Warburton-Pedirka Basin SEEBASE® Update

Geognostics Project Team

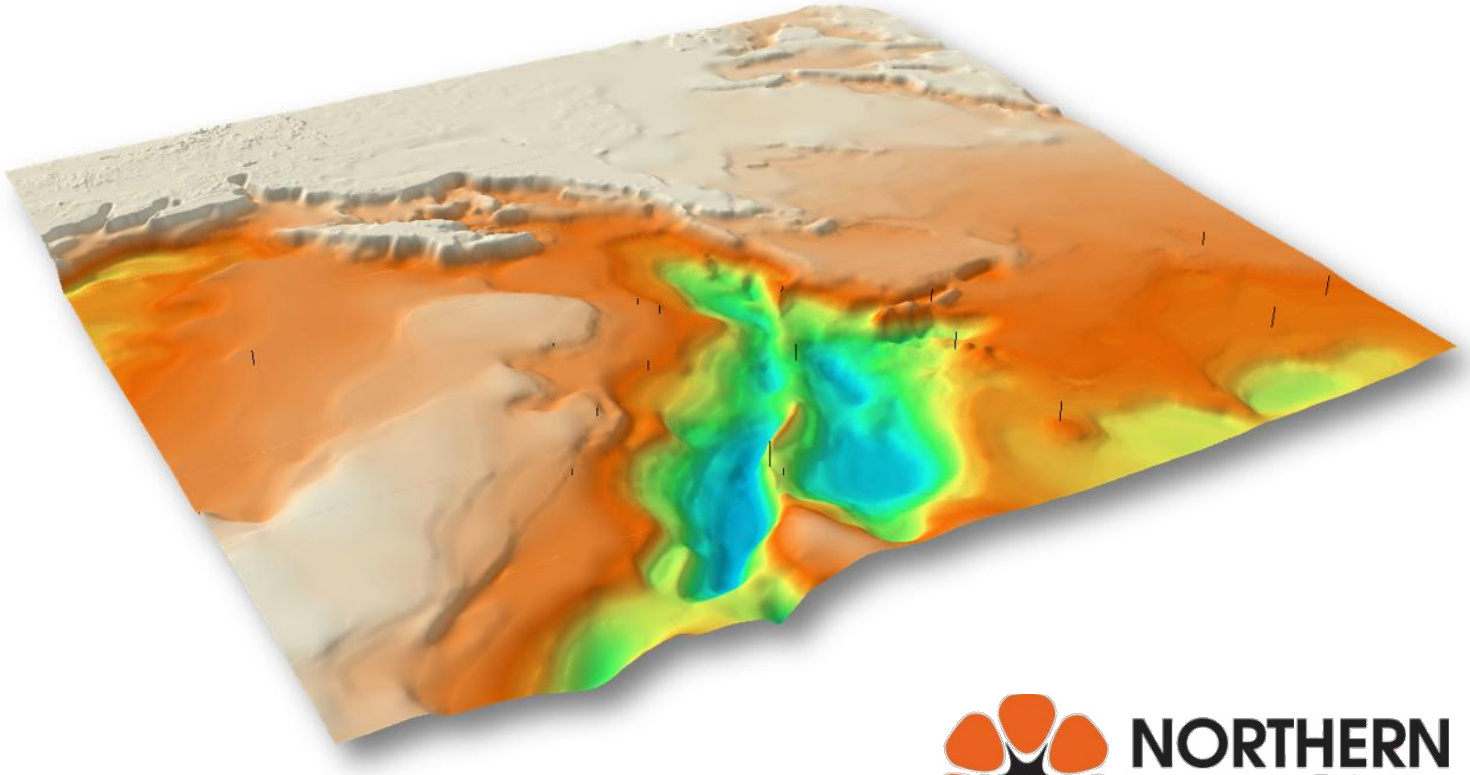
Lynn Pryer, PhD (Principal Geoscientist)

Jane Blevin, PhD (Principal Geoscientist)

Marina den Hartog, MSc (Geoscientist)

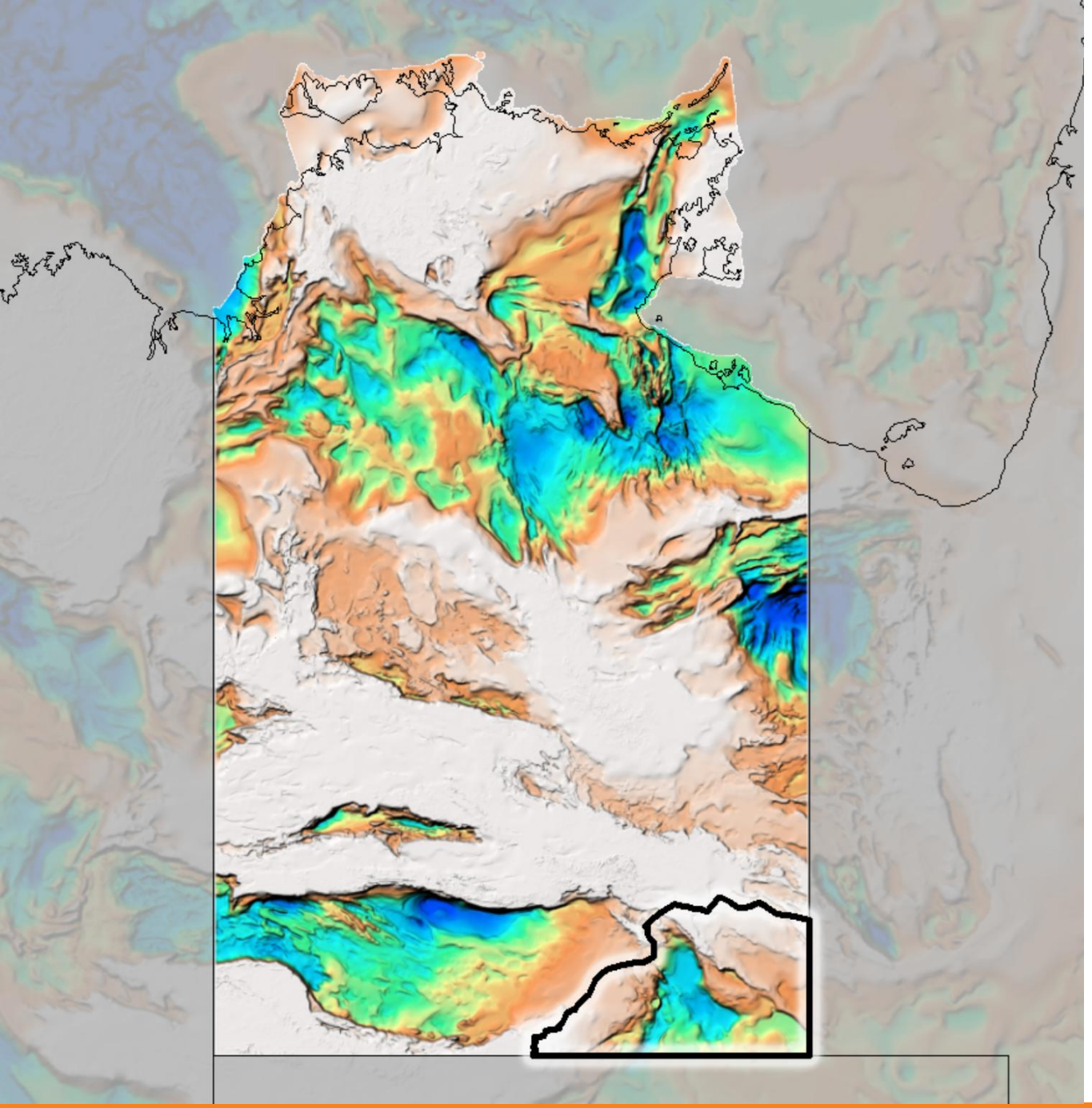
Zhiqun Shi, PhD (Principal Geophysicist)

Phil Henley (Managing Director)



Geognostics
Exploration through Innovation

NORTHERN TERRITORY GOVERNMENT



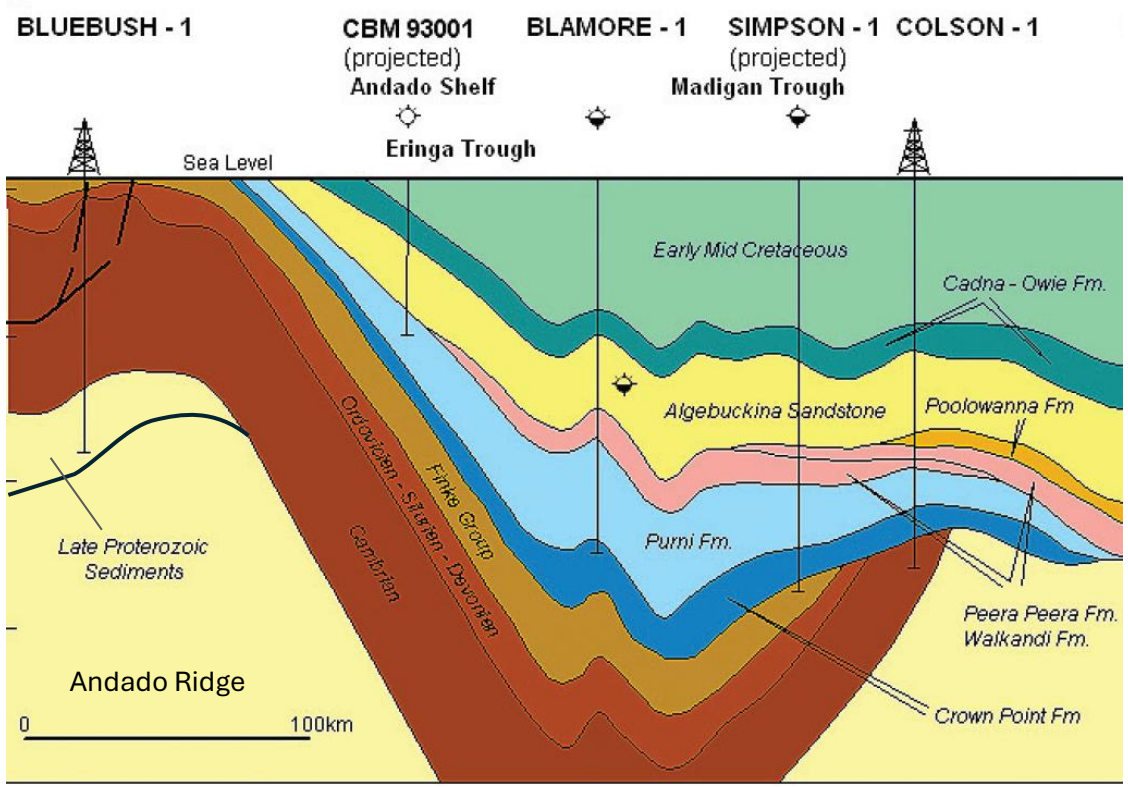
Introduction

- The Northern Territory SEEBASE® Study and GIS was released in early-2021 (NTGS and Geognostics Australia, 2021)

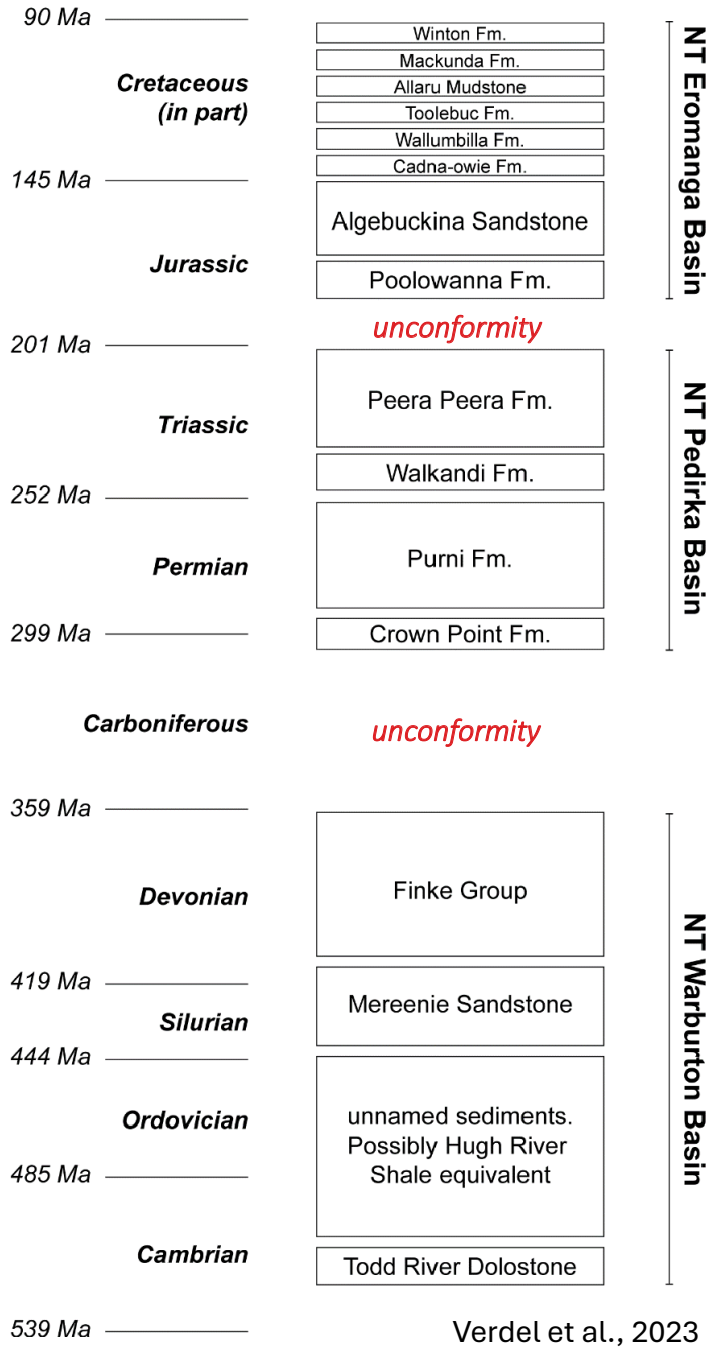
- Only legacy scanned seismic and variable quality potential field data, were available to support the 2021 SEEBASE interpretation in the area covered by the Warburton-Pedirka and Eromanga basins

- **The Warburton-Pedirka-Eromanga Basins SEEBASE® Update** focused on updating the SEEBASE® and basin overview based on new gravity data, geochronology, reprocessed seismic, and updated stratigraphic correlations.

