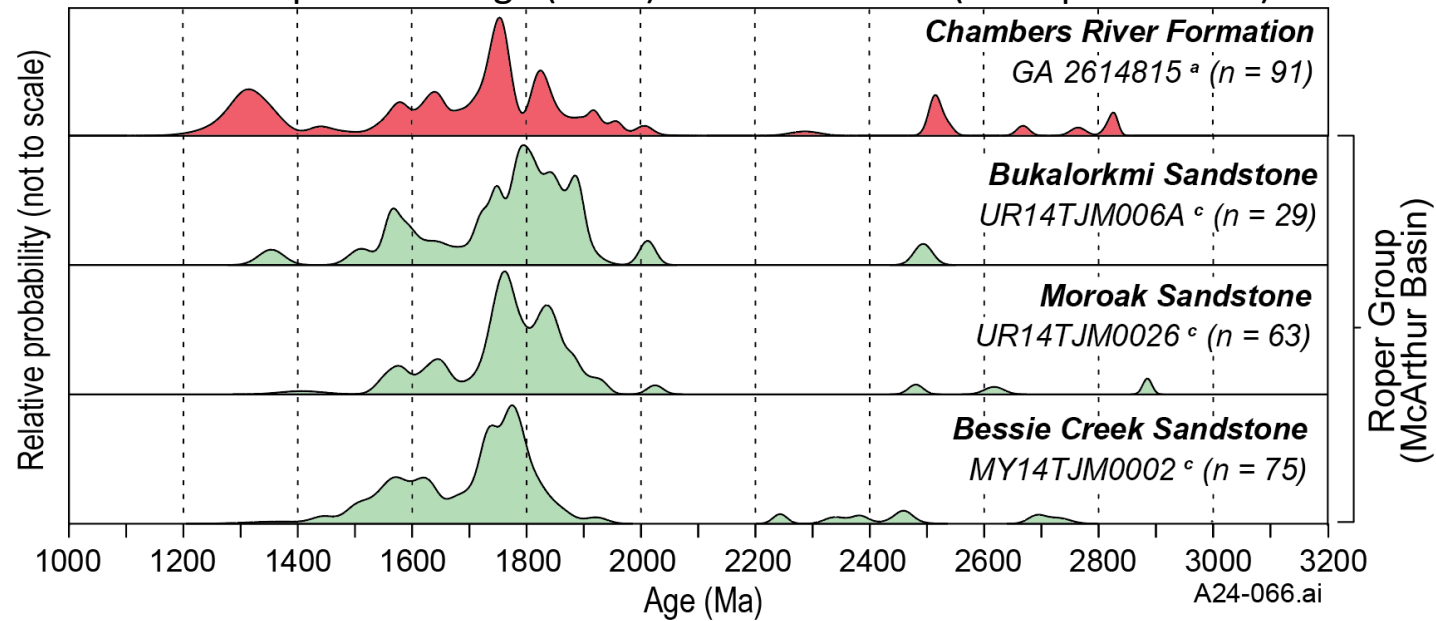


SEEBASE™ depth-to-basement map of northern NT

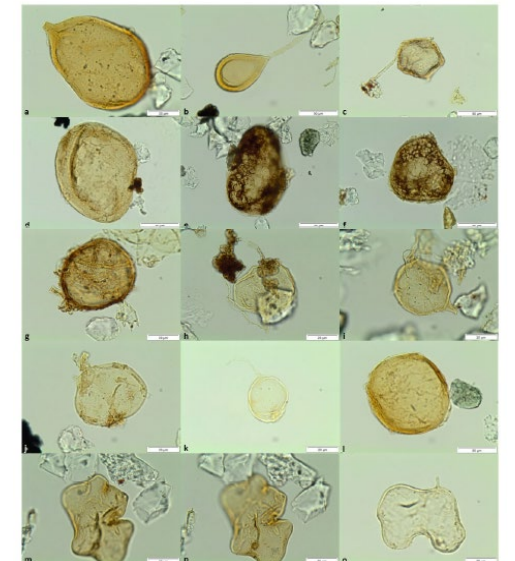
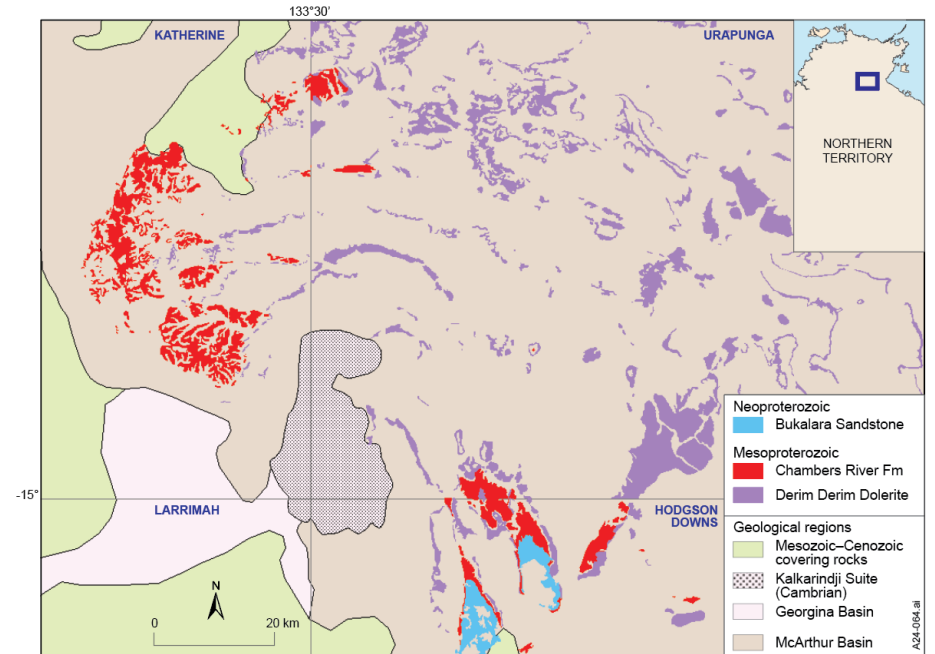


## Chambers River Formation: age and stratigraphic affinities

- Unconformably overlain by Neoproterozoic Bukalara Sandstone (Georgina Basin).
- Not intruded by ca 1330–1295 Ma Derim Derim Dolerite.
- Folded and faulted by late Mesoproterozoic Post-Roper Group deformation, which indicates a late Mesoproterozoic age.
