An update to the Warburton-Pedirka-Eromanga Basin SEEBASE®

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The Northern Territory SEEBASE® Study and GIS was released in early-2021 (NTGS and Geognostics Australia 2021) and provided the NT government and explorers with valuable new basement mapping and regional interpretations. The Warburton-Pedirka-Eromanga Basin (WPEB) in the southeastern corner of the NT was a small portion of that larger project (**Figure 1**) and limited data were available at the time; in general, only low-resolution gravity data, and limited well, geochronology and legacy seismic data.

Since 2021, the NTGS has undertaken new surface geology mapping, acquired new gravity data, reprocessed seismic surveys, enhanced the accessibility of exploration subsurface data, undertaken new geochronology and updated stratigraphic correlations across the region. These new datasets provided the opportunity to update the SEEBASE in the stacked west WPEB system with the deep basement surface (SEEBASE), which is largely equivalent to the base of the older Warburton Basin. Subsurface mapping was also recently done by Geoscience Australia in this region as part of EFTF2 (Bradshaw *et al* 2024; Iwanec *et al* 2024, 2025) but this work largely focused on the younger Pedirka and Eromanga basins. The new work by Geognostics on the deeper Warburton Basin provides complementary new insights into basement, tectonics, basin evolution, structures and regional stratigraphy.

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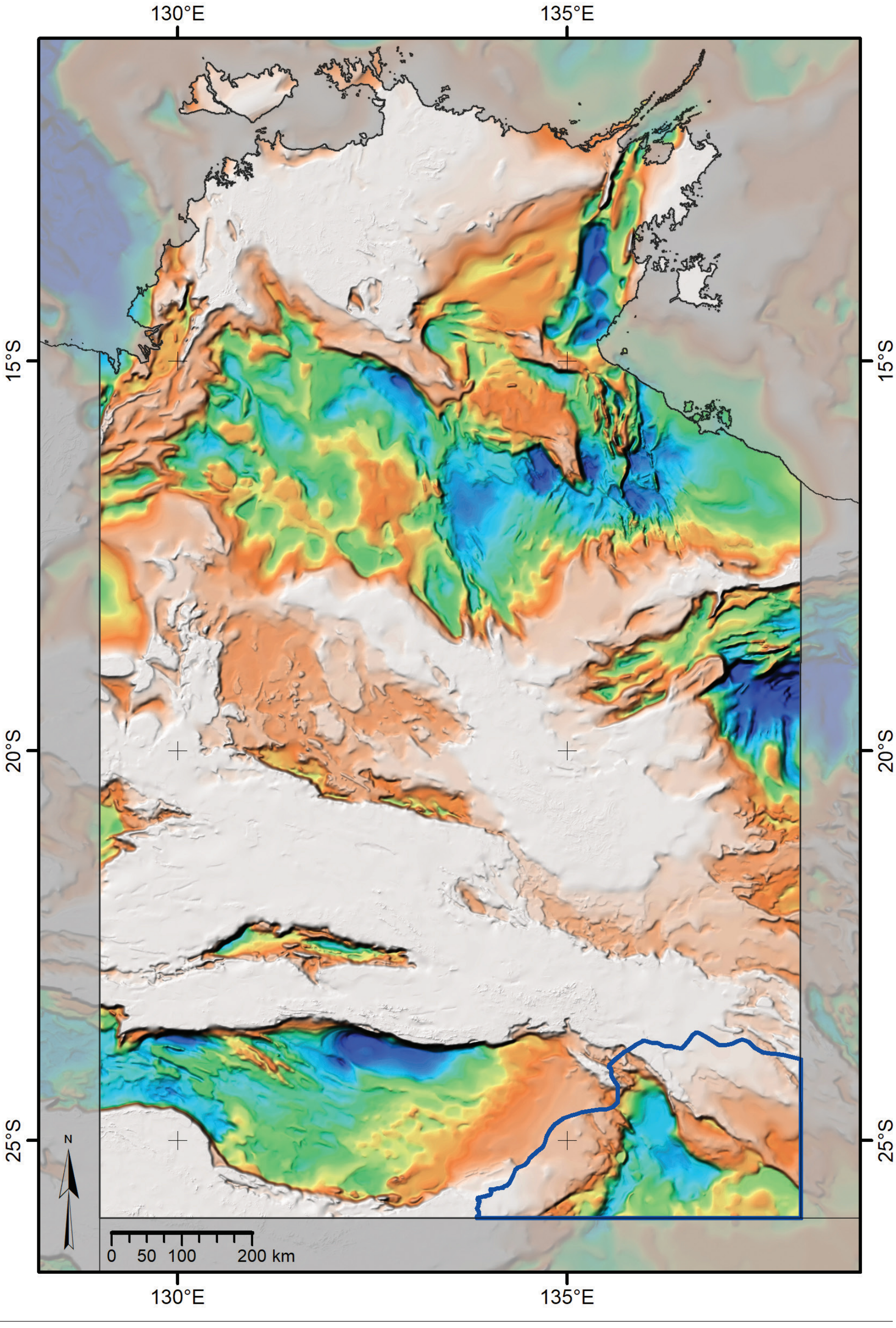

