Dating and characterising a newly discovered sedimentary basin in the East Tennant region

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The greater McArthur Basin encompasses the exposed McArthur Basin in the north and northeast, the Beetaloo Sub-basin to the centre and southwest, the Tomkinson Province in the south, and the Birrindudu Basin in the west (**Figure 1**). These are all interpreted through seismic and geochronological data to be laterally continuous in the subsurface. To the east, equivalent successions occur in the South Nicholson Basin and in the Mount Isa region, which are separated from their western equivalents by a palaeogeographical high of the Murphy Inlier (Rawlings 1999, Jackson *et al* 2000, Ahmad and Munson 2013). The Neoproterozoic to Devonian Georgina and Wiso basins, and the Mesozoic Carpentaria and Arafura basins unconformably overlie the region and bury a basement high long known to link the Murphy Inlier with the Tennant region (**Figure 1**).

Stratigraphic drillhole NDIBK10, located ~200 km east of Tennant Creek, was drilled in this Murphy to Tennant region, targeting a low magnetic/gravity corridor that has been named the Brunette Downs Rift Corridor by Geoscience Australia in their 'Barkly Deep Crustal Reflection Seismic Survey' (Carson *et al* 2021). It is situated next to the Carrara Domain of the South Nicholson Basin, where it is bound by a steeply dipping basement-penetrating fault (Carson *et al* 2021). A complex fault zone separates its western edge from the Beetaloo-McArthur domain. It was originally targeted to intercept shallow basement; however, the drilling revealed sedimentary rocks of unknown origin below the basalts of the Helen Springs Volcanics.

Aeromagnetic images show several southwest–northeast-trending structures within the Brunette Downs Rift Corridor. Seismic interpretations of the structures reveal two southeasterly dipping half-grabens. These are controlled by steeply dipping, extensional faults with sub-parallel subsidiary faults (Carson *et al* 2021). The half-grabens extend to depths of ~6 km and are interpreted by Carson *et al* (2021) to contain all four 'superbasin' sequences of the Mount Isa region: the Paleoproterozoic Leichhardt, Calvert and Isa superbasins and the Mesoproterozoic Roper Superbasin. With this in mind, we suggest that the unknown sedimentary rock sequence in NDIBK-10 lies within a small version of these half-graben structures, beneath the Helen Springs Volcanics (base found at 297 m) and continuing to the basement (contact at 724 m). The top portion of the drillhole passes through ~300 m of the extensive Cambrian to Devonian Georgina Basin, which covers much of the surrounding region. The Georgina Basin was deposited in an intracontinental environment, and is thought to be part of the interconnected Centralian Superbasin during the Cambrian (Walter *et al* 1995). It may have been open to the Palaeozoic Pacific Ocean to the east. The base of the Georgina Basin is marked by the Helen Springs Volcanics of the Kalkarindji Province, which extends over large areas