- Mesoproterozoic age is also supported by palynological investigations.
- U–Pb detrital zircon age spectrum resembles those of Roper Group.
- Maximum depositional age (MDA) is  $1320 \pm 15$  Ma (Mesoproterozoic).



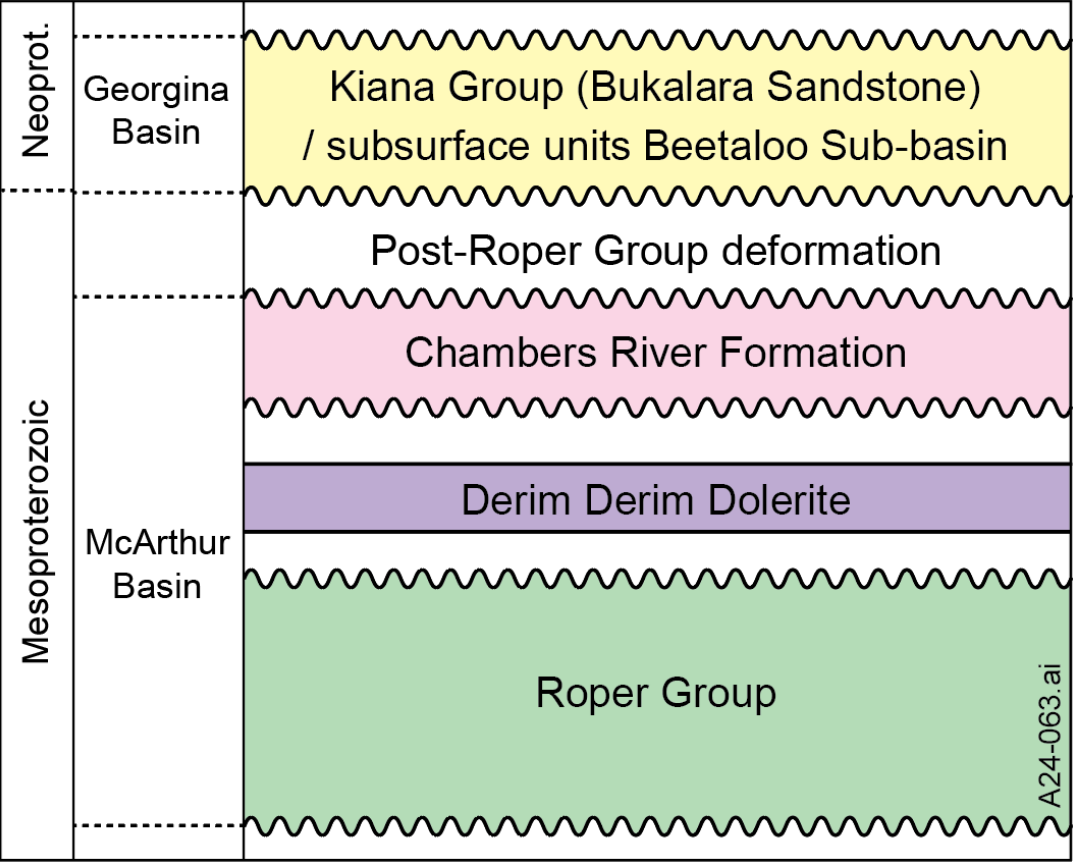
Comparative relative probability diagram of U–Pb detrital zircon age data.  $n$  = number of analyses;  
 $a$  = Kositsin *et al* (2017);  $b$  = Carson (2013);  $c$  = Munson *et al* (2018).



