The Northern Territory SEEBASE®: An updated, Territory-wide depth-to-basement model for explorers

Tim Debacker[1,2], Karen Connors[3], Lynn Pryer[1], Jane Blevin[1,4], Phil Henley[1] and Zhiqun Shi[1]

In early 2021, the Northern Territory Geological Survey (NTGS) released a territory-wide SEEBASE® depth-to-basement structural model for public download. The Northern Territory SEEBASE project was undertaken for the NTGS by Geognostics Australia Pty Ltd with funding sourced from the Northern Territory's *Resourcing the Territory* initiative. The project built on three previous studies that covered the region: OZ SEEBASE (2005), OZ Proterozoic SEEBASE (2006), and the more recent greater McArthur SEEBASE Structural Study and GIS (2018), which were undertaken by Frogtech Geoscience for the NTGS. The full NT SEEBASE report and GIS are available for download or dispatch from the Northern Territory's Geoscience Exploration and Information System (GEMIS[5]; NTGS and Geognostics Australia Pty Ltd 2021).

The NT SEEBASE is a regional map/grid of the depth to economic basement for petroleum systems elements (**Figure 1**). The SEEBASE defines the basin shape and depth by mapping major basement structures and the base of the sedimentary section. Basement is defined as the top of igneous or metamorphic crust at the base of

[1] Geognostics Australia Pty Ltd, 157 Cranneys Road, North Tumbulgum NSW 2490, Australia
[2] Email: tim.debacker@geognostics.com
[3] WH Bryan Mining & Geology Research Centre, Sustainable Minerals Institute, University of Queensland
[4] Email: jane.blevin@geognostics.com