Figure 1. Northern Territory SEEBASE® 2021 with blue polygon showing the west Warburton-Pedirka-Eromanga Basin (WPEB) area that was updated during the current study.

SEEBASE calibration

The Warburton-Pedirka-Eromanga portion of the NT-wide 2021 SEEBASE relied heavily on the available gravity and magnetics datasets. The lack of subsurface calibration data made it difficult to identify if the source of anomalies was due to basement depth or basement composition. The improved quality of the gravity and reprocessed seismic data has resulted in significant changes to the basement model.

To calibrate the interpretation, seismic data was displayed with the coincident profiles of gravity and magnetics, although imaging of the deeper section in seismic can be poor (**Figure 2**). Across the Andado Ridge, anomalies reflect variation in basement composition. Moving east into the basin, the Eringa Trough generates a broad negative gravity anomaly. At McDills 1, the inversion anticline produces a shorter wavelength positive anomaly primarily sourced in the shallow section, where older sediments in the anticline are juxtaposed against younger sediments in the trough. The magnetic profile is smooth and relatively flat reflecting flat-lying sources or non-magnetic basement. To the east of the McDills trend, gravity data do not reflect basement depth and must be related to density contrast in the basement.

In the northern Madigan Trough, there is a strong negative gravity anomaly that indicates a granite in the basement. The Warburton sedimentary section is clearly imaged in seismic above the granite but loses coherency away from the granite. This may indicate a lack of impedance contrast between the basin and the metasedimentary basement.

Basement terranes

Basement terranes were mapped using a combination of gravity, magnetics and outcropping basement. Subsurface basement intersections in wells are limited in the study area. When different potential field datasets are compared, the signature of the filtered images emphasises the independence of density and susceptibility in the filtered gravity and magnetics, respectively (**Figure 3**).

The age of basement is taken as the last deformation event that could have metamorphosed sediments. The McDills trend formed above the boundary between the hard Rodinga and softer West Thomson terranes. From oldest to youngest terrane: Mount Barrington is Paleoproterozoic; Amburla and the displaced Aileron basement is Palaeo-Mesoproterozoic locally reworked during Alice Springs