Mesoproterozoic acritarchs from  
Chambers River Formation  
(Hawkes 2017).



# Chambers River Formation: Conclusions



- Chambers River Formation postdates both Roper Group and ca 1330–1295 Ma Derim Derim Dolerite
- Chambers River Formation predates late Mesoproterozoic Post-Roper Group deformation.
- Post-Roper Group deformation predates flat-lying Bukalara Sandstone and subsurface Neoproterozoic units of Beetaloo Sub-basin.
- Chambers River Formation is unconformably overlain by Bukalara Sandstone.
- Age of Chambers River Formation is therefore constrained to late Mesoproterozoic.

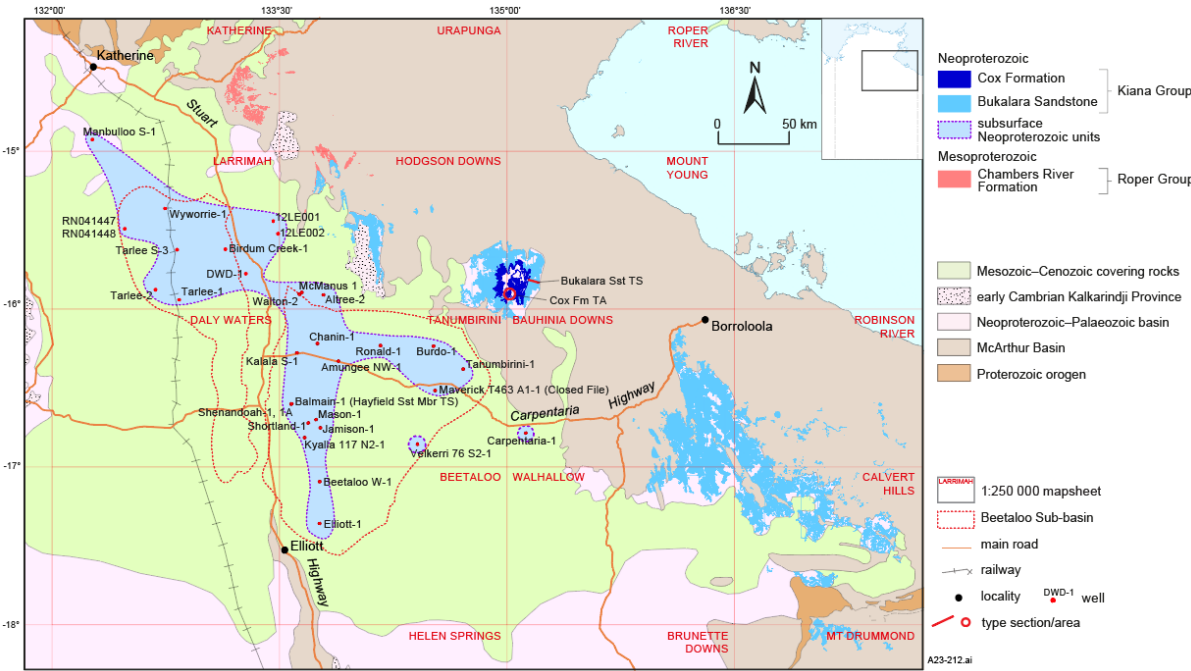
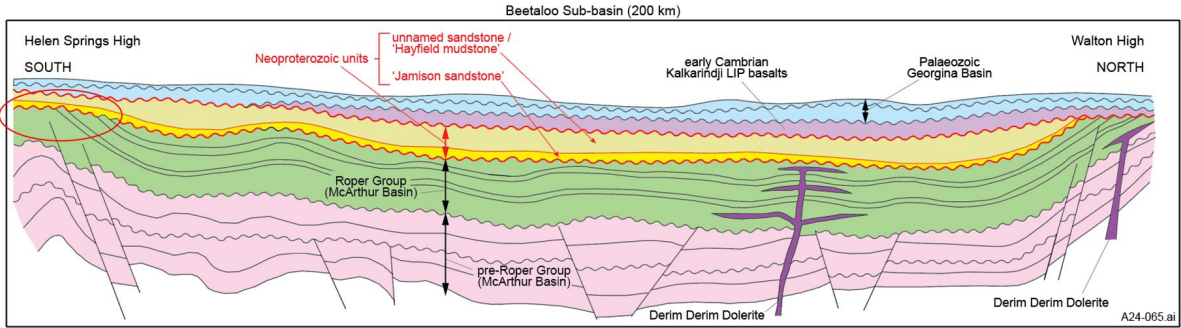
**Chambers River Formation is not a Neoproterozoic formation and is not related to subsurface Beetaloo Sub-basin formations.**