[5] https://geoscience.nt.gov.au/gemis/ntgsjspui/handle/1/91172

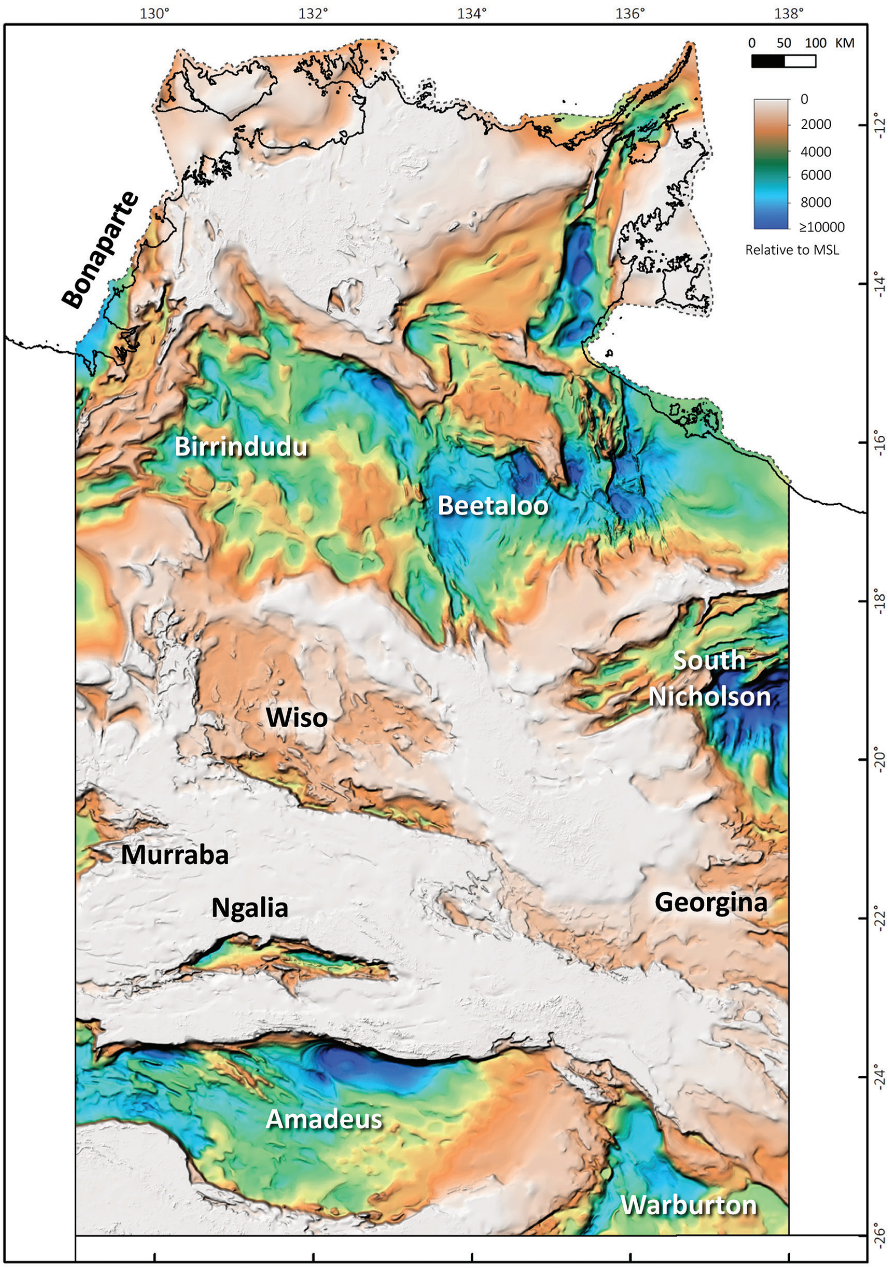

Figure 1. The Northern Territory SEEBASE® image with basins labelled.

undeformed sedimentary rocks, regardless of age. Note that in deeper parts of some basins, such as the McArthur Basin, the deepest section may be metasedimentary. The NT SEEBASE study also includes an interpretation of the tectonic evolution of basement and basin systems, basement composition and an estimate of present-day heat flow. Collectively, all these technical elements provide a platform to explore for petroleum, minerals, geothermal energy, and deep ground water, as well as other commodities such as helium and uranium.

The NT SEEBASE project had three main work streams:

1. update of the 2018 NTGS-funded greater McArthur SEEBASE Study with new datasets acquired through the NTGS's *Resourcing the Territory* initiative and Geoscience Australia's *Exploring for the Future Program* (EFTF)
2. incorporation and update of the existing SEEBASE of the Amadeus Basin that was undertaken for Santos Limited in 2015
3. production of a new SEEBASE that covers the remaining areas of the Northern Territory, including the Warburton/Pedirka, Ngalia, Wiso, Georgina and onshore Bonaparte basins, along with intervening areas of shallow basement.

The NT SEEBASE provides an upgraded, high-resolution 3D view of depth-to-basement that defines the geographic extent of subsurface basins systems. The NT SEEBASE report (see web link[6]) includes the following datasets and interpretative results generated from the NT-wide project:

- SEEBASE depth-to-basement grid and image with interpretation confidence and comments
- basement terranes with updated boundaries and tectonic definition
- processed and enhanced potential field datasets
- regional insights into gravity and magnetic signatures (report only)
- major structural boundaries
- basement composition that incorporates recent results from the NTGS and Geoscience Australia
- tectonic events
- insights into basin systems including basement controls, key events and basin geometry (report only)
- crustal-scale gravity models across the southern NT (gravity models in the northern NT can be found in the 2018 greater McArthur SEEBASE Study by [Frogtech Geoscience 2018])
- magnetic depth modelling to support depth-to-basement analysis
- basement-derived heat flow analysis
- total sediment thickness (SEEBASE derivative)
- Base Wilton (updated) and Base Glyde (new) stratal surfaces for the greater McArthur and South Nicholson basins
- depth-to-Moho
- basement thickness (SEEBASE derivative)

Key findings and results

SEEBASE and tectonic events

- The report presents a summary of 26 major tectonic events and fault event maps spanning ca 1870–270 Ma.
- The SEEBASE shows a different structural style and tectonic history north and south of the Aileron terranes: terranes to the north in the North Australian Element (NAE) remained relatively stable from ca 1800 Ma; terranes to the south accreted to the NAE during Late Palaeoproterozoic and later were deformed from Late Palaeoproterozoic to Carboniferous. This difference in tectonic history is also reflected in basin shape on the SEEBASE, with a more variable style of basins to the south, whereas intracratonic basins dominate to the north.
- The basement mapped in the SEEBASE ranges in age from Palaeoproterozoic in the north to as young as Devonian in the south.
- The tectonic history across the NT as captured in the SEEBASE has been summarised in a simplified time-space diagram from ca 2000 Ma to Present (**Figure 2**). The time-space diagram and SEEBASE are compatible and together allow the identification of new areas of currently undocumented Palaeoproterozoic- to Mesozoic-age sedimentary rocks.