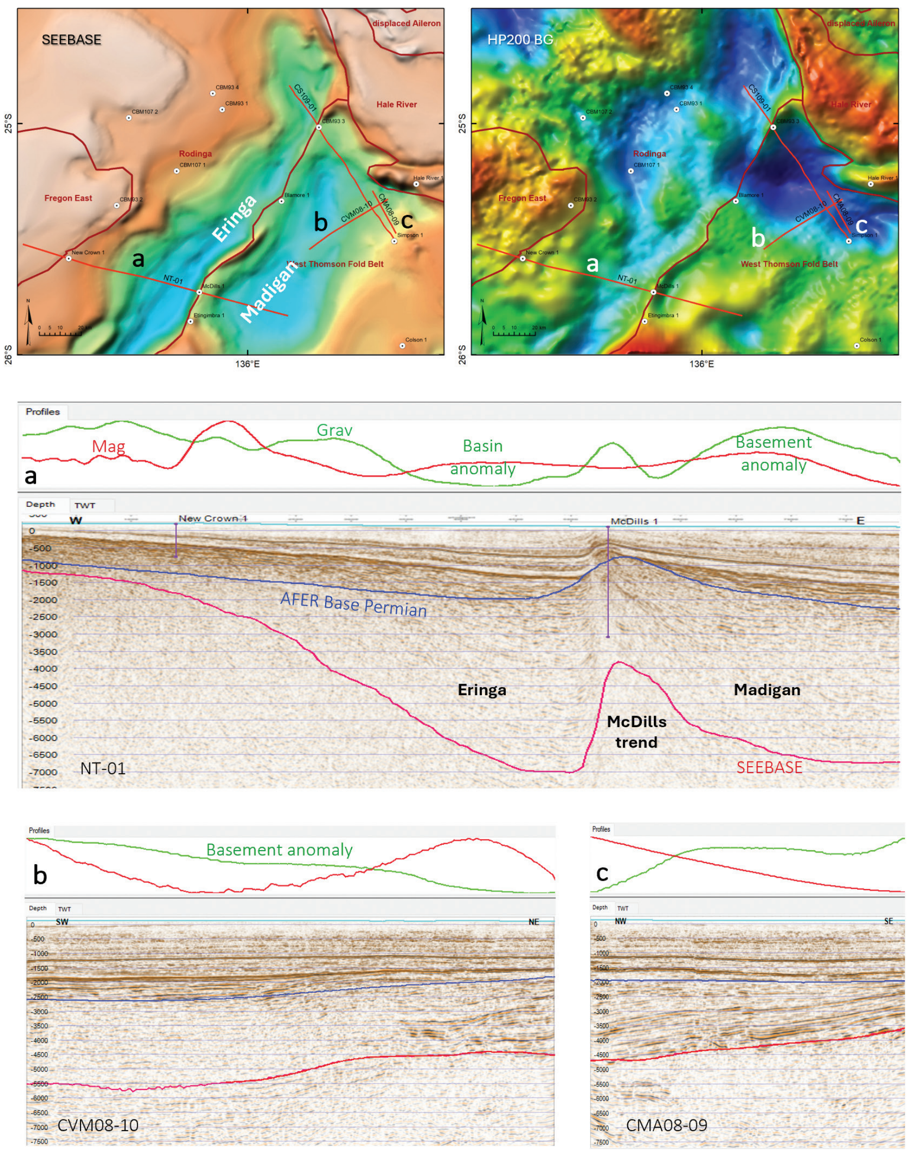

Figure 2. Seismic images used for depth calibration. (**a**) NT-01. (**b**) CVM08-10. (**c**) CMA08-09. Magnetic (red) and gravity (green) profiles are shown above each line. Horizons shown on the seismic: SEEBASE in red; Australia's Future Energy Resources (AFER) base Permian (Bradshaw *et al* 2024) in blue. Vertical scale is in metres. SEEBASE and gravity maps show well and line locations.

Orogeny (ASO); Rodinga and Fregon formed a single terrane beneath the Centralian Basin until the Petermann Orogeny exhumed the Musgrave Province of which Fregon is the NE tip; Irindina-Harts Range consists of Neoproterozoic to Cambrian sediments equivalent to the Amadeus Basin, metamorphosed in the Ordovician and exhumed during ASO; Hale River is interpreted to have originally been part of West Thomson, deformed during the ASO. Terrane details are included in the project GIS that is available through GEMIS.

Superimposing terrane boundaries on SEEBASE illustrates the basement control on basin evolution and