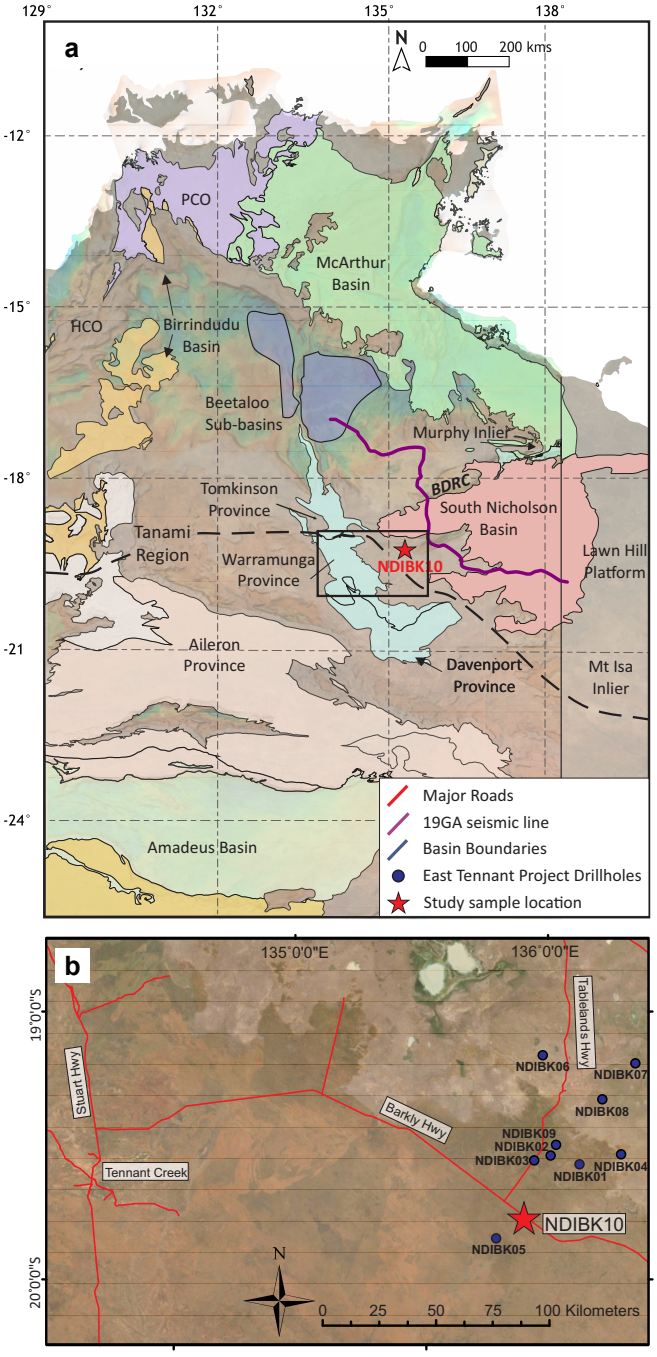

Figure 1. (**a**) SEEBASE® depth to basement map showing the 19GA seismic line (purple line), the extent of the Brunette Downs Rift Corridor (BDRC) and surrounding basins, location of the drill hole studied (Carson *et al* 2021), extent of **Figure 1b** (rectangle), and the location of main basins and provinces. The southern extent of the greater McArthur Basin is marked with a bold dashed line. PCO = Pine Creek Orogen; HCO = Halls Creek Orogen. (**b**) Location map showing all 10 holes drilled as part of the MinEx CRC National Drilling Initiative East Tennant Project in relation to major roads. Background map from Google Earth.

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of the Northern Territory, northern Western Australia and western South Australia (Ware *et al* 2018). It is part of a large igneous province that formed in the middle Cambrian from continental flood basalts (Ware *et al* 2018). The Helen Springs Volcanics overlie an unconformity and the newly discovered unknown sedimentary rock sequence.

The main aims of the study were to determine when the original sediments were deposited, under which depositional conditions, and whether the resulting sedimentary rocks still record the chemistry of the environment at which they formed or have been overprinted by later diagenesis or hydrothermal alteration. From these data, we can make an informed hypothesis of the possible provenance and correlations of this unknown sedimentary rock package.

The sedimentary rocks were logged in detail from 277–740 m, between the base of the Helen Springs Volcanics and the basement (**Figure 2**). This stratigraphic sequence was divided into six distinct units that were defined in the NDIBK10 HyLogger™ Data Package 0107 (Smith 2021) and correlated with changes in physical rock properties. The units are referred to as Sedimentary Unit A, B, C, D and E. The uppermost unit (Unit A) is separated from the rest by an erosional unconformity. Overall, there is evidence for two marine transgressions in the lower units, with an initial flooding above the basal unconformity that led to a regressive sequence built on the initial flooding surface and marked by the transition from the shelf sands of Unit E to the tidal flat deposits of Unit D. The sequence linking from Units D through to B forms a second major transgression: from a tidal lagoon facies (Unit D) through to a carbonate shelf (Unit C) that is drowned by a deep marine environment marked by the thinning-upward turbidites of Unit B. These transgressions are likely related to syn-depositional rifting and activation of the half-graben bounding faults.