# Neoproterozoic units in Beetaloo Sub-basin and Georgina Basin: Summary of stratigraphic relationships

	Unconformable or disconformable on Roper Group	Intruded by Derim Derim Dolerite	ca 1300–1050 Ma post-Roper Gp deformation?
Kiana Group (outcrop)	Yes	No	No (flat-lying)
Subsurface formations (Beetaloo Sub-basin)	Yes	No	No (flat-lying)
Chambers River Fm	Yes	No	Yes (folded)
Roper Group		Yes	Yes (folded)

- Kiana Group and ‘Jamison/Hayfield’ units occupy the same relative stratigraphic position.
- Bukalara Sandstone and Cox Formation have the same geological characteristics as ‘Jamison sandstone’ and ‘Hayfield mudstone’ respectively.
- Kiana Group is the only possible outcropping correlative of the ‘Jamison/Hayfield’ succession in the vicinity of the Beetaloo Sub-basin.

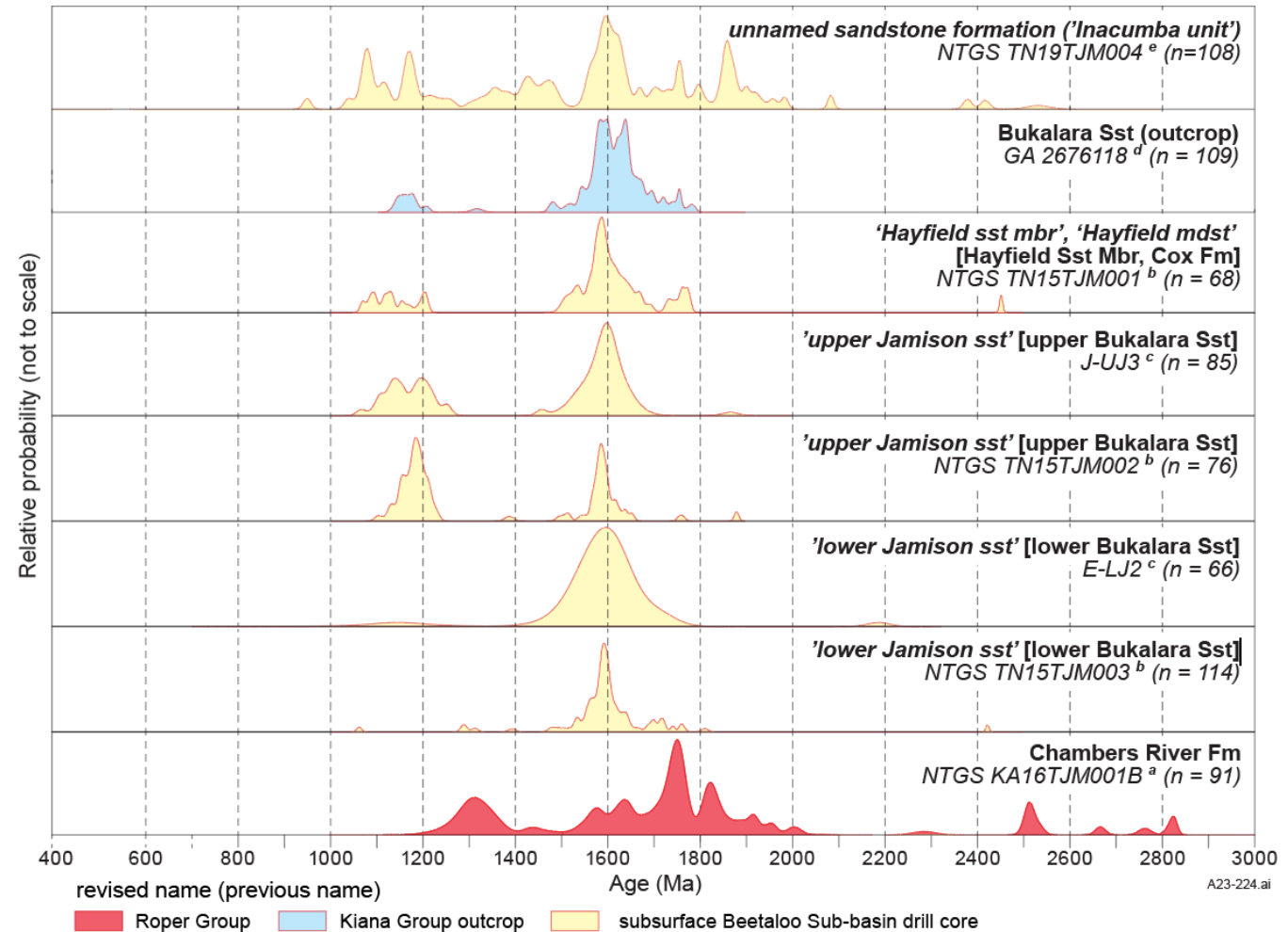




## Neoproterozoic units: Summary of geochronology results and comparison with other detrital zircon age spectra

U–Pb detrital zircon age data support lithostratigraphic evidence that Kiana Group and subsurface Neoproterozoic units in Beetaloo Sub-basin are equivalents.

- ‘Jamison/Hayfield’ units have very distinctive bimodal detrital zircon age spectra with sparse zircons older than 1900 Ma.
- Genuine Bukalara Sandstone spectrum is indistinguishable from those of upper ‘Jamison sandstone’ and ‘Hayfield mudstone’.
- Conservative maximum depositional age for Bukalara Sandstone is indistinguishable from that of upper ‘Jamison sandstone’. These units are probable age-equivalents.
- Maximum depositional ages (youngest zircons) for all formations are all <1100 Ma, whereas those of underlying Roper Group (including Chambers River Formation) are all >1300 Ma.