Basement and heat flow

Figure 3 shows a map of basement terranes in comparison to the Northern Territory geological regions (Ahmad and Scrimgeour 2006). Potential field data suggest that Tanami basement occurs beneath up-thrusted Aileron rocks in the Aileron North terrane. This implies that mineral deposits throughout the Aileron North terrane may be remobilised from deeper basement. The potential field data combined with geological information on rock-type and ages suggest that the Aileron terranes were originally passive margin, deep-water sediments off the southern margin of the NAE that were remobilised and reattached as an accretion complex after ca 1820 Ma.

Heat flow analysis derived from basement composition, basement thickness, composition and depth-to-Moho show that areas of the Northern Territory are hotter than average continental crust – primarily due to high heat-producing radiogenic granites (**Figure 4**). Late Palaeoproterozoic granites are widely distributed and have a higher heat production than either older or younger granites. Thermal maturity in basins overlying these rocks is expected to be higher than average. Higher heat flow could also have implications for geothermal energy potential.

Basin systems

There is a strong correlation between basement character, structural (terrane) boundaries, and basin type – including

[6] https://geoscience.nt.gov.au/gemis/ntgsjspui/handle/1/91172

basin geometry, subsidence and reactivation histories, as well as basin preservation. Collectively, these elements impact petroleum systems analysis for both conventional and unconventional exploration. A 3D map of Total Sediment Thickness is shown in **Figure 5**.

The NT SEEBASE frequently interpreted basin depths as deeper than previous estimates. The implications of increased basin depth include: 1) thicker Neoproterozoic to Devonian age sedimentary rocks than observed from drilling and outcrop; and 2) Palaeoproterozoic to Neoproterozoic sediments may be more widely distributed than current boundaries suggest. In particular, older sediments may be present in the deeper parts of the Wiso and Georgina basins.

Three significant stratal surfaces were interpreted as part of the greater McArthur Basin Update component of the project: Base Wilton (updated surface), Base Glyde (new surface), and the updated SEEBASE surface (**Figure 6**). A series of isopachs were also produced using new EFTF seismic datasets that extend into the Carrara Sub-basin (which underlies the South Nicholson Basin). The new mapping has allowed greater resolution of the stratal succession within the Carrara Sub-basin, which was first identified from gravity datasets in the OZ Proterozoic SEEBASE study in 2006.

Many of the basins were initiated during, and inherited structure from, much older events. For example, a basin in the area currently defined as the Wiso Basin initially formed in response to Aileron accretion as a foreland basin during the Palaeoproterozoic. Its history during the Mesoproterozoic is unknown, but judging from the documented events affecting the NT, there may have been further foreland basin development and extension during the Mesoproterozoic, followed by extension during the Neoproterozoic. The basin was further reactivated as a foreland basin during the Palaeozoic (Alice Springs Orogeny; current definition of the Wiso Basin). Gravity modelling suggests that the Wiso Basin is floored by granites (current model), or it may be deeper than shown in SEEBASE, thus implying a much thicker succession of older underlying sediments.

Acknowledgements

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Figure 2. Simplified time-space diagram for the Northern Territory from ca 2000 Ma to Present. The figure is oriented from the NNW (left) to SSE (right). The three rows of column headers are: (1) oldest known basin; (2) name of Orogen/Province, with domain/area, as used by NTGS; and (3) basement terrane(s) as defined in present study. The chart is based on the time-space diagram of Ahmad and Scrimgeour (2006).