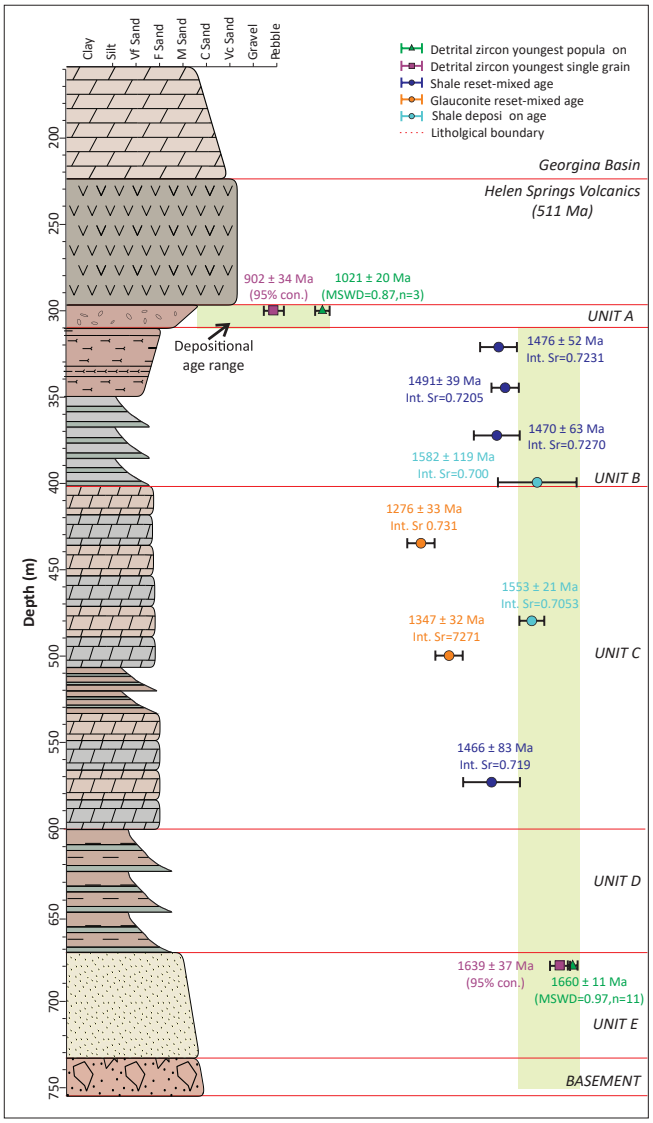

Figure 2. Simplified stratigraphic log showing depth compared to all age results from sedimentary rocks, and depositional windows established from results. MSWD = Mean Squared Weighted Deviates; Int. Sr = Initial $^{87}Sr/^{86}Sr$ ratio with no ingrown radiogenic component; con. = Concordant; n = number of analyses.

Multiple palaeo-redox proxies from shale geochemistry suggest that sediments were deposited in a primarily oxic environment, becoming less oxic up section (at ~350 m depth). This change coincides with one of two transgressional sequences defined from the sedimentology. Shales from NDIBK10 have Eu* ranging from 0.819–0.924 (average 0.85); Ce* values between 0.798–0.951 (average 0.89); Mo values of 0.058–5.959 (average 0.66); and Th/U ratios which vary between 3.96–8.83.

Maximum depositional ages (U–Pb in zircon) from both above and below the Unit A unconformity yielded ages of 902 ± 34 Ma (Unit A) and 1649 ± 37 Ma (Unit E) respectively, based on youngest concordant grain (**Figure 3**). This confirms that the thin Unit A is Neoproterozoic and likely represents a continuation of the pre-Cambrian part of the Georgina Basin in this area. In hopes of constraining a minimum depositional age for the older sediments, Rb–Sr in shales (Subarkah *et al* 2021), carbonates and glauconites were collected. A combined shale and carbonate sample from Unit C returned what is interpreted to be close to a minimum depositional age of 1547 ± 13 Ma. Combined with results from U–Pb geochronology, a depositional window between 1671 Ma and 1534 Ma was established.

How do these sediments correlate to the greater McArthur Basin and from where could they have been sourced?