- Unnamed sandstone formation at top of subsurface succession has some age peaks in common with Kiana Group, but an otherwise distinctive and different spectrum. Maximum deposition age of  $952 \pm 8$  Ma (single grain) clearly shows that this is a Neoproterozoic formation.



Comparative relative probability diagram of U–Pb detrital zircon age spectra. Revised names in square brackets. n = number of analyses. a = Kositcin *et al* (2017); b = Munson *et al* (2018); c = Yang *et al* (2018); d = Anderson *et al* (2019); e = Munson *et al* (2020).

Summary and conclusions:

Based on lithostratigraphic evidence supported by U–Pb detrital zircon geochronology results:

- The Chambers River Formation is late Mesoproterozoic in age and has no equivalents in the subsurface Beetaloo Sub-basin.
- The ‘Jamison sandstone’ and ‘Hayfield mudstone’ in the Beetaloo Sub-basin are identified as subsurface Kiana Group (Georgina Basin), equivalent to the Bukalara Sandstone and Cox Formation respectively.
- Older, formally defined Kiana Group names take precedence over informal Beetaloo Sub-basin names and have nomenclatorial priority.

Summary of nomenclature changes

Previous studies		Record 2023-012	
ungrouped	unnamed sandstone formation / Inacumba unit	Kiana Group	unnamed sandstone formation
	Hayfield Mudstone/mudstone (including Hayfield sandstone member)		Cox Formation (including Hayfield Sandstone Member)
	upper Jamison Sandstone/sandstone/sands		upper Bukalara Sandstone
	lower Jamison sandstone/sandstone/sands		lower Bukalara Sandstone

**Report:** Munson TJ, 2023. Revision of the Neoproterozoic stratigraphic nomenclature of the Beetaloo Sub-basin, Northern Territory. *Northern Territory Geological Survey, Record 2023-012.*



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