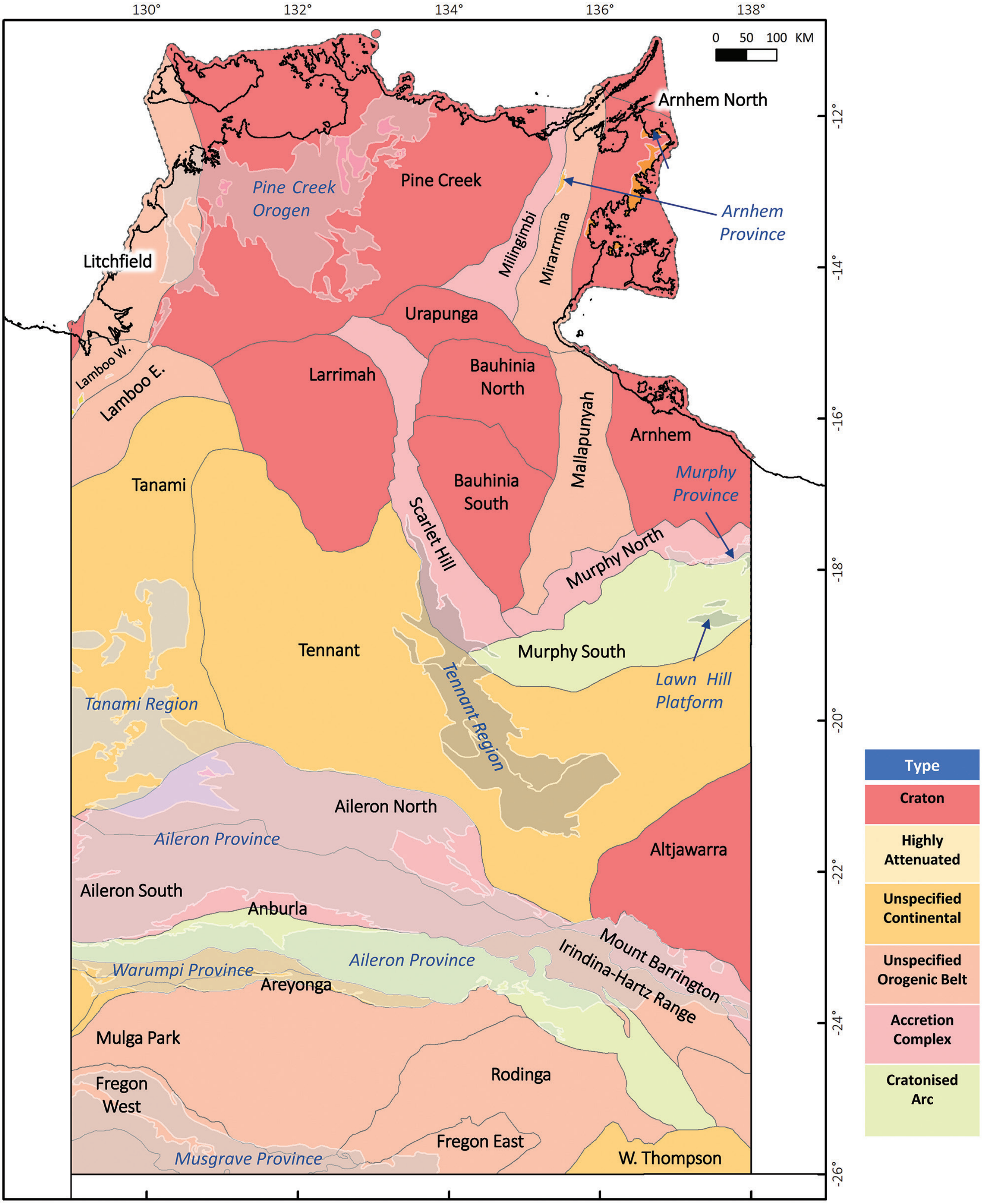

Figure 3. Terrane map of the Northern Territory (bold labels) compared with Northern Territory geological regions (italics labels; Ahmad and Scrimgeour 2006).