The greater McArthur Basin (and Beetaloo Sub-basin) are found to the north and west of the drillhole NDIBK10. To the west of the drillhole, sit the Warramunga and Tomkinson provinces, and to the far west, the Tijunna and Bullita groups in the Birrindudu Basin. All these areas provide potential correlatives of the sediments in NDIBK10. With such vast amounts of data, using multi-scale dimensional (MDS) plots provides a simpler way to visualise the detrital zircon spectra and make comparisons to potential correlatives and provenance source areas (Vermeesch 2013). The age distribution of detrital zircons shows that the unknown sedimentary rocks are most similar to the lower McArthur Group (Glyde package) or Bullita Group (Favenc package). The shale Rb–Sr age, interpreted to be close to the age of deposition at 1547 ± 13 Ma, suggests that the Favenc Package (**Figure 3**) is the most likely of these

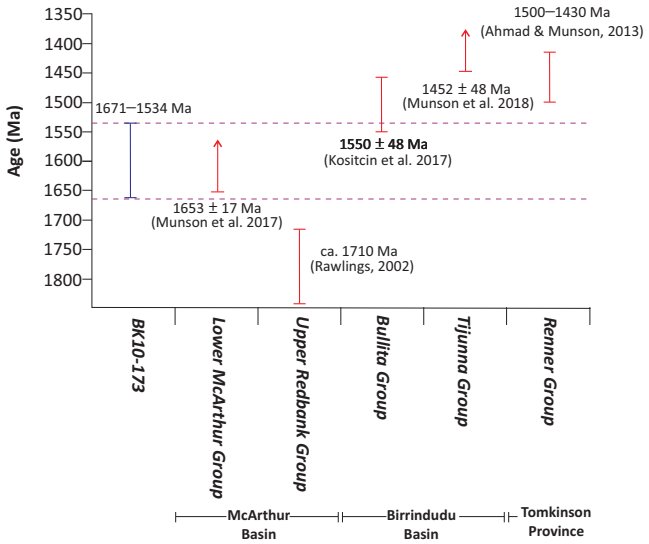

Figure 3. Comparison between interpreted depositional window of sedimentary rocks from NDIBK10 with surrounding sedimentary packages (Rawlings 2002, Ahmad and Munson 2013, Munson *et al* 2018, Kositcin and Carson 2017, Munson 2019).

possibilities. The provenance of these detrital zircons can also be unravelled using a MDS plot. Both the Arnhem and Tanami provinces plot close to NDIBK10. However, both provinces are geographically distant to the drillhole and seemingly were not experiencing uplift during this timeframe. A possibility is the Aileron Province to the south due to uplift in the region during this time (Chewings Event at ca 1600–1570 Ma; Claoué-Long *et al* 2008), although determining this would require more robust detrital studies of both the lower McArthur Group and the paleo-tectonism. Another possibility is that the sediments were recycled from another sedimentary basin, thus the detrital studies would reflect the source basin's age distribution of zircons.

The work conducted illustrates the power of using a multi-proxy approach on an unknown sequence of rocks; it has been used to a) correlate between sequences and boreholes up to 1000 km apart; b) determine and understand the depositional environment using geochemistry and sedimentology; and c) unravel the tectonic evolution of the basin by examining source-to-sink pathways for sediments through time.

From this study, we have determined the following:

- Maximum depositional ages were established from both above and below the Unit A unconformity by using U–Pb in detrital zircons. These yielded ages of 902 ± 34 Ma and 1649 ± 37 Ma respectively, based on youngest concordant zircon.
- A minimum depositional age of 1547 ± 13 Ma was established using Rb–Sr dating from a shale in Unit C. Glauconite (Rb–Sr) have been reset between 1350–1250 Ma, suggesting a later Mesoproterozoic hydrothermal infiltration.
- This sedimentary package is comprised of turbidites, carbonates and sands; and overall can be interpreted to represent two main transgressions whereby these sediments were deposited in a relatively oxic environment.
- The provenance of the detrital zircons within NDIBK10 shows similarity to the Favenc package (and Bullita Group in the Birrindudu Basin), which could provide a correlative. Populations within these sediments also suggest derivation from the south Aileron Province; however, recycling of other basin material cannot be discounted.