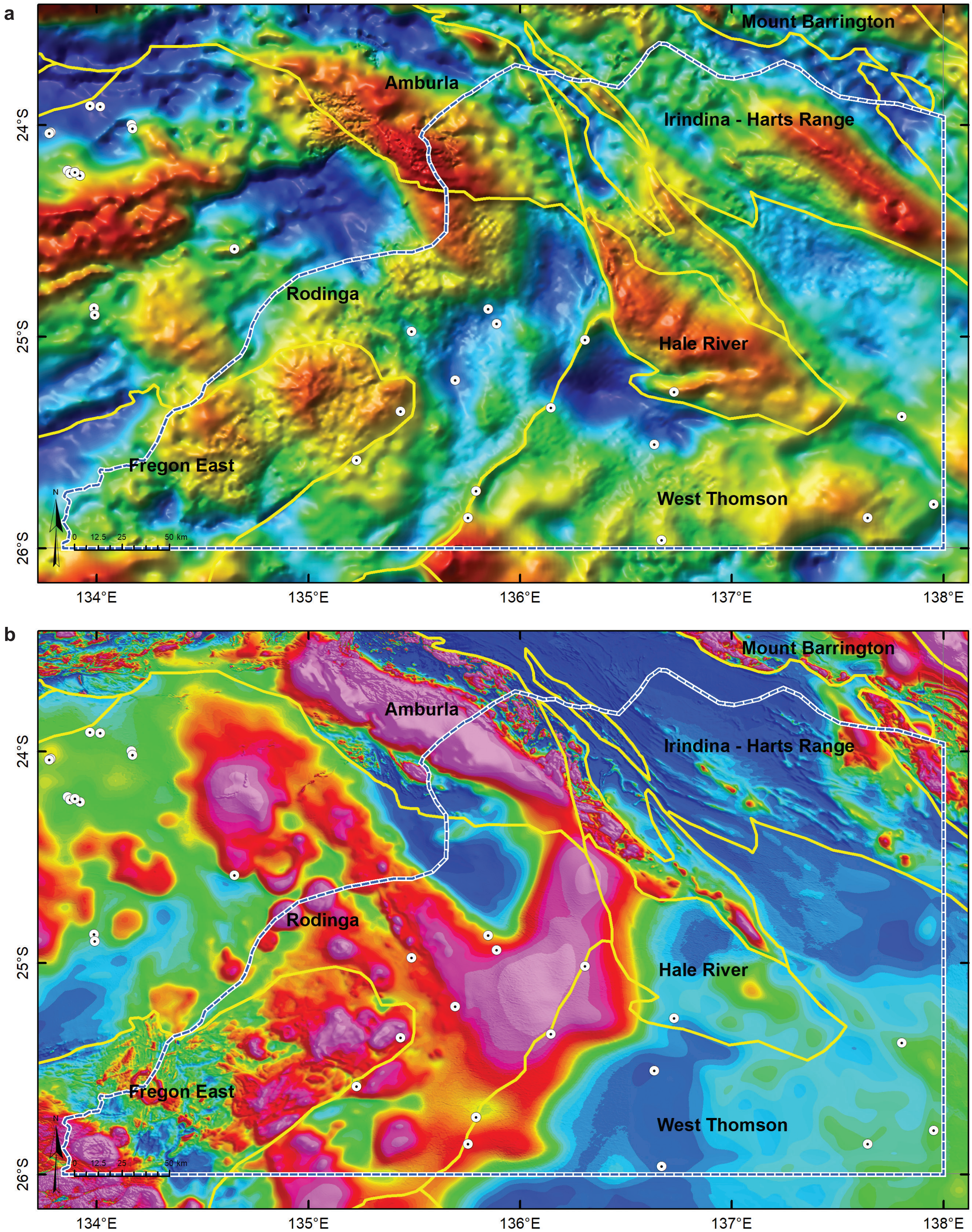

Figure 3. Basement terrane boundaries on (**a**) 200 km high-pass filter of Bouguer gravity (top) and (**b**) RTP magnetics (bottom). The study area is noted by the dashed blue polygon.

geometry (**Figure 4**). Subsidence was localised on the boundary between the Rodinga and West Thomson terranes, which was also the focus of inversion.

Tectonic events

Tectonic events that could have influenced basin development in the Warburton Basin took place in surrounding areas beginning with the Centralian extension in the Neoproterozoic. Extension was followed by the early Cambrian Petermann Orogeny responsible for exhumation of the Musgrave Province, and the mid-Cambrian Delamerian Orogeny which was focused to the south and may have been responsible for the folding of West Thomson metasediments. The Early Ordovician Larapintine extension was focused in Irindina-Harts Range. This was followed by three phases of the 450–300 Ma ASO in the Arunta Region; the Permo-Triassic Hunter-Bowen Orogeny on the eastern Australian margin; and far-field stresses associated with Miocene and younger collision on the northern Australian margin.

Focusing on the basement and kinematics of the ASO, magnetic data show the Rodinga and Fregon terranes were heavily intruded by Pitjantjatjara Suite (1220–1120 Ma) increasing basement strength. Compression during the ASO concentrated at the nose of Rodinga 'indenter' (**Figure 4**). Rodinga went into and under Ambrula (Aileron) resulting in intense inversion/deformation in Irindina-Harts Range with bivergent strike-slip at indenter shoulders. Deformation from this event dies out to the SE.

The study area lies SE of the documented evidence of Alice Springs deformation and the Rodinga indenter. Well documented sinistral strike-slip deformation occurred on the NW side of the indenter while dextral displacement of the 'displaced Aileron' terrane took place to the SE. Uplift of Hale River block likely occurred during this time, as a 'pop-up' structure formed on a left-stepping restraining bend in a dextral strike-slip system. Analogue modelling from McClay and Bonora (2001) shows that pop-up structures exhume older rocks in the core.

To get information on the timing of fault movement in the basin, a preliminary interpretation was done on two cross-basin seismic lines. Line CSI09-01 transects the northern end of the basin and is down-dip from the saddle connecting the Amadeus and Warburton basins (**Figures 4** and **5a**). This is the only line through the Eringa and Madigan troughs that clearly images basement, although unfortunately, the line has no deep well tie. Line NT-01 farther south ties to McDills 1 well and provides critical stratigraphic constraints (age). The well penetrated the Warburton Basin down to the Todd River Dolostone but did not intersect basement. Unfortunately, well-imaged basement is absent from this line, thus much of the seismic interpretation is based on character matching of seismic signatures between the distal constraining lines.

Flattening of seismic line CSI01-09 on the top of interpreted Todd River Dolostone shows onlap onto basement (**Figure 5b**). The basement has been interpreted as Centralian fault blocks deformed and eroded during the Petermann Orogeny. However, new isotopic dating (in progress) of carbonates at McDills-1 could provide new age constraints on the units tagged as Todd River Dolostone; early results suggest the unit may be younger than Early

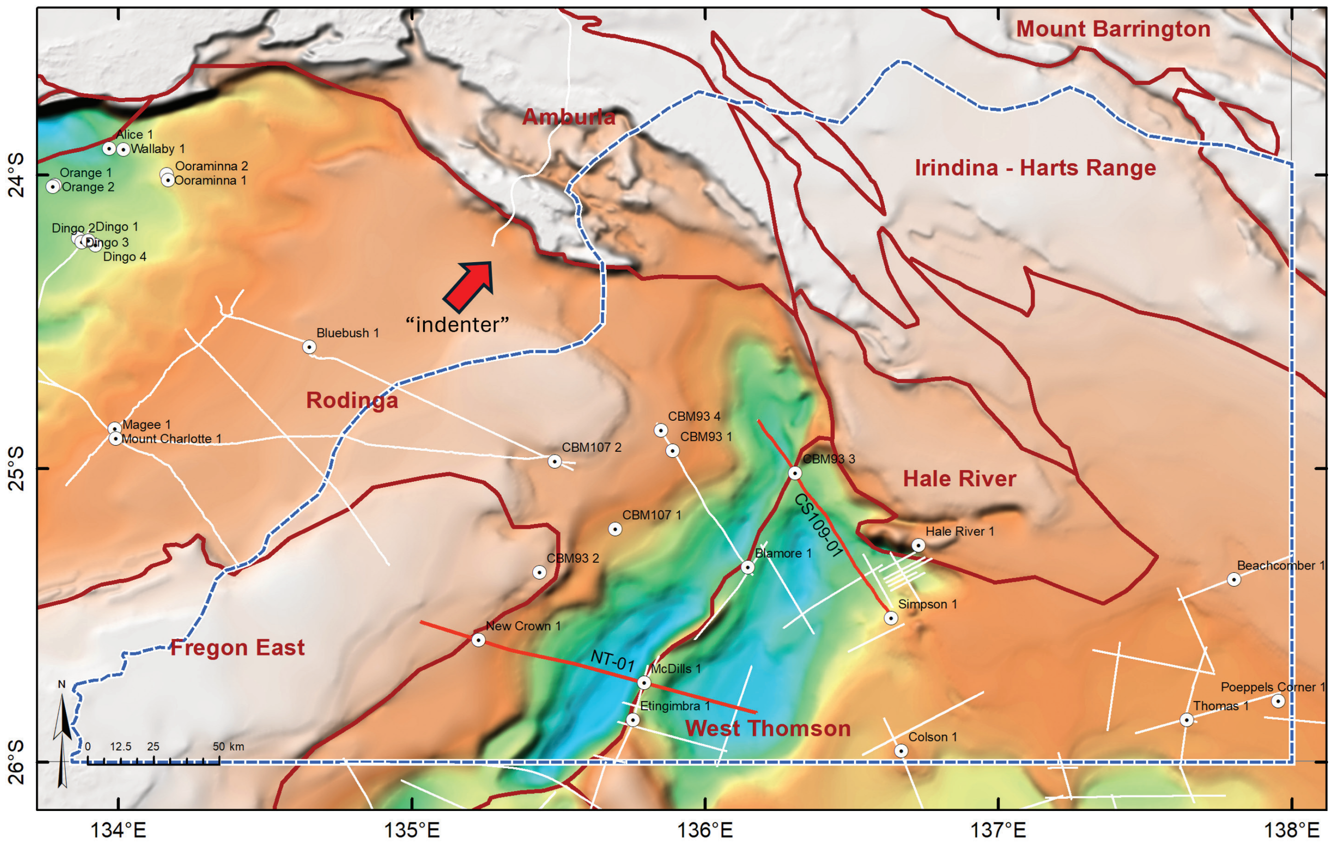

Figure 4. Updated Warburton-Pedirka-Eromanga Basin SEEBASE image overlain by basement terranes (red polygons), seismic locations (white) and wells. The locations of interpreted seismic lines NT-01 and CSI09-01 in **Figure 5** are shown in red.

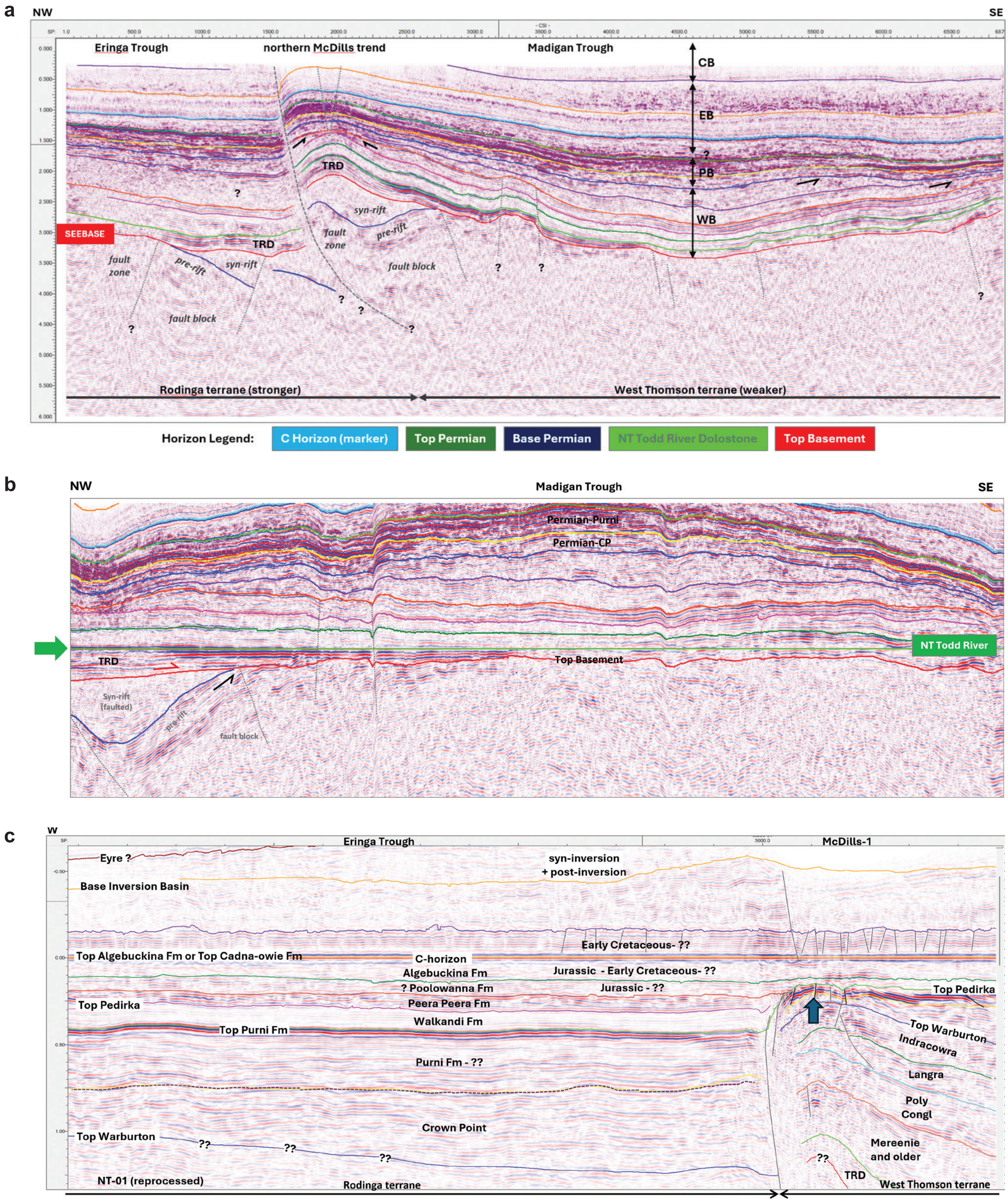

Figure 5. (**a**) Preliminary interpretation by Geognostics of seismic line CSI09-01 crossing the Eringa Trough, the northern McDills trend and the Madigan Trough. The stacked basin system is labelled: WB = Warburton Basin; PB = Pedirka Basin; EB = Eromanga Basin, CB = Cenozoic Basin. The Rodinga and West Thomson basement terrranes are also labelled. The portion of the line shown in (**Figure 5b**) is indicated by the blue arrow. (**b**) Preliminary interpretation by Geognostics of seismic line CSI09-01 flattened in Kingdom on the Near-Top Todd River Dolostone (520-513Ma) suggests the carbonates were deposited as relatively flat-lying strata overlying a gently sloping Top Basement depositional surface. Geometries and truncation of rotated fault blocks and interpreted (strongly faulted) syn-rift below the Top Basement horizon are evidence of an early (pre-Petermann?) extensional event. A pre-rift section is also imaged in the fault block suggesting deposition occurred before extension. Extension is interpreted as Centralian age with post-extension deformation possibly related to the Petermann Orogeny. (**c**) Preliminary interpretation by Geognostics of reprocessed seismic line NT-01 flattened in Kingdom on the C-horizon (a regional seismic marker). Flattening clearly shows that the Warburton sediments comprising the McDills anticline were strongly deformed in the ASO prior to uplift and juxtaposition against sediments of the relatively undeformed Eringa Trough in the Late Carboniferous (Top Purni Formation). This event created accommodation space for deposition of the Walkandi and Peera Peera formations.

Cambrian (C Verdel, NTGS, pers comm). Further work is underway and should be reviewed in future for impacts on the current basin model.

Flattening of seismic line NT-01 on the Eromanga C-Horizon shows the uplift of the West Thomson terrane that occurred during the Hunter-Bowen Orogeny along with erosion of the Purni Formation west of McDills-1. Deposition of the Walkandi Formation occurred during Hunter-Bowen time, while the Peera Peera Formation was deposited after the event (**Figure 5c**). There is no expression of the McDills trend in the flattened Eromanga and younger section at this time, which indicates that the main movement on the McDills trend occurred later. This event, which is responsible for the present-day configuration of the basin, occurred during the Miocene and younger due to far-field collision along Australia's northern margin. This event has reshaped the entire west WPEB system.

Key study results

The updated west Warburton-Pedirka-Eromanga Basin SEEBASE has redefined basement terranes, major structures and tectonic events that controlled the evolution of the basin system, as well as refined the depth and geometry of the overlying younger basin systems (Pedirka and Eromanga basins).

The key differences in the updated SEEBASE, basement and basin interpretations include:

- The McDills trend, which separates the Eringa Trough to the northwest from the Madigan Trough to the southeast, is much more prominent in the updated interpretation due to improved imaging in gravity data.
- The additional seismic data for depth calibration in the northern Eringa and Madigan troughs has shown that the depth is less than previously interpreted and that the prominent negative gravity anomaly is due to a felsic intrusion in the basement.
- Conversely, the southern Madigan Trough is deeper than previously interpreted and the positive gravity signature reflects the differences in the density of the basement beneath the trough. Maximum sediment thickness could locally reach around 7 km.
- The interaction between regional kinematics and the deformation/response of basement terranes (terrane boundaries and rheology) has controlled deposition and preservation of the Warburton and Pedirka basins.
- The boundary between the Rodinga and West Thomson terranes (ie the McDills trend) has been a repeated focal point of complex strike-slip and thrust faulting from the Early Cambrian onwards (post-Petermann Orogeny). The result is the present-day juxtaposition of relatively undeformed sediments overlying the competent Rodinga terrane (Eringa Trough) against the older and more deformed overthrust sediments of the weaker West Thomson terrane (Madigan Trough).
- Much of the sediment deformation in the Madigan Trough was the result of successive tectonic events during the Alice Springs and Hunter-Bowen orogenies, however, the majority is related to late far-field uplift in the mid-Miocene, which reshaped the entire basin system and accentuated the McDills trend.
- The boundary of the Madigan Trough and the Colson Shelf is likely to coincide with a deformation front associated with Delamerian deformation to the southeast.

Acknowledgements

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