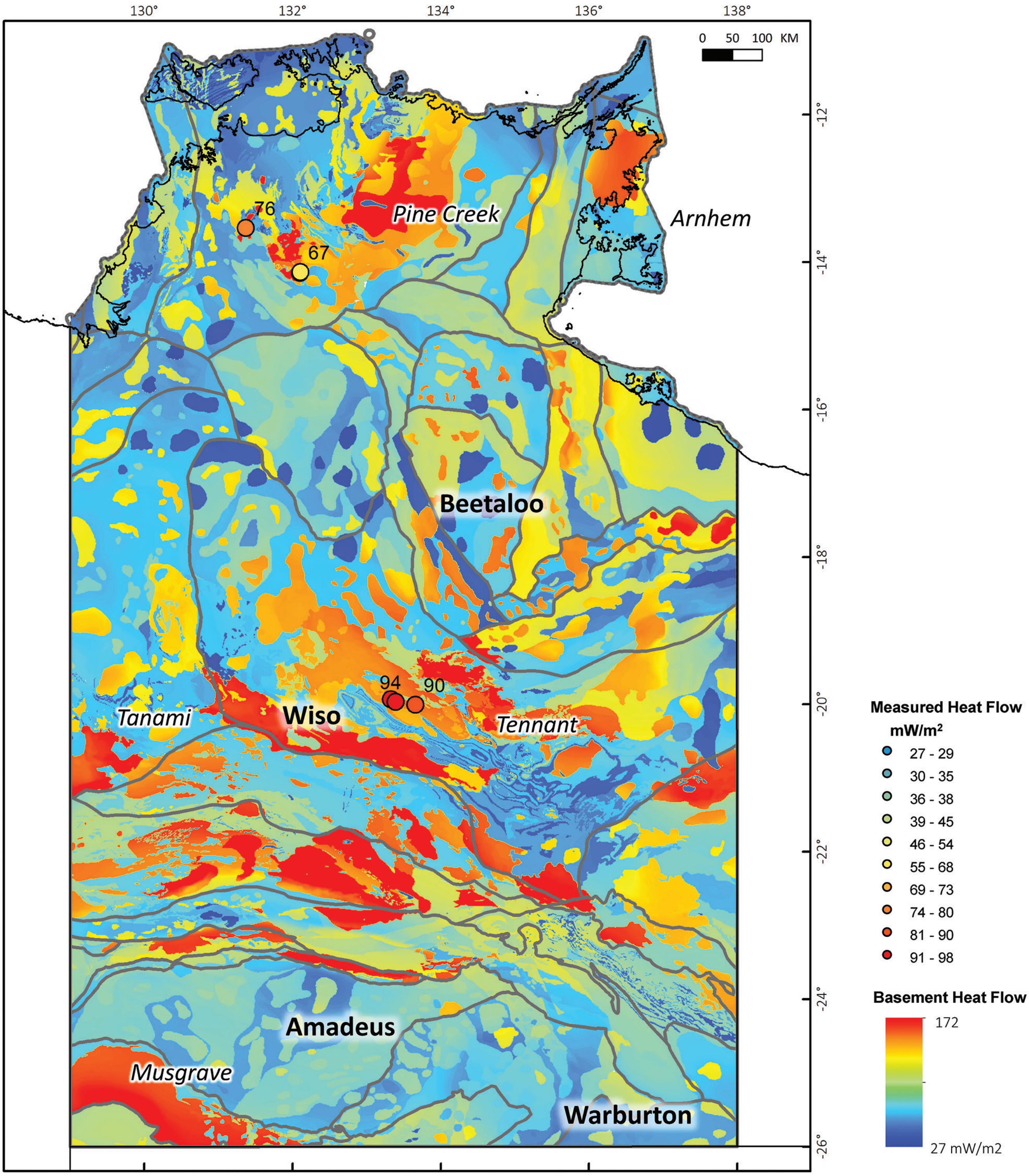

Figure 4. Basement heat flow map of the Northern Territory.