References

Ahmad M and Munson TJ (compilers), 2013. Geology and mineral resources of the Northern Territory. *Northern Territory Geological Survey, Special Publication* 5.

Southby C, Rollet N, Carson C, Carr L, Henson P, Fomin T, Costelloe R, Doublier M and Close D, 2021. The *Exploring for the Future* 2019 Barkly 2D Deep Crustal Reflection Seismic Survey: Key discoveries and implication for resources: in '*Annual Geoscience Exploration Seminar (AGES) Proceedings, Alice Springs, Northern Territory, 20–21 April 2021*'. Northern Territory Geological Survey, Darwin, 24–29.

Claoué-Long J, Maidment DW, Hussey K and Huston D, 2008. The duration of the Strangways Event in central Australia: Evidence for prolonged deep crust processes. *Precambrian Research* 166, 246–262.

Jackson MJ, Southgate PN, Winefield PR, Barnett K and Zeilinger I, 2000. Revised sub-division and regional correlations of the McArthur Basin succession based on NABRE's 1995–8 sequence stratigraphic studies. *Australian Geological Survey Organisation, Record* 2000/03.

Kositcin N, Carson CJ, Hollis J, Glass L, Close D, Whelan J, Webb G and Donellan N, 2013. Summary of results: Joint NTGS-GA geochronology project : Arunta Region, Davenport Province and Pine Creek Orogen, July 2009–June 2011, *Northern Territory Geological Survey, Record* 2012-008.

Munson TJ, 2019. Detrital zircon geochronology investigations of the Glyde and Favenc packages: Implications for the geological framework of the greater McArthur Basin, Northern Territory: in *'Annual Geoscience Exploration Seminar (AGES) Proceedings, Alice Springs, Northern Territory, 19–20 March 2019*'. Northern Territory Geological Survey, Darwin, 33–43.

Munson TJ and Revie D, 2018. Stratigraphic subdivision of the Velkerri Formation, Roper Group, McArthur Basin, Northern Territory. *Northern Territory Geological Survey, Record* 2018-006.

Rawlings D, 2002. *Sedimentology, volcanology and geodynamics of the Redbank Package, McArthur Basin, northern Australia*. PhD thesis, University of Tasmania, Hobart.

Rawlings DJ, 1999. Stratigraphic resolution of a multiphase intracratonic basin system: The McArthur Basin, northern Australia, *Australian Journal of Earth Sciences*. 46(5), 703–723.

Smith BR, 2021. HyLogger drillhole report for NDIBK10, MinEx CRC National Drilling Initiative, Campaign 1 East Tennant, Northern Territory. *Northern Territory Geological Survey, HyLogger Data Package* 0107.

Subarkah D, Blades ML, Collins AS, Farkaš J, Gilbert S, Löhr SC, Redaa A, Cassidy E and Zack T, 2022. Unraveling the histories of Proterozoic shales through in situ Rb-Sr dating and trace element laser ablation analysis. *Geology* 50(1), 66–70.

Vermeesch P, 2013. Multi-sample comparison of detrital age distributions. *Chemical Geology* 341, 140–146.

Walter MR, Veevers JJ, Calver CR and Grey K, 1995. Neoproterozoic stratigraphy of the Centralian Superbasin, Australia. *Precambrian Research* 73(1–4), 173–195.

Ware BD, Jourdan F, Merle R, Chiaradia M and Hodges K, 2018. The Kalkarindji Large Igneous Province, Australia: Petrogenesis of the oldest and most compositionally homogenous province of the Phanerozoic. *Journal of Petrology* 59(4), 635–665.

Yang B, Collins A, Blades M, Munson T, Payne J, Glorie S and Farkaš J, 2022. Tectonic controls on sedimentary provenance and basin geography of the Mesoproterozoic Wilton package, McArthur Basin, northern Australia. *Geological Magazine* 159(2), 1–20. https://doi.org/10.1017/S0016756820001223.