Warburton-Pedirka-Eromanga Basins and Stratigraphy



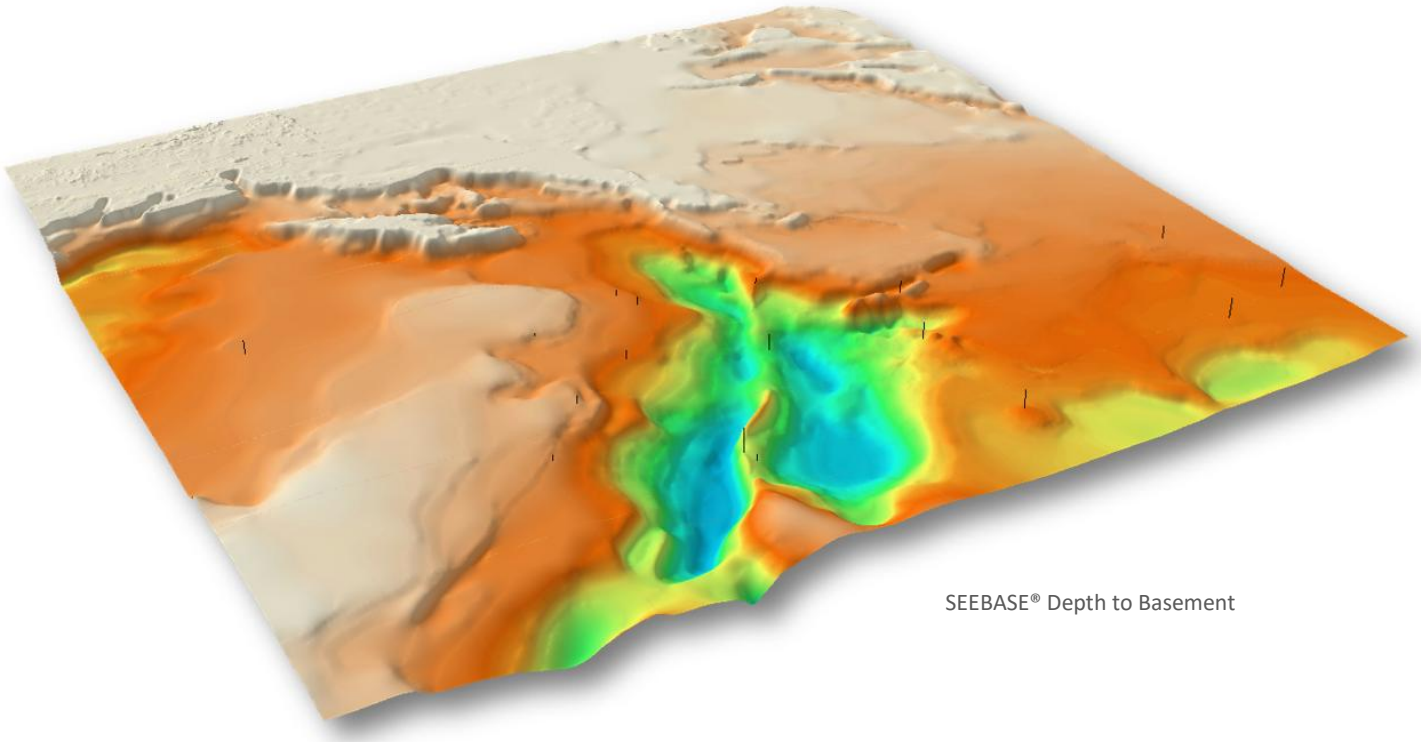
Modified from Ambrose and Heugh, 2012



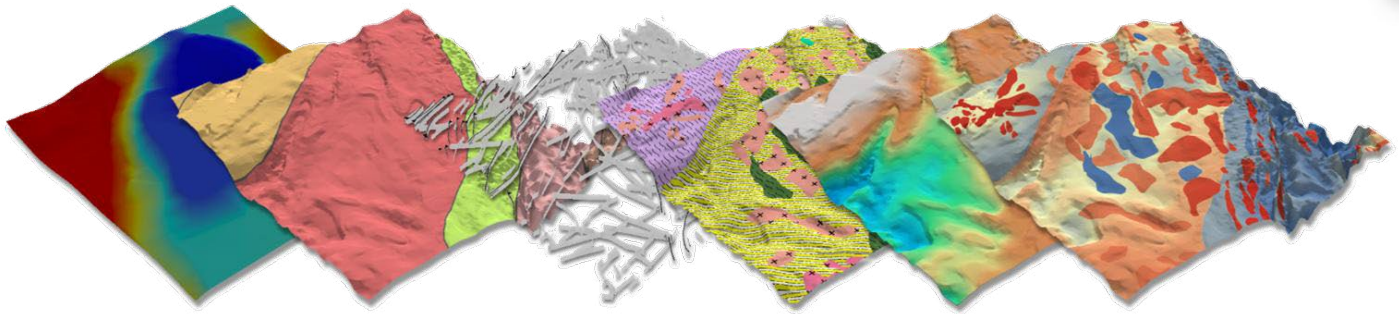
Verdel et al., 2023

What is SEEBASE?

- an **interpreted model** of basement, basin architecture and basement control on basin evolution.
- multilayered model of basement and the underlying crust.
- gravity and magnetics interpretation integrating available geophysical and geological data
- SEEBASE® Depth to Basement is a hand-contoured surface that emphasises basement structure.



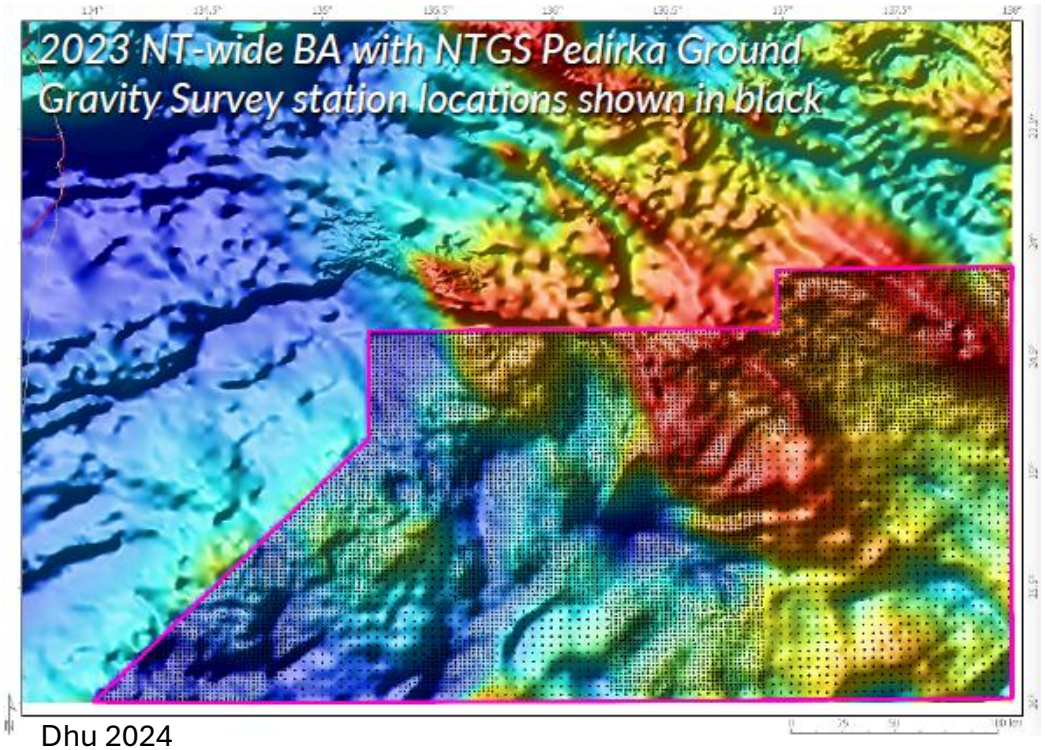
SEEBASE® Depth to Basement



Depth to Moho | Basement Terranes | Structure and Tectonic Events | Basement Composition | SEEBASE® Depth to Basement | Basement Heat Flow

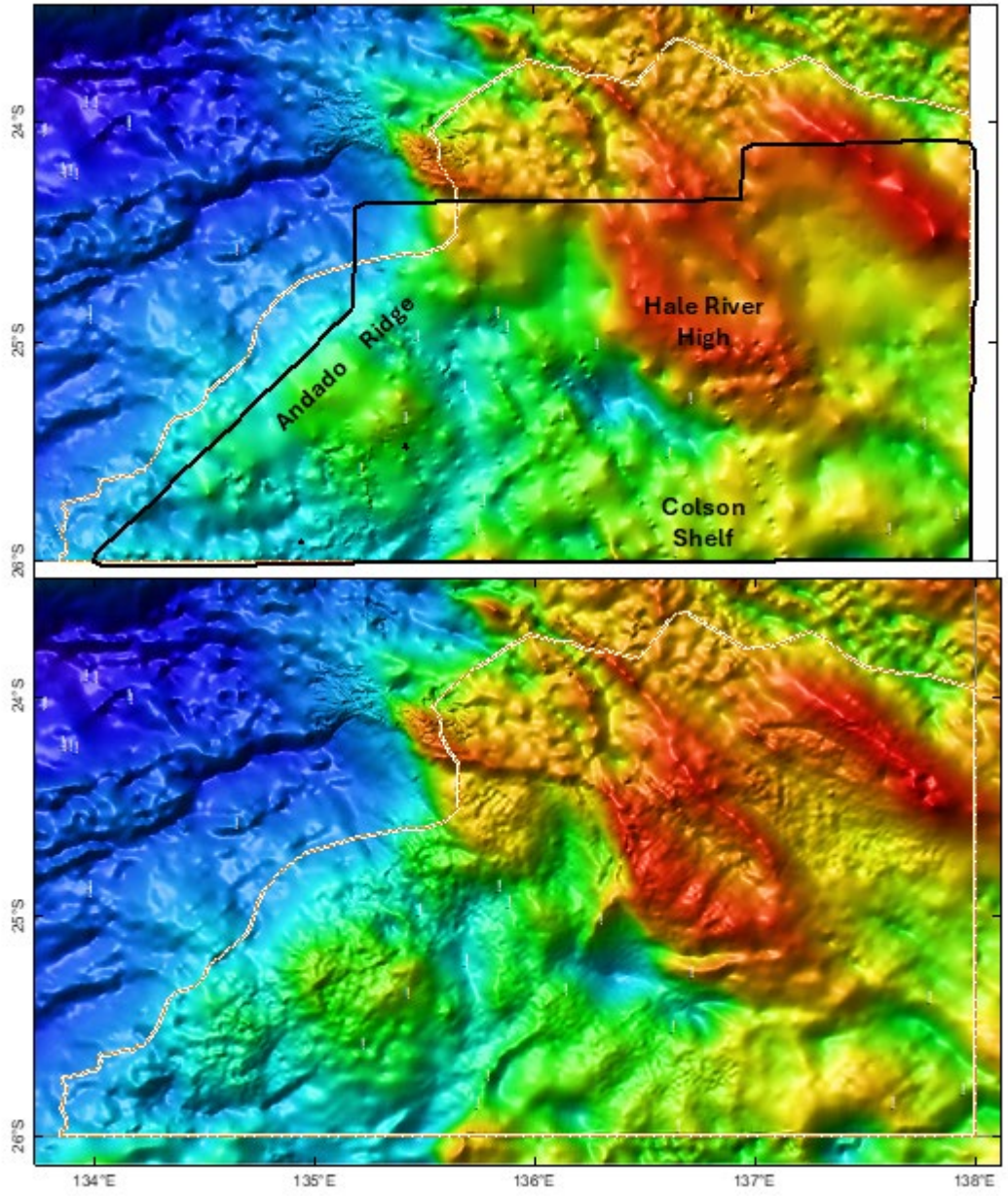
Key Datasets:
Gravity

NTGS Pedirka Ground Gravity Survey
Released April 2024
~61,000 km^2 at 4x4km and 2x2km spacing



Dhu 2024

2021 NT-wide gravity dataset - Bouguer Gravity (2.67g/cc)

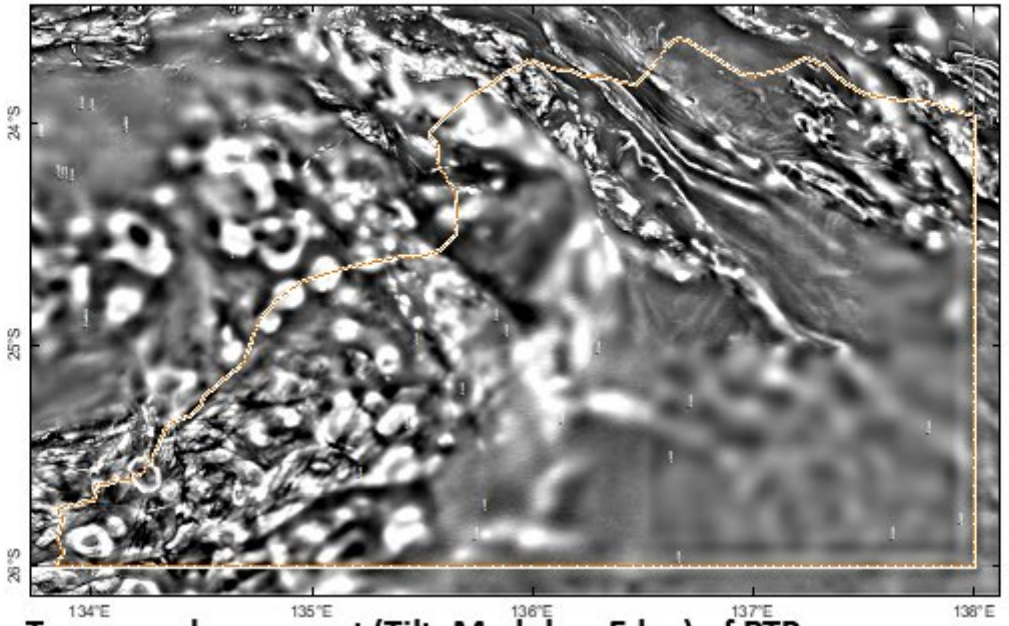


2024 NT-wide gravity dataset - Bouguer Gravity (2.67g/cc)

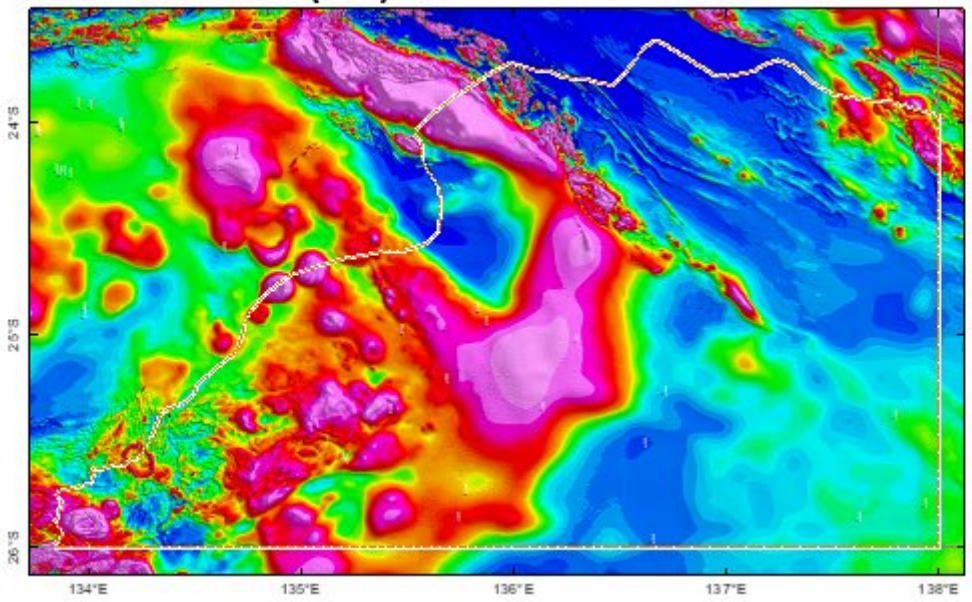
Key Datasets:
Magnetics

- Northern Territory Geological Survey, February 2020. NT-wide geophysical stitch: Magnetic, gridded data.
- No change to the NT-wide magnetic datasets in the Warburton-Pedirka-Eromanga area since 2020

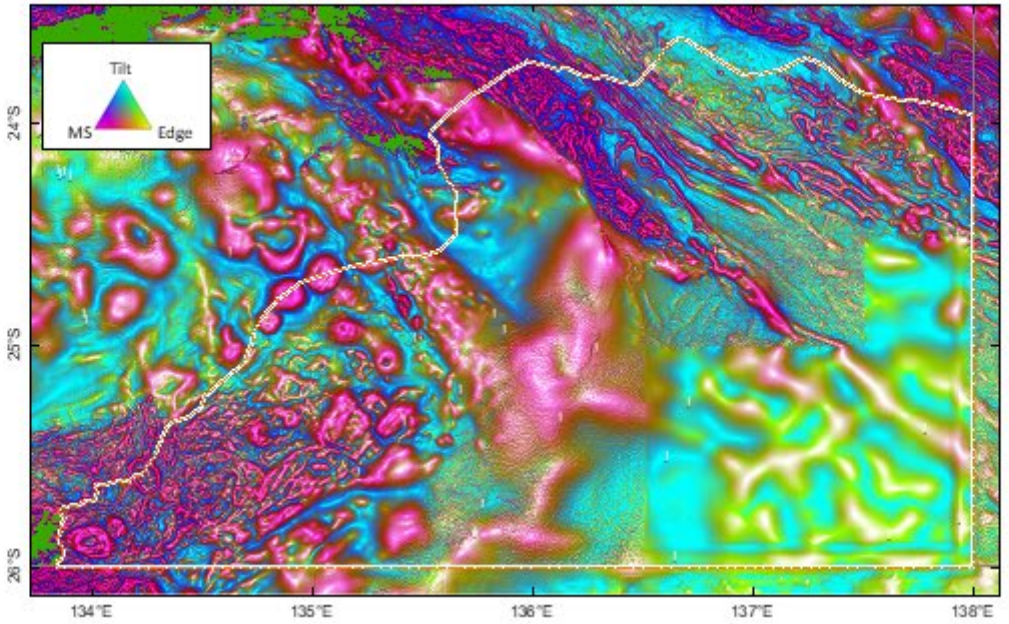
Automatic Gain Control (AGC) 200 of RTP



Reduction to Pole (RTP)



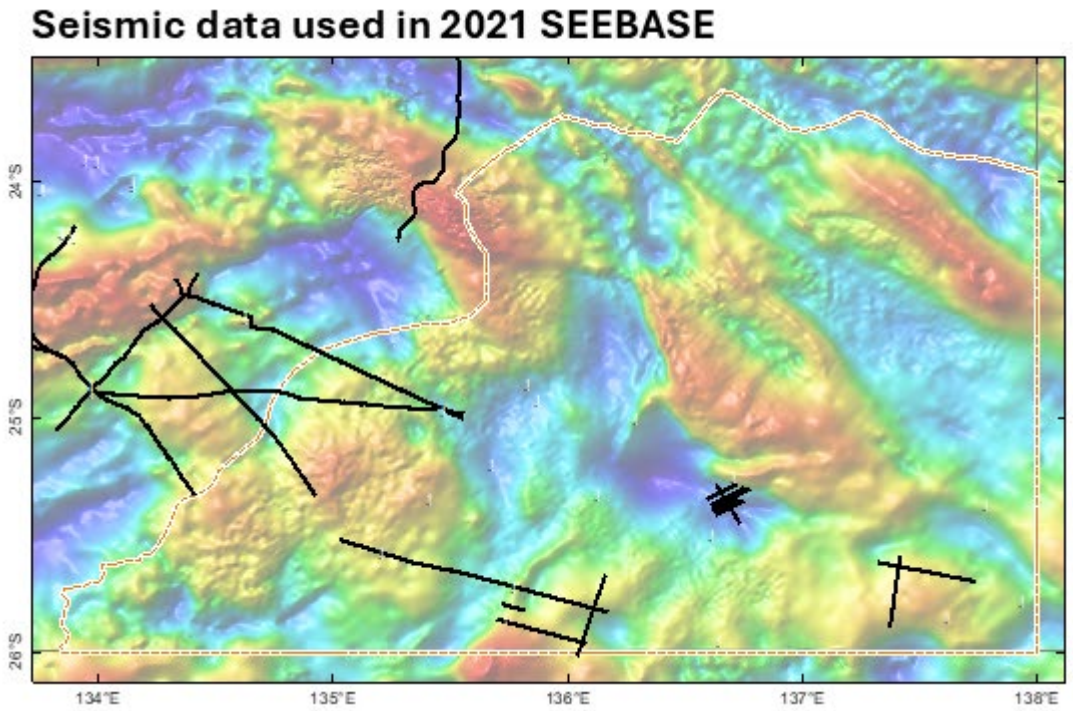
Ternary enhancement (Tilt, Modulus, Edge) of RTP

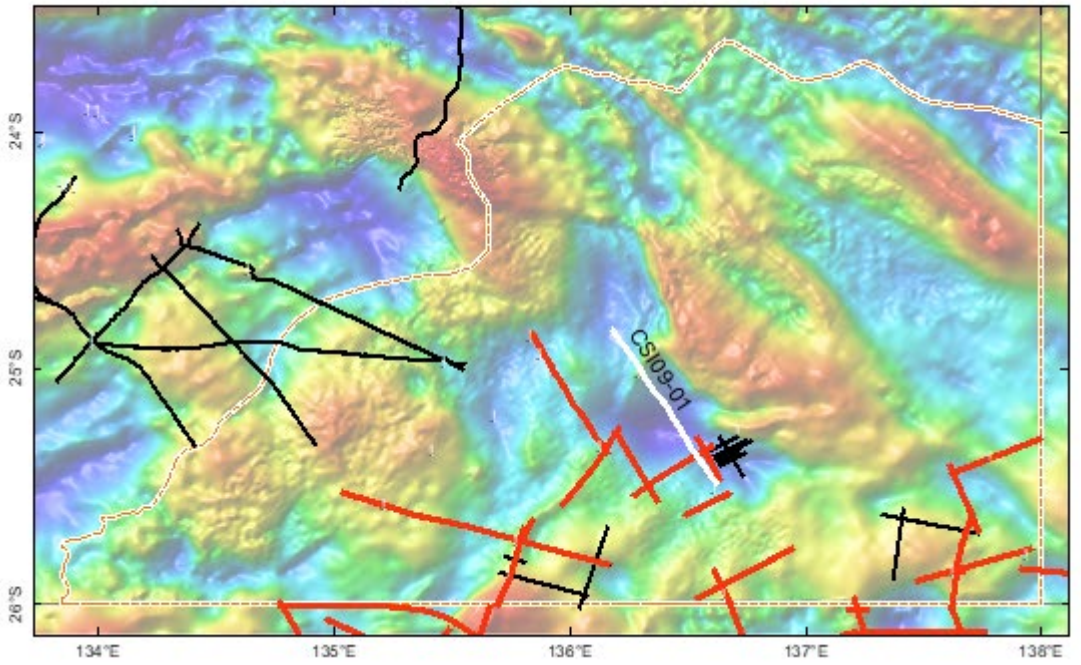


Key Calibration Data:
Seismic Data

Reprocessed Seismic

- Pedirka-Simpson Basin 2D Reprocessed Seismic Data Package 2021-2022 (Phase 1 and 2).
- Central Australian Basins 2D Reprocessed Seismic Data Package 2023
- CSI09-01 from NTGS from 2009/2010 Central Petroleum survey reprocessed by Fugro Seismic Imaging Pty Ltd in 2012.

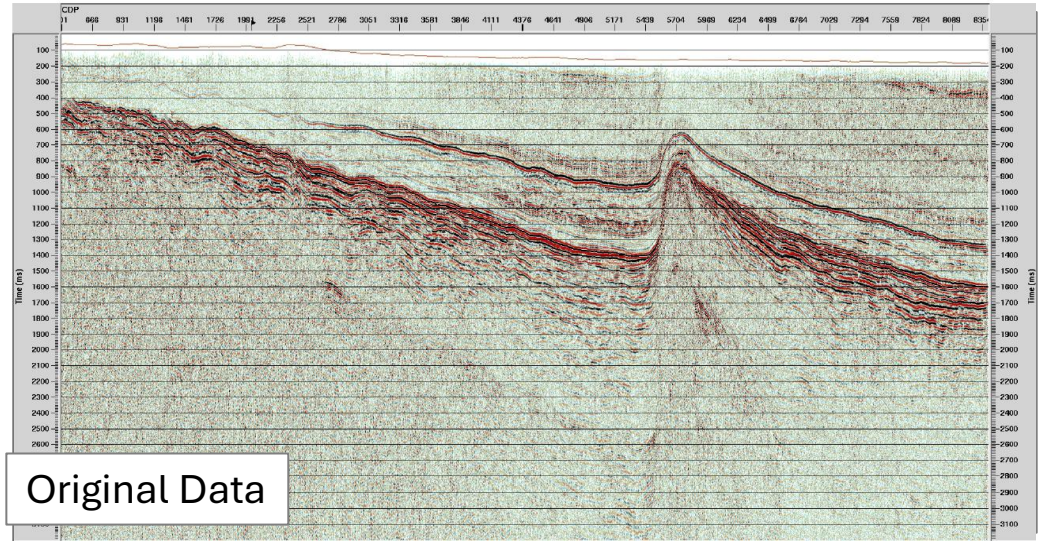




Geoscience Australia (2022). 2D Reprocessed Seismic

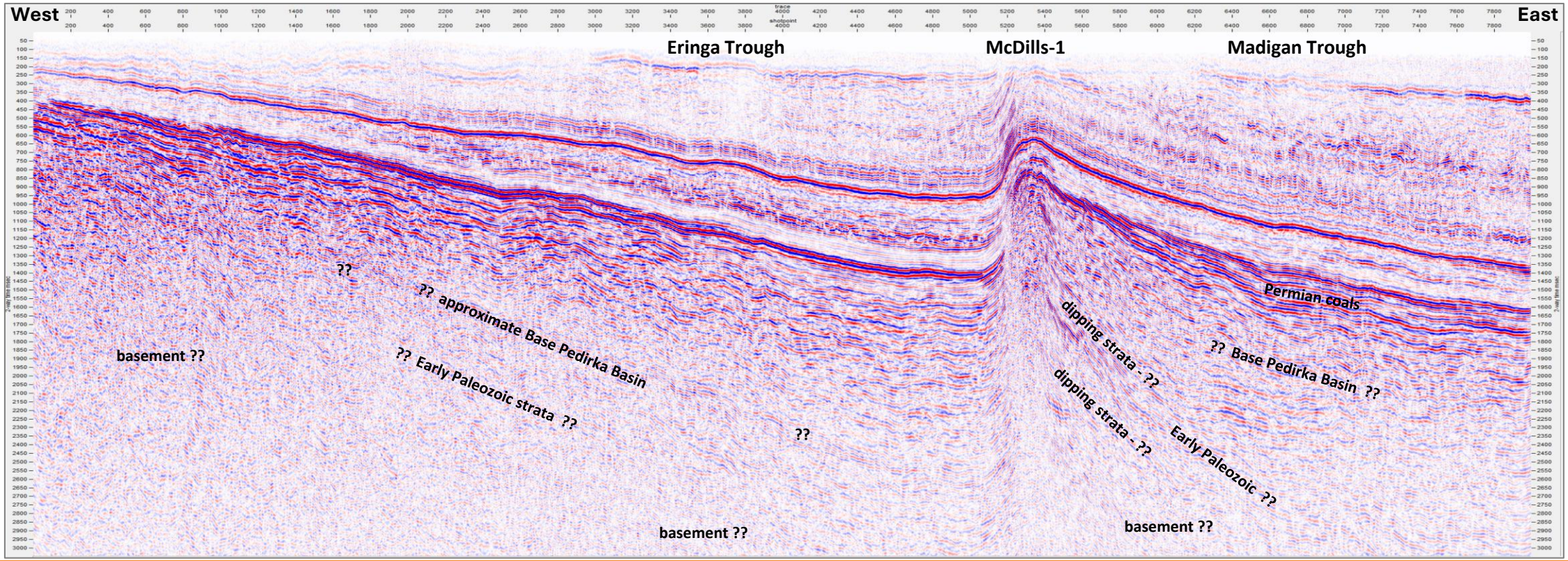
Seismic Reprocessing

Example of Line NT-01



Original Data

Reprocessed Data

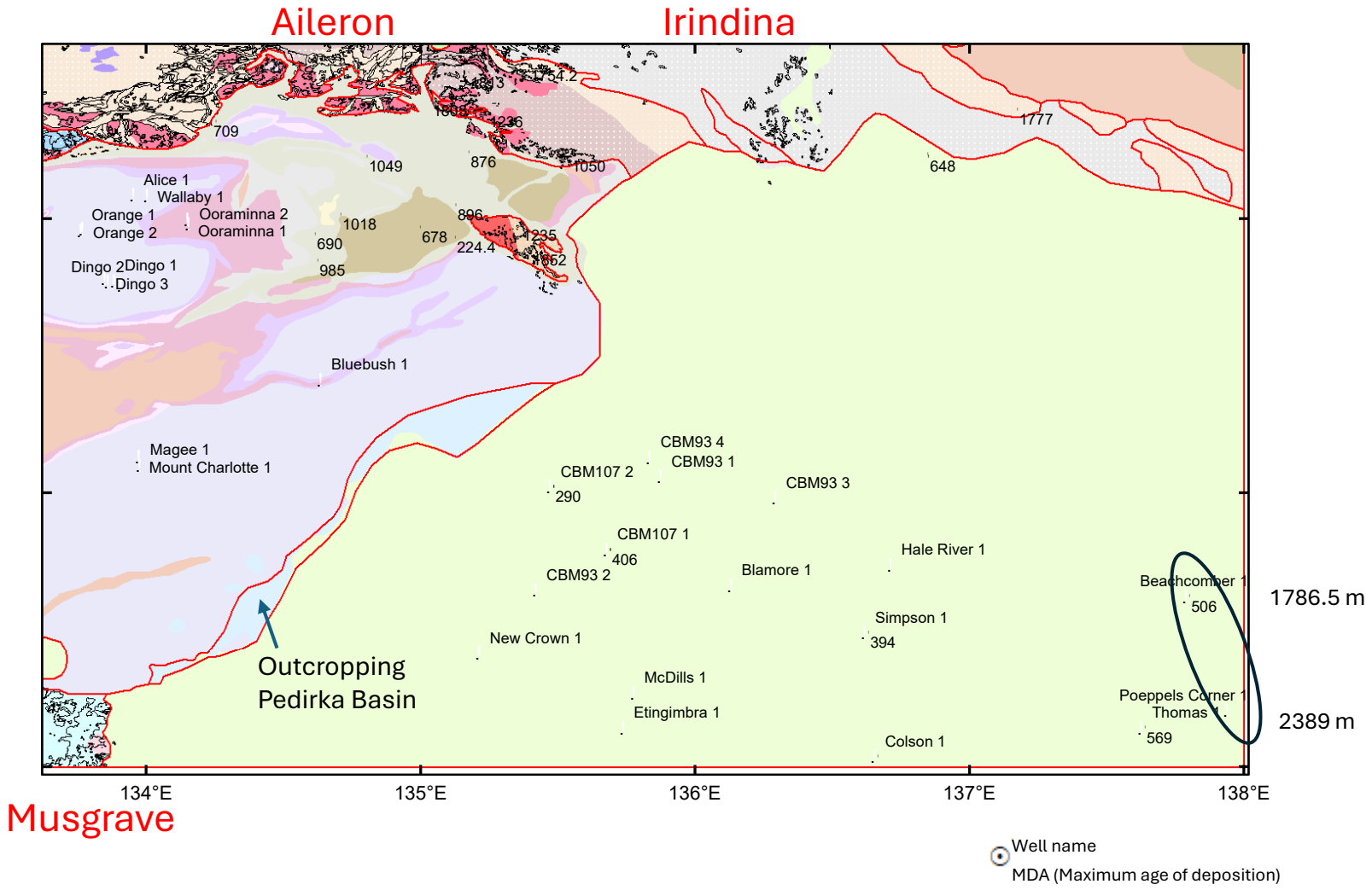


Surface Geology, Geochron, Well Data

- NTGS 2500k and 250k digital geology
- NTGS Petroleum wells and drill holes (NTGS STRIKE)
- NTGS Petroleum Geoscience data, Digital Information Package, DIP034 (Doig and Jarrett, 2023)
- New geochronology (MDA) of key samples (Kositcin et al., 2023)

Only two wells in the AOI intersect basement:

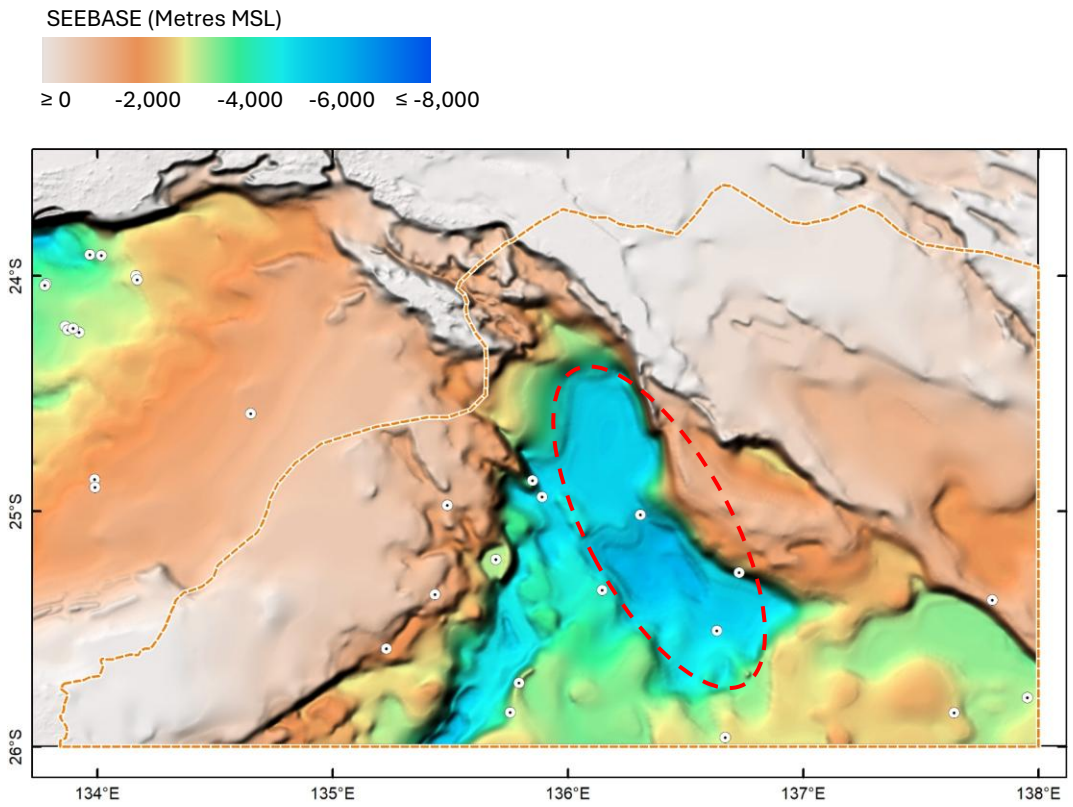
- Beachcomber 1 where Peera Peera Fm overlies metasediment with MDA of 506 Ma
- Poeppels Corners 1 where Walkandi Fm overlies basement



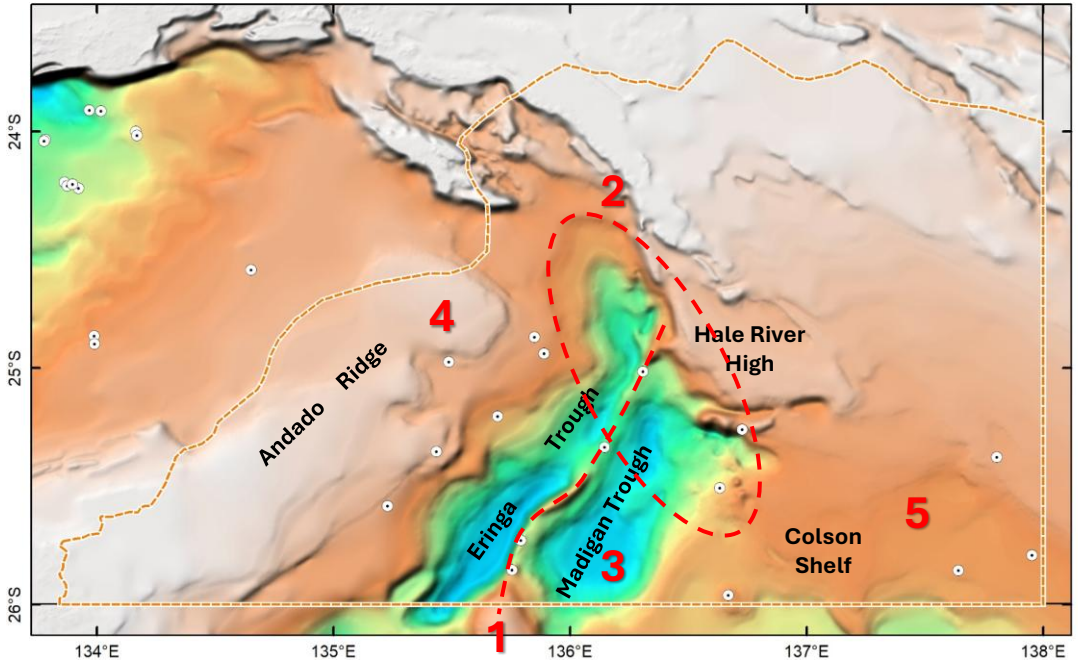
SEEBASE®

Improved quality of input data (gravity and seismic) has resulted in significant changes to the basement depth model

1. McDills trend much more prominent
2. North Eringa and Madigan troughs shallower
3. Southern Madigan Trough deeper
4. Reduced topographic variation on the Andado Ridge
5. Reduced topography on Colson Shelf

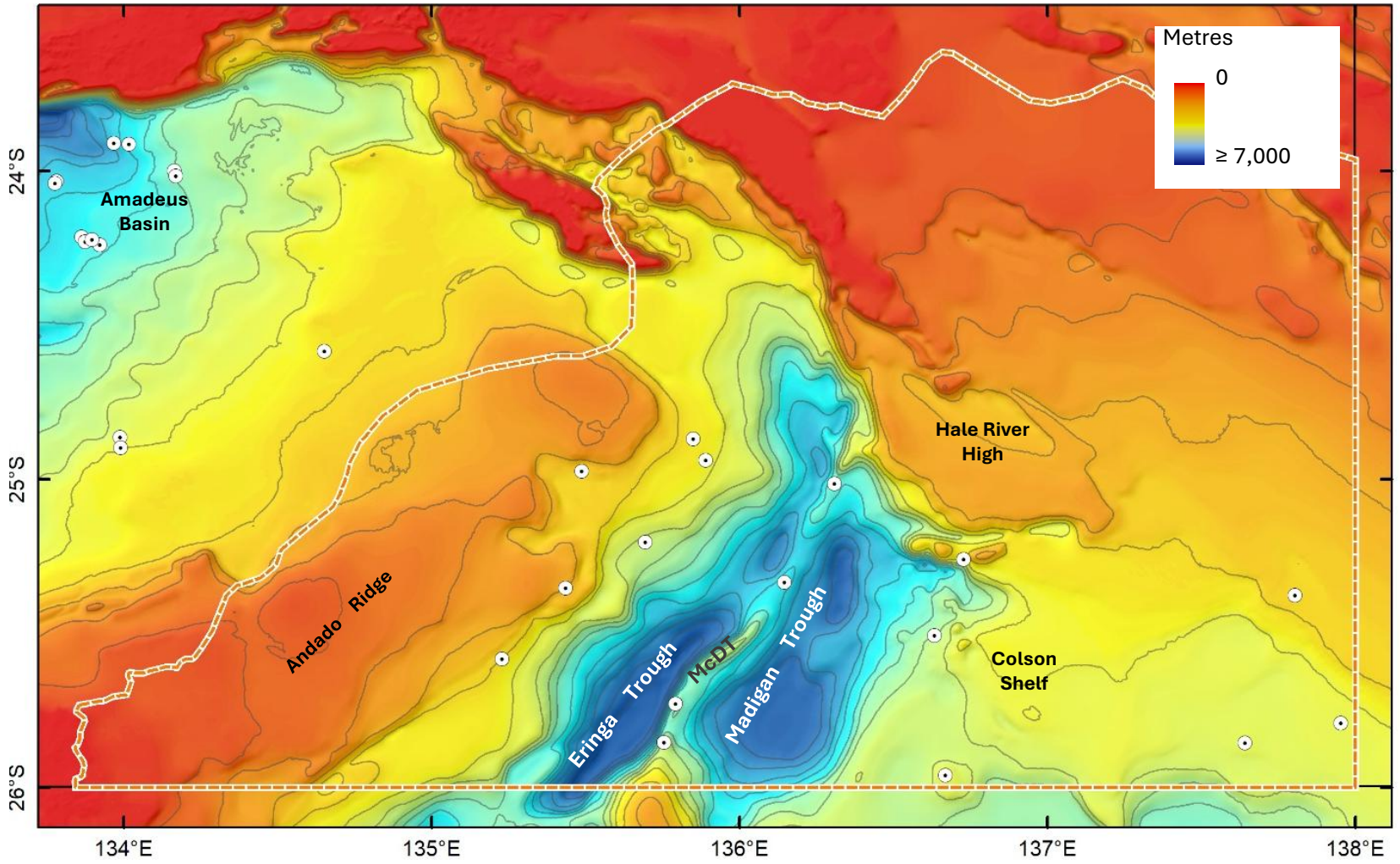


2021 Northern Territory SEEBASE®



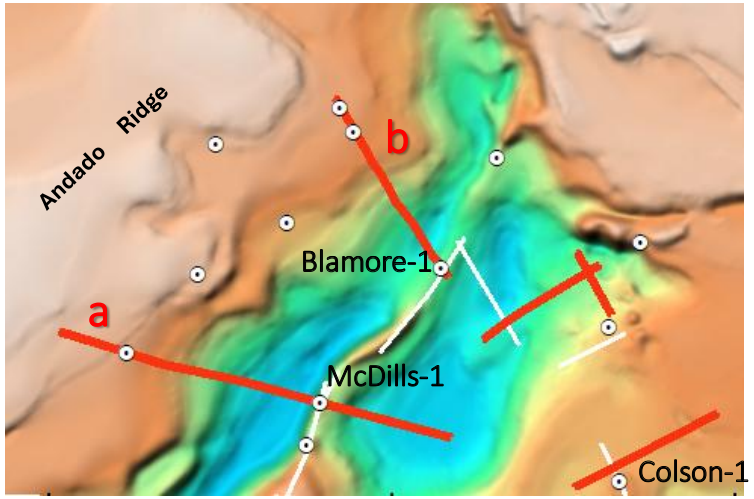
2025 Warburton-Pedirka-Eromanga Basins SEEBASE® Update

Total Sediment Thickness Map



Seismic Calibration

- Western margin onlaps Andado Ridge
- Top basement on Andado Ridge appears smooth in seismic, however imaging is poor
- Anomalies reflects basement composition
- Eringa Trough generates a negative gravity anomaly (green profile)
- McDills trend generates a positive anomaly primarily due to shallow inversion anticline



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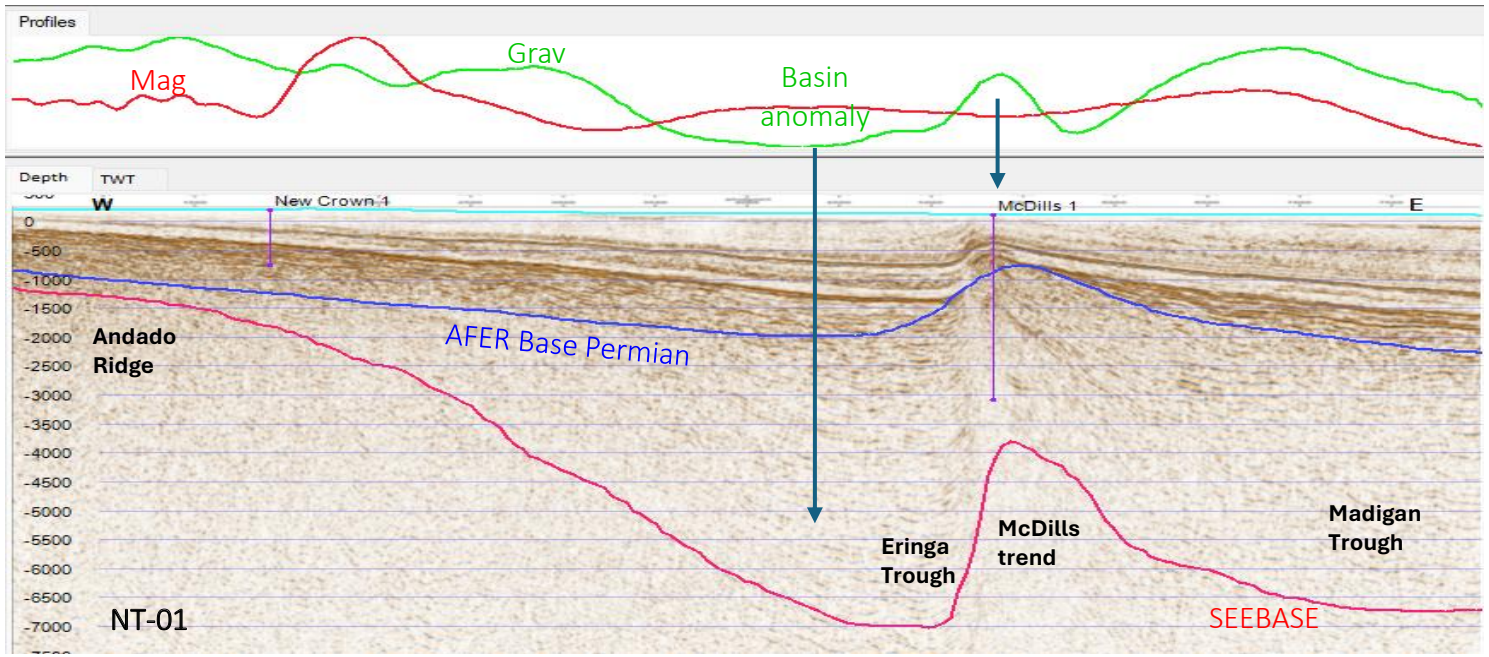
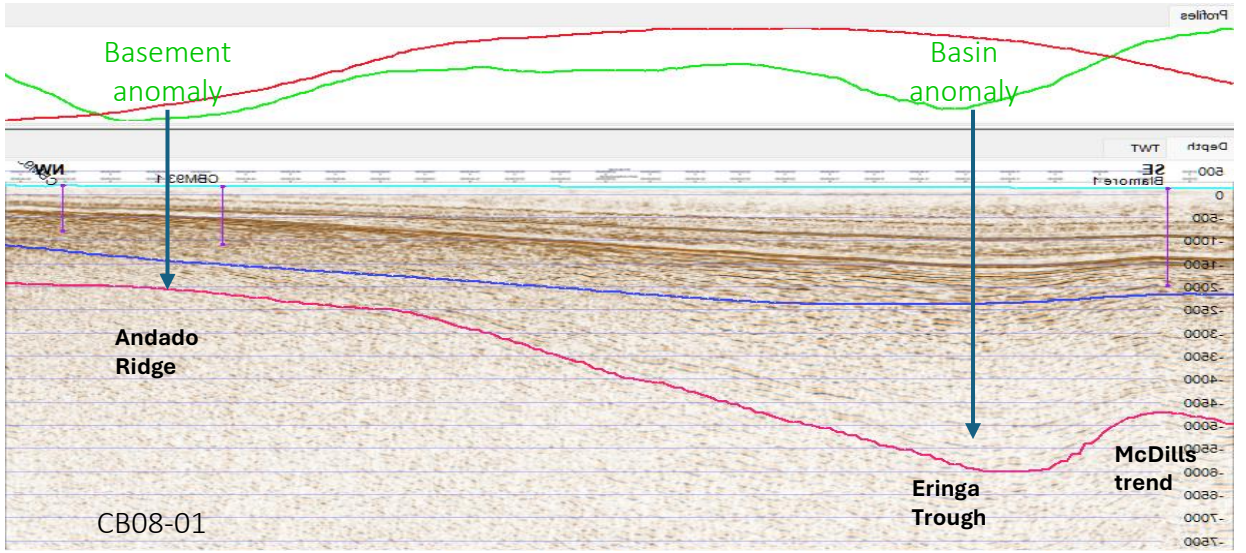


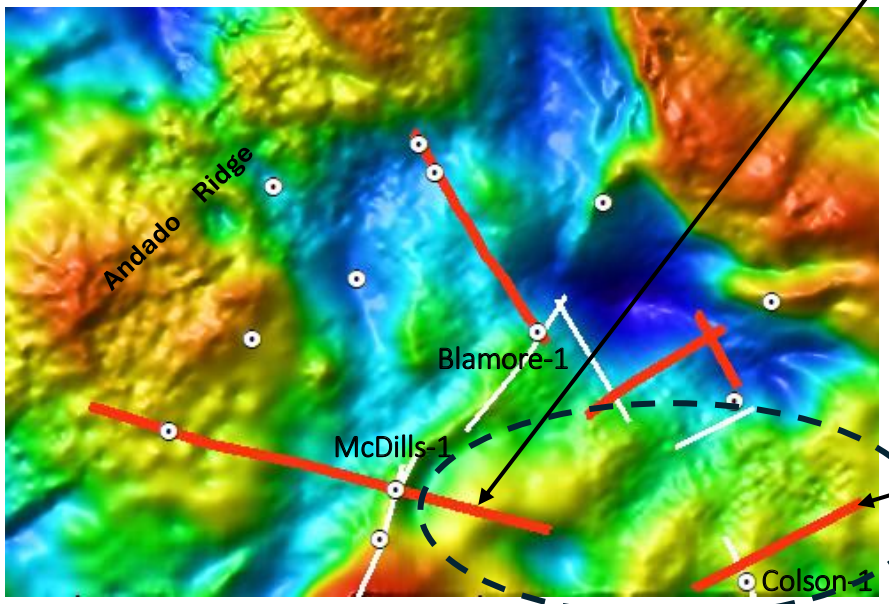
AFER – Australia's Future Energy Resources

b

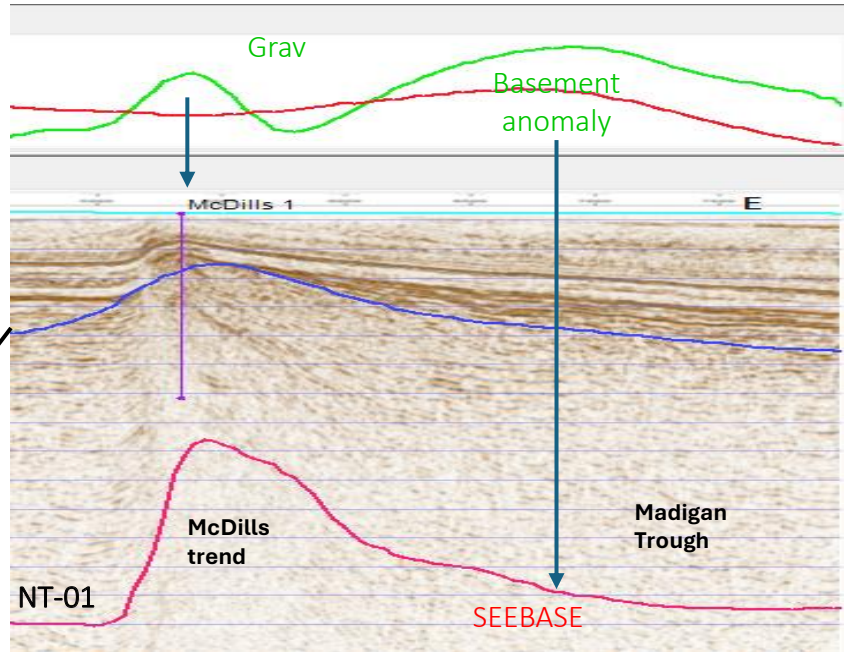


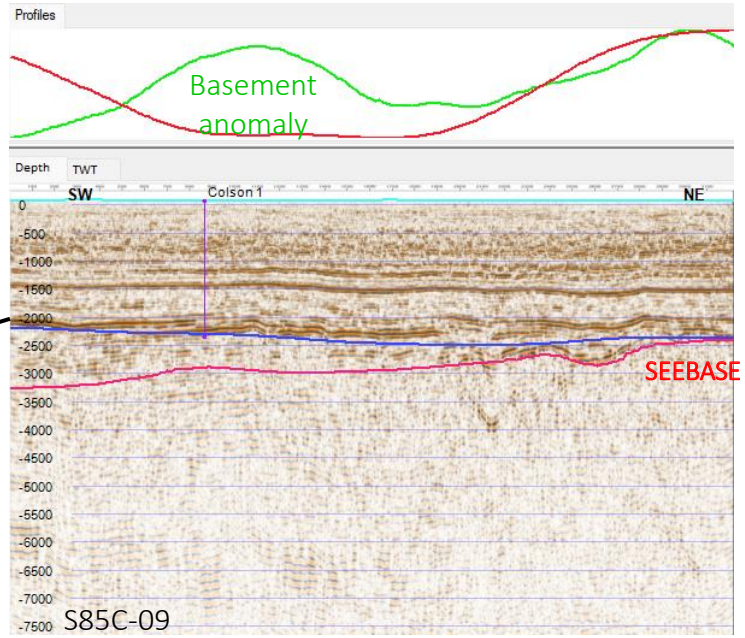
Seismic Calibration

- East of McDills trend gravity data do not generally reflect basement depth
- Gravity anomalies are due to density contrast in the basement



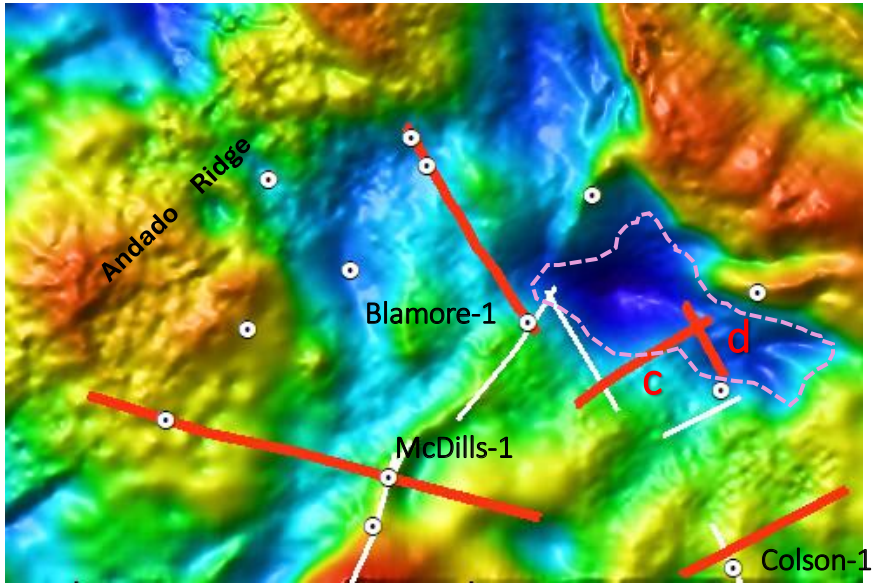
HP200BG





Seismic Calibration

- Warburton Basin sediments are only clearly imaged in reprocessed seismic where basement is granitic



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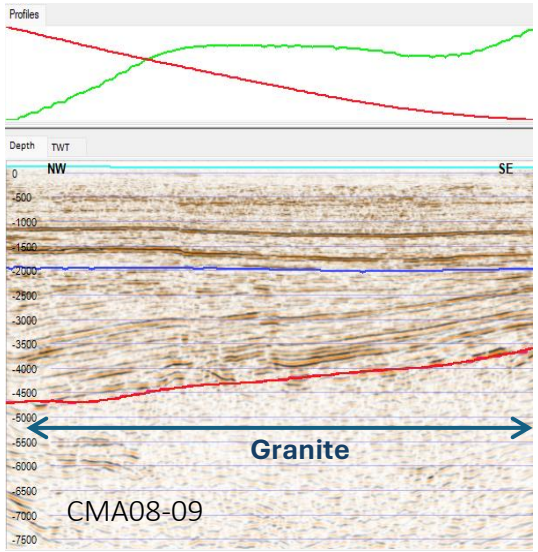

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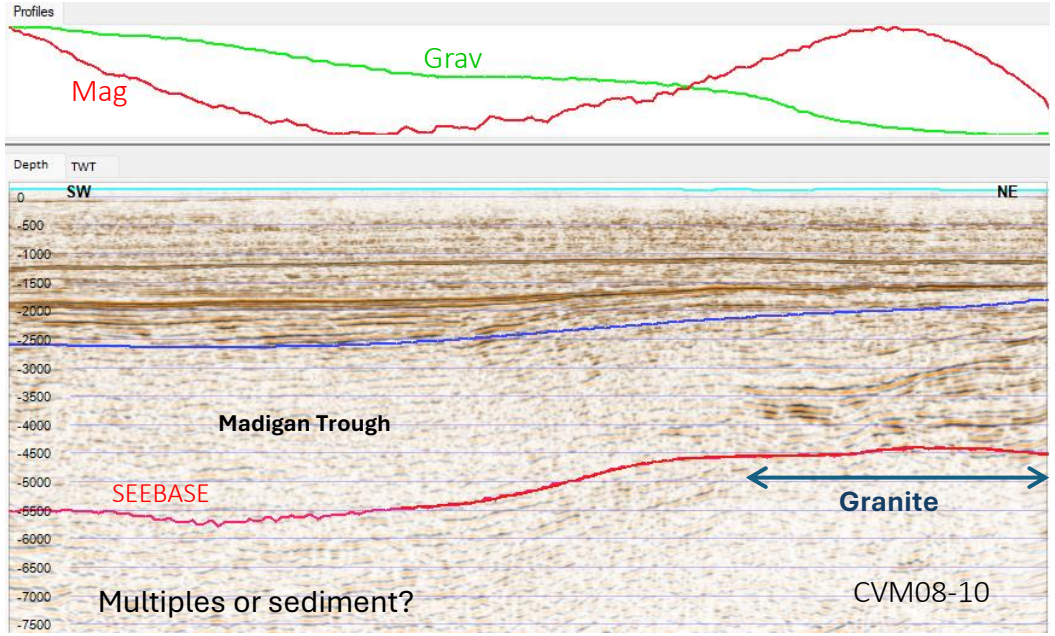
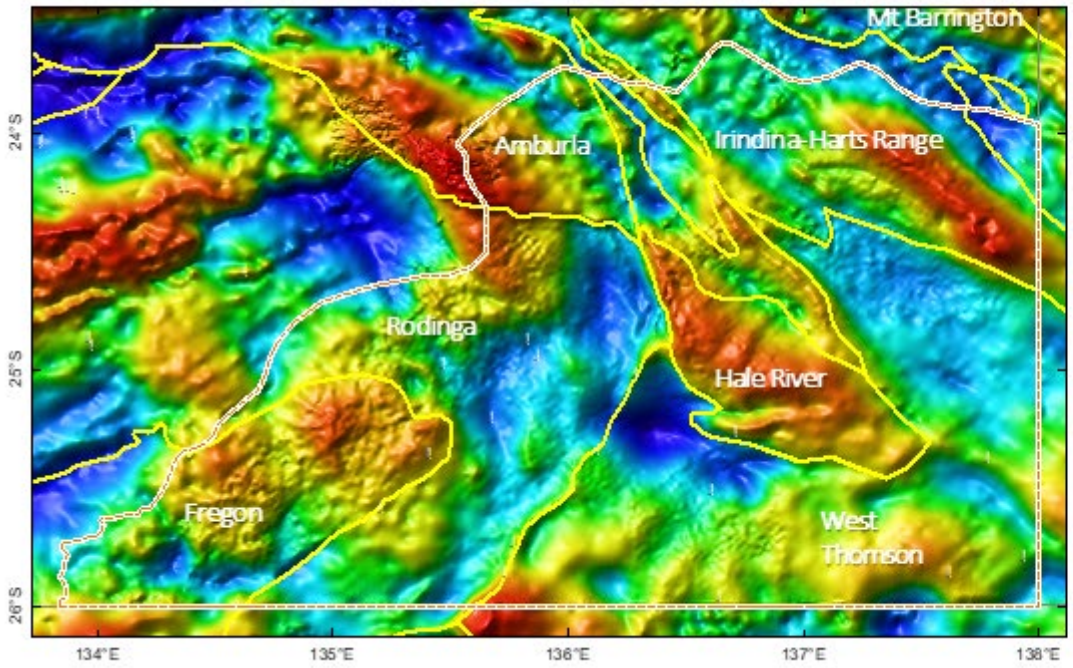


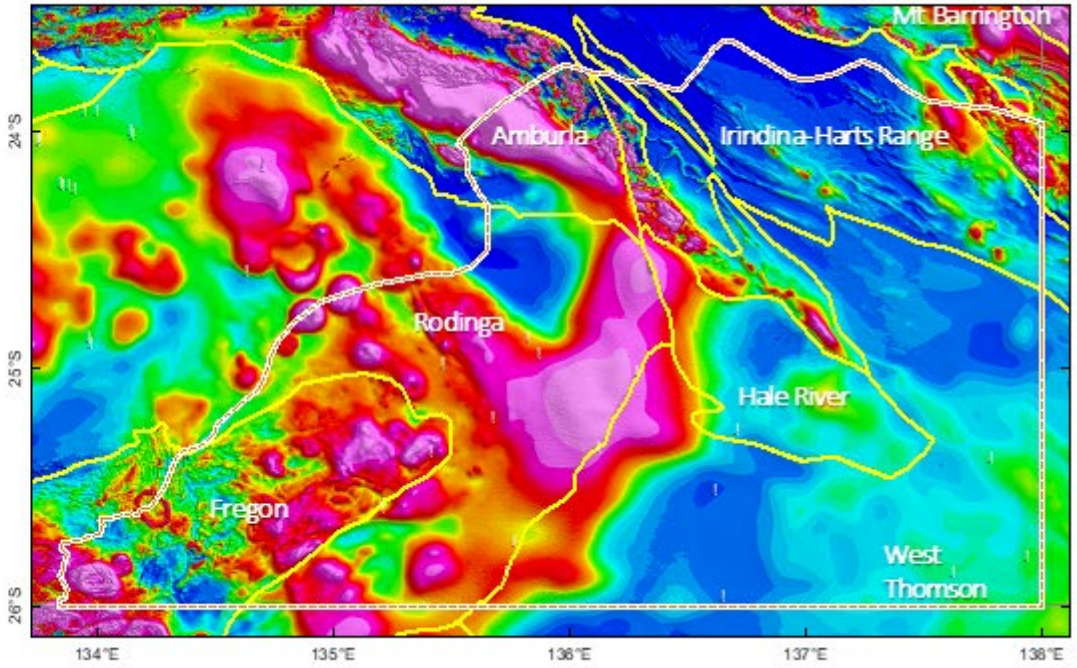
Basement Terranes

- Terrane boundaries are mapped using a combination of gravity, magnetics and outcropping basement

Gravity

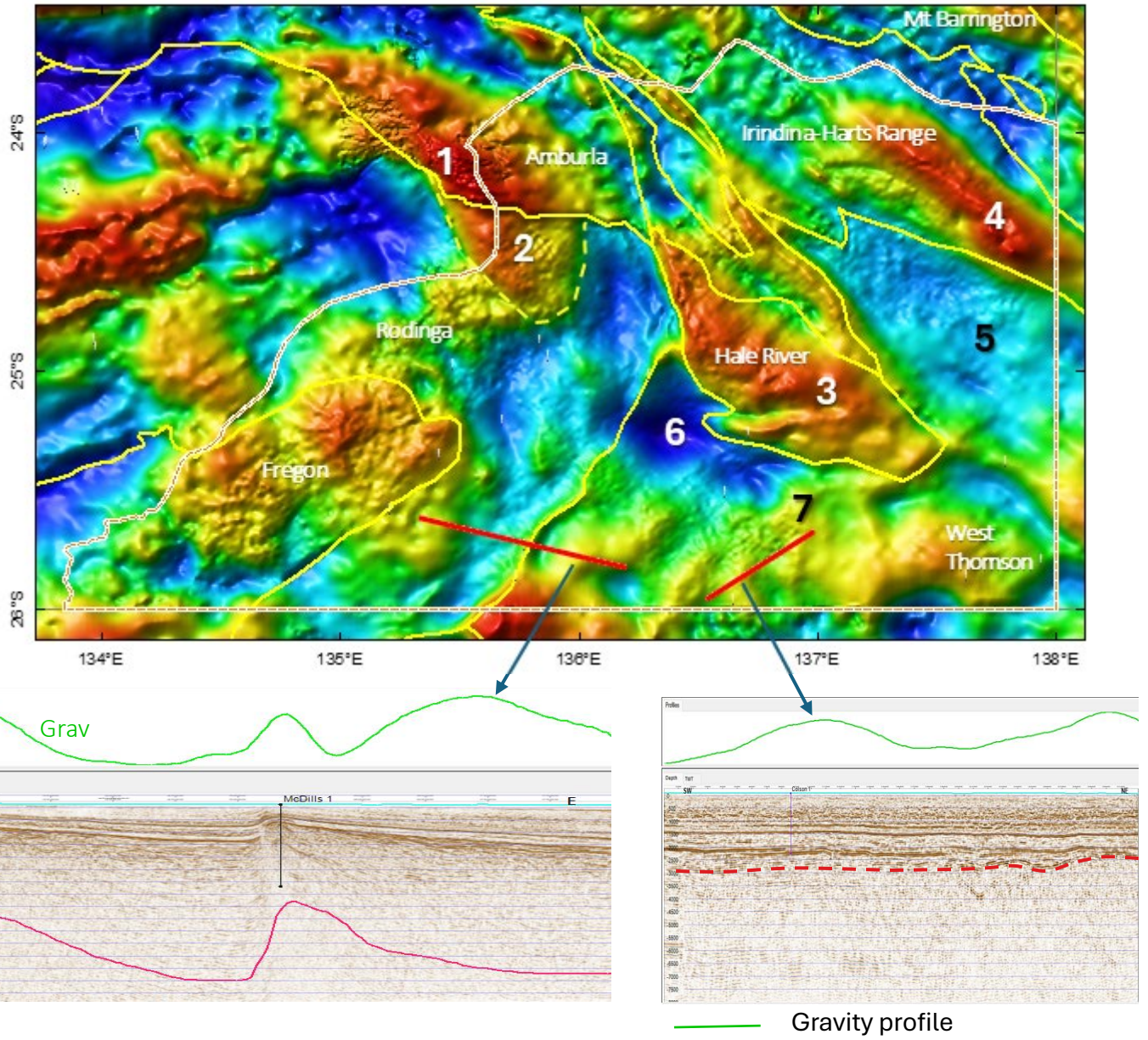


Magnetics



Gravity Signatures

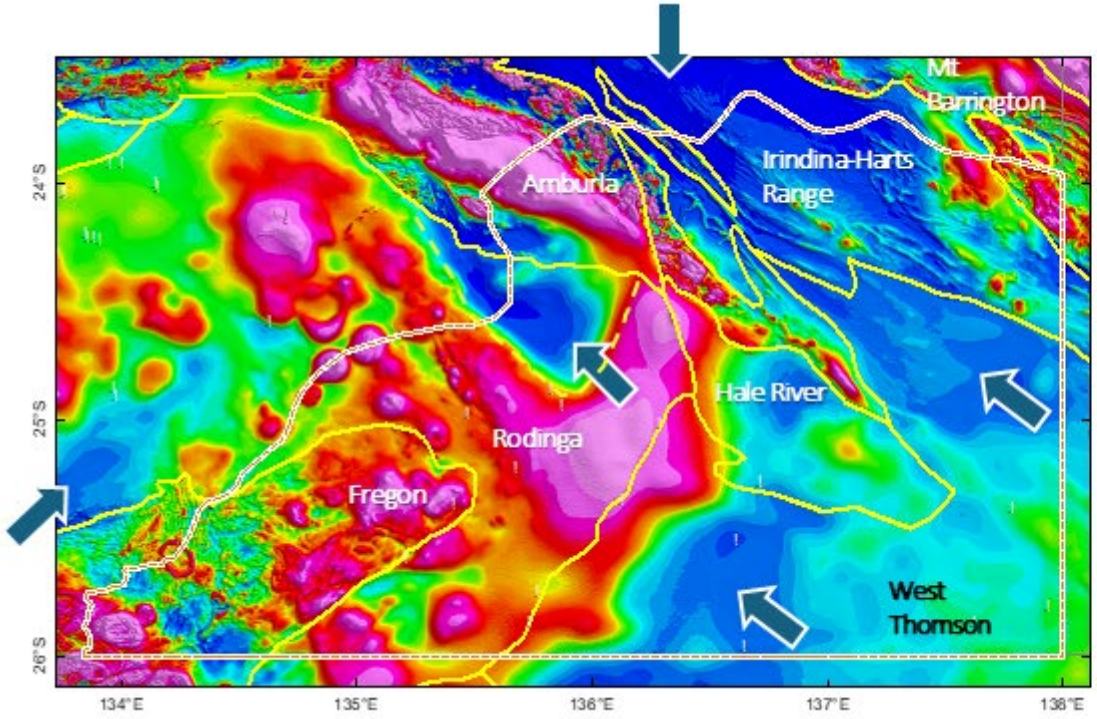
1. High-density gneiss
2. Continuation of positive anomaly that correlates with negative magnetic anomaly - continuation of Amburla terrane to the S ?
3. High density signature of Hale River block
4. Positive anomaly possibly related to Larapinta rift-related mafic units beneath metasediments
5. Low-density metasediments
6. Negative anomaly primarily due to underlying felsic intrusion in basement
7. Linear anomalies interpreted to be due to Delamerian folding or tilting in basement metasediments that are not imaged in seismic



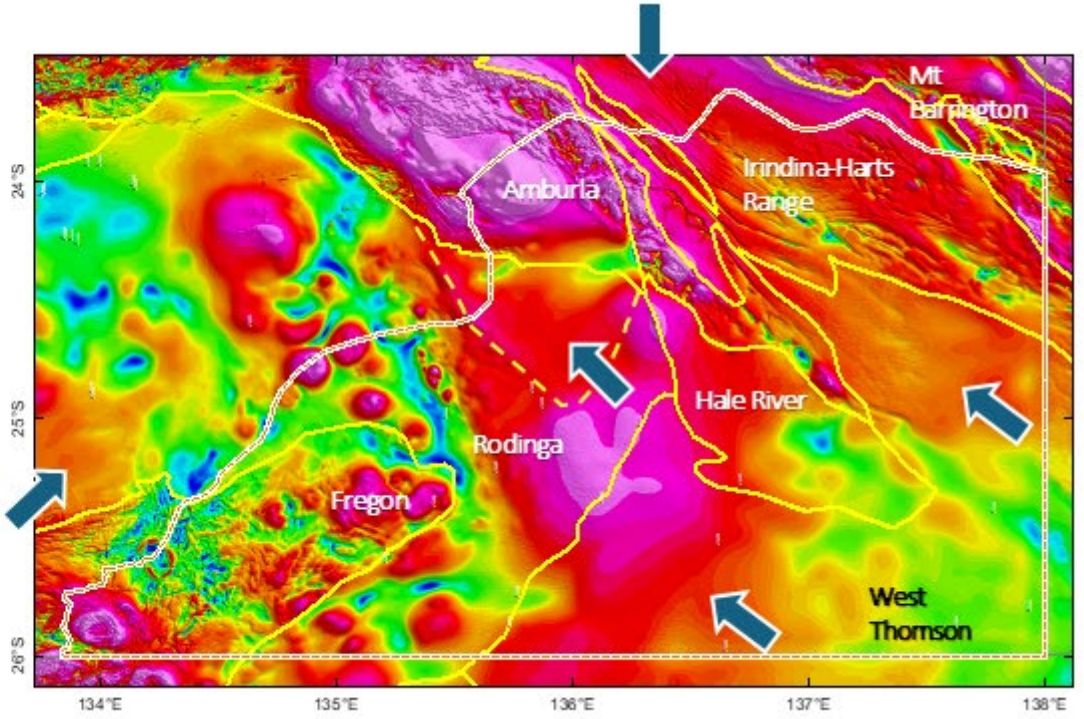
Magnetic Signatures

- Positively magnetised intrusives, orthogneiss, contact aureoles and volcanics

- Negatively magnetised metasedimentary basement (arrows)



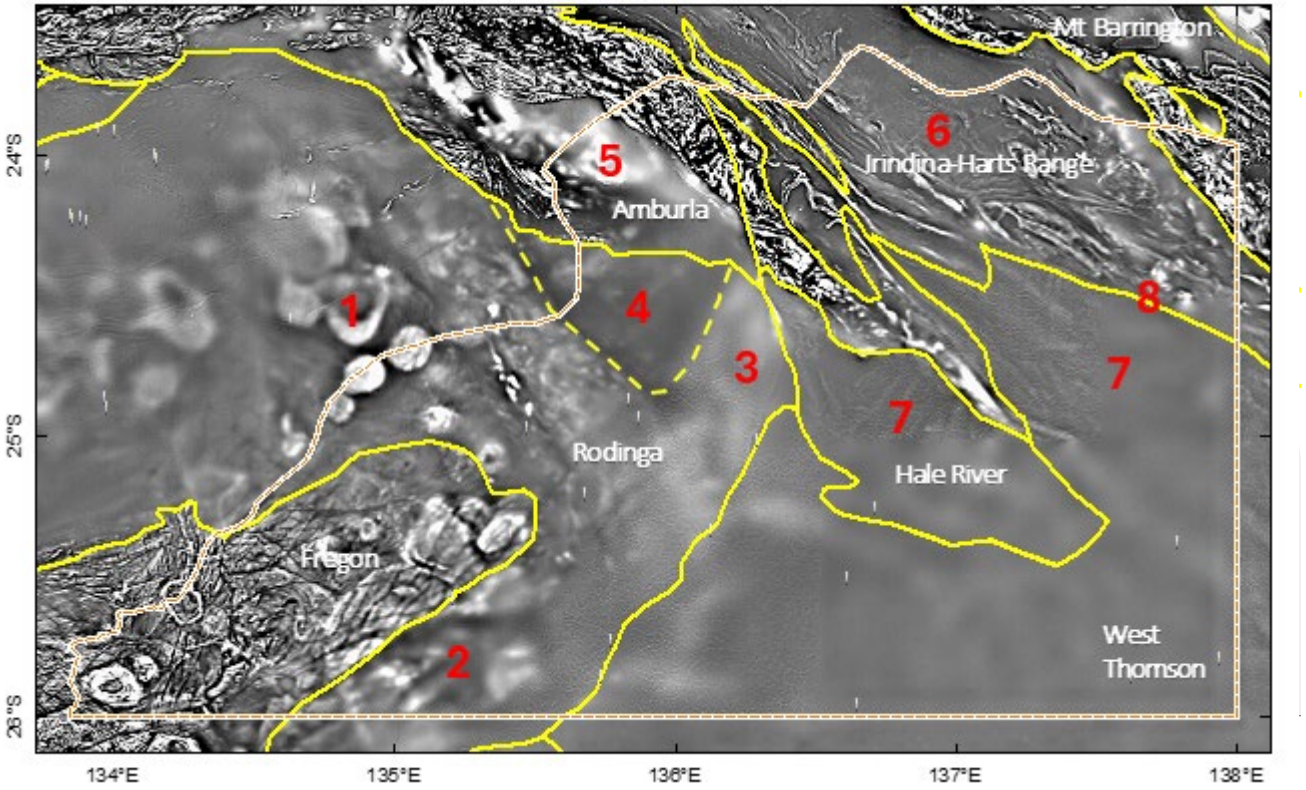
RTP



CA – Compound Anomaly Filter

RTP 1VD shows character and depth to magnetic sources

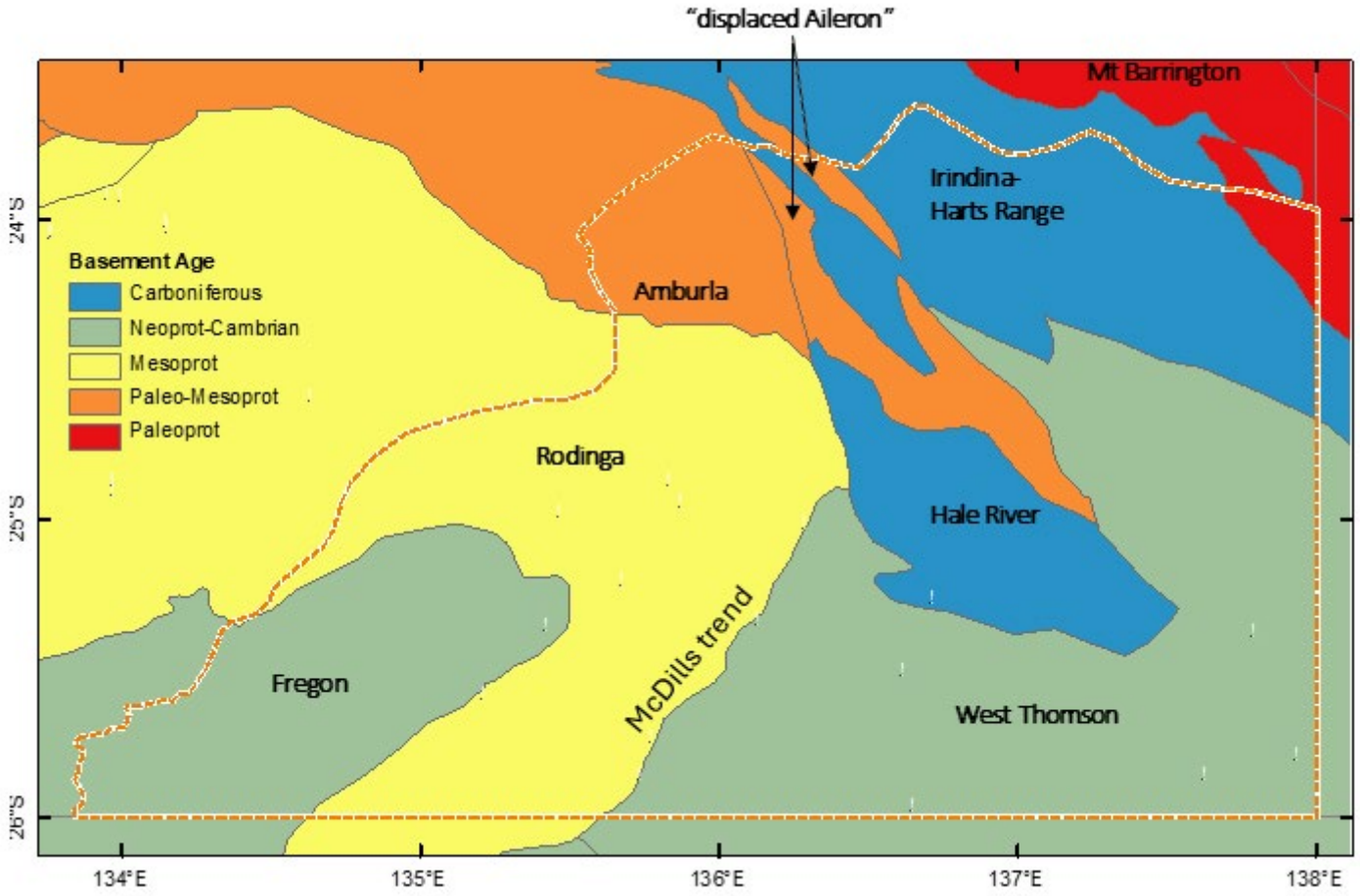
1. Undeformed Pitjantjatjara intrusives (1220-1120Ma)
2. Rodinga basement beneath Warburton sediments
3. Deep, positively magnetised volcanic layer truncated to the NW
4. Negative anomaly correlates with positive gravity anomaly - continuation of Amburla terrane?
5. Amburla basement beneath Amadeus sediments
6. Tightly folded metasediments and metamafics with tightness of folds decreasing to the E
7. Non-magnetic metasedimentary basement – **Hale River indistinguishable from West Thomson in magnetics**



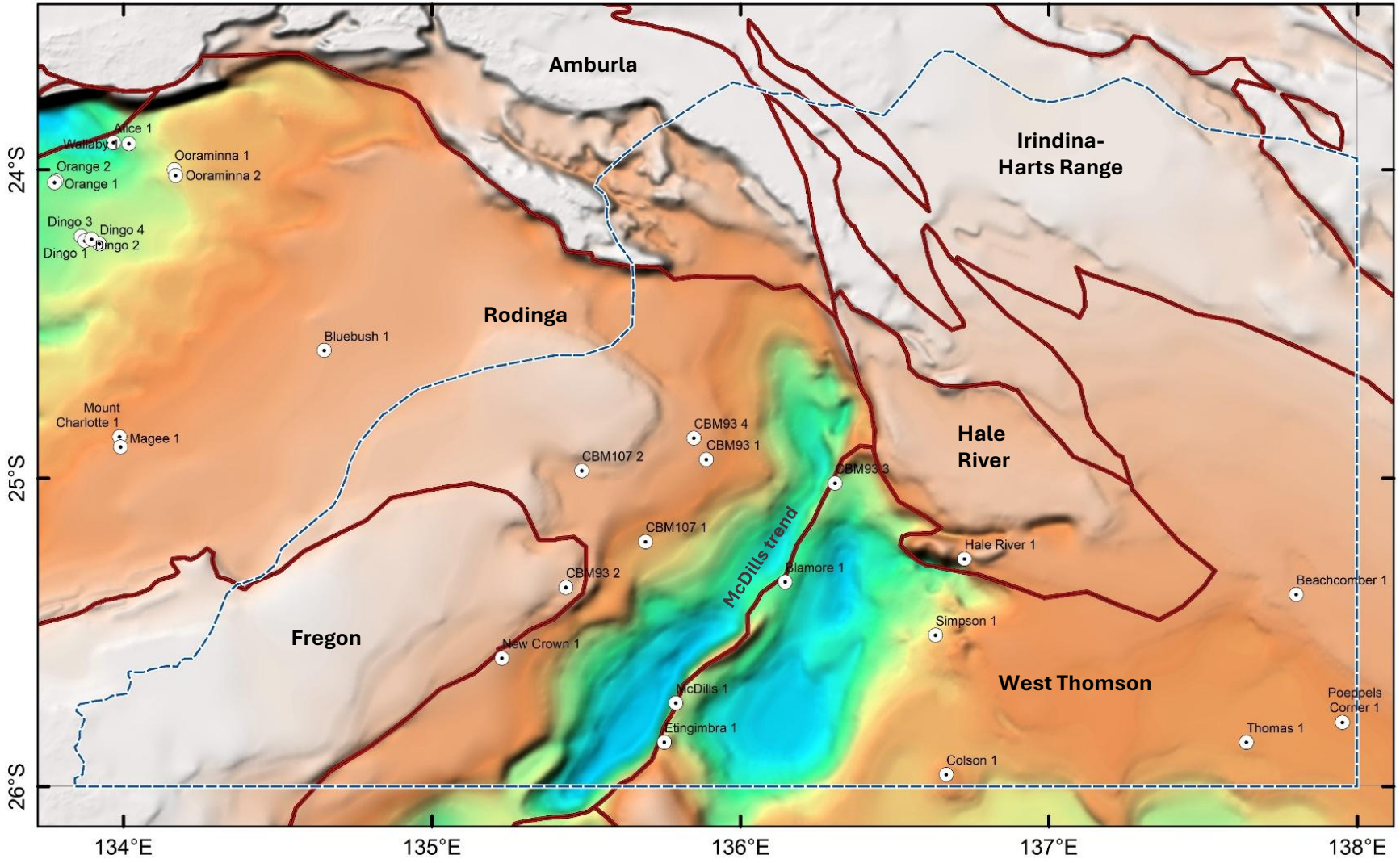
8. The boundary between Irindina and West Thomson may be metamorphic rather than tectonic (as is the Fregon-Rodinga boundary) as the intensity of the Alice Springs deformation dies out to the SE.

Basement Age

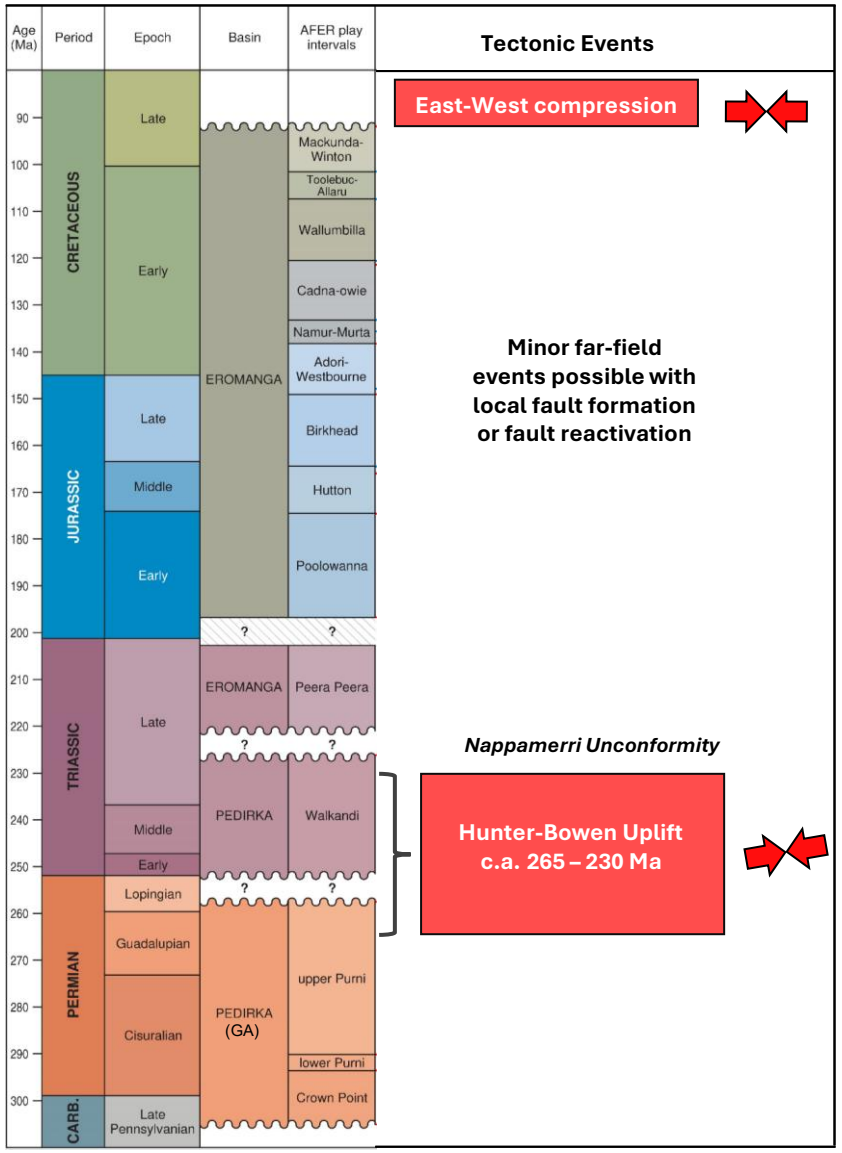
- Mount Barrington (Aileron Province) basement age is Paleoproterozoic
- Amburla (Aileron Province), and the “displaced Aileron” basement age ranges from Paleo- to Mesoproterozoic and locally early to mid Paleozoic due to reworking during the Alice Springs Orogeny
- Rodinga and Fregon formed a single Mesoproterozoic terrane prior to the 580-530 Ma Petermann Orogeny, which reworked