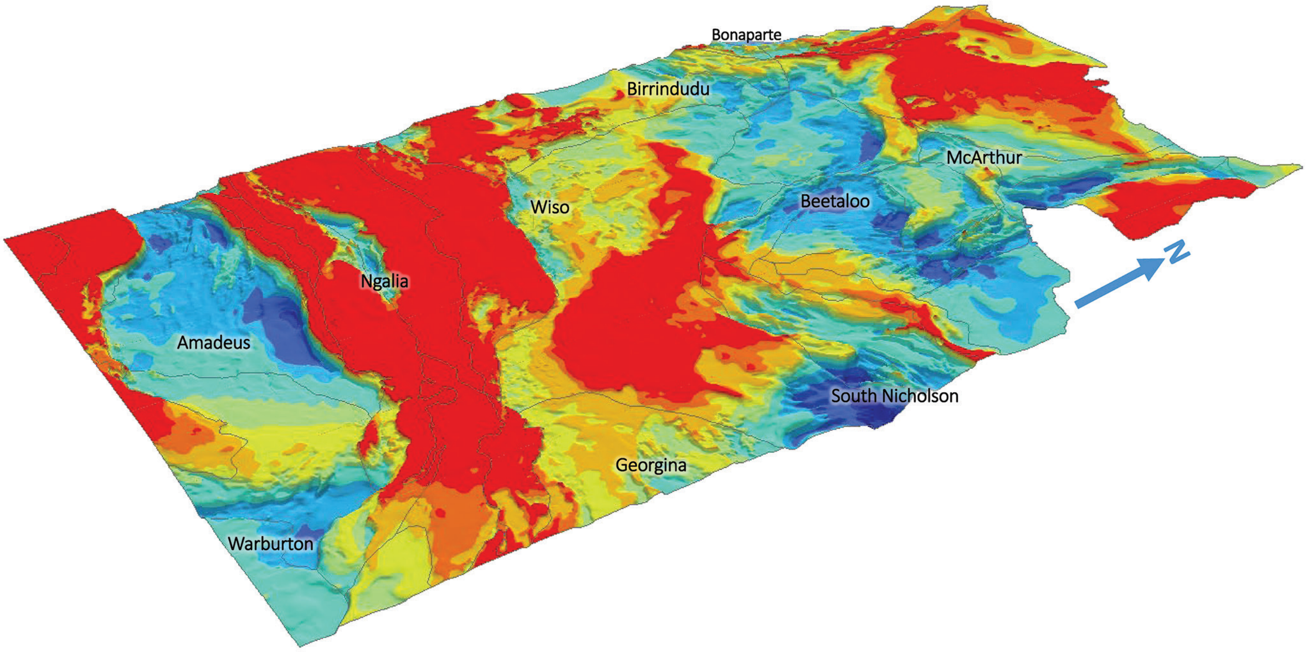

Figure 5. 3D view of the Total Sediment Thickness derivative grid from the NT SEEBASE and DEM.

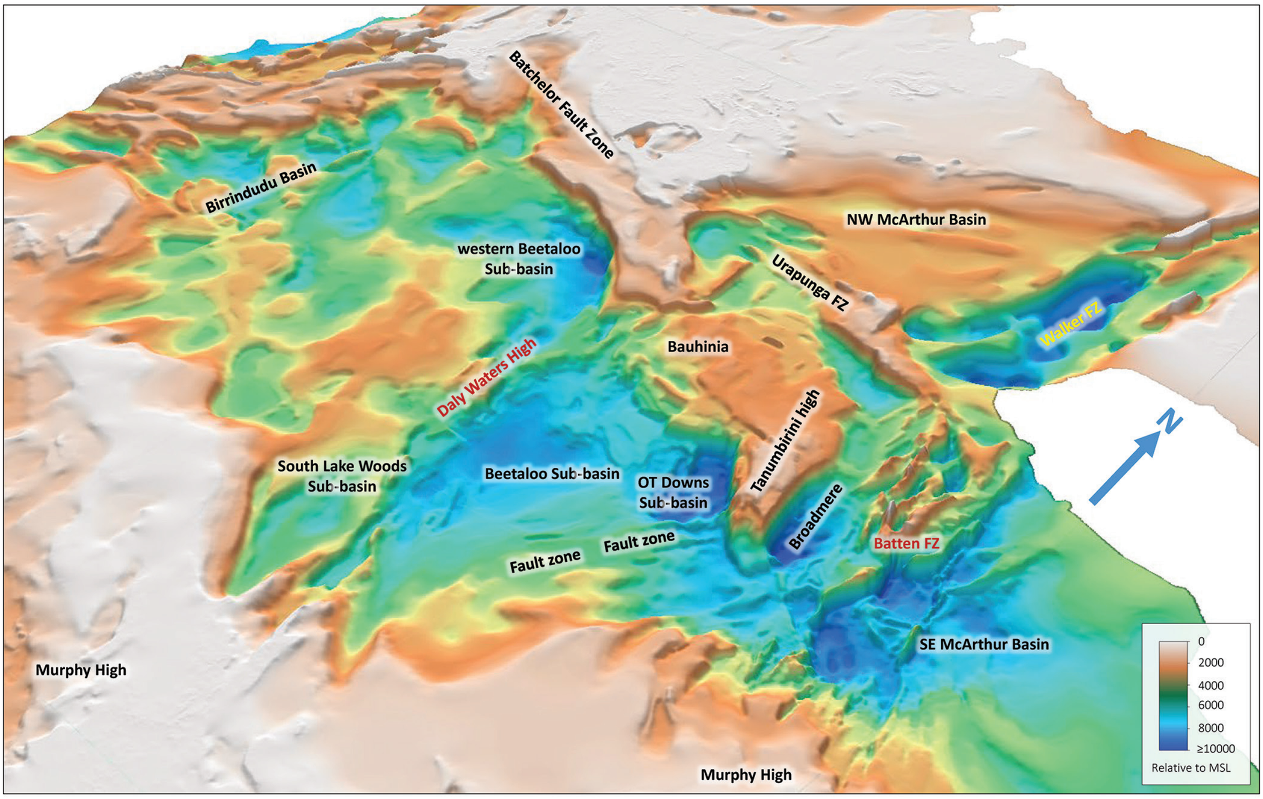

Figure 6. 3D view of the updated SEEBASE map in the greater McArthur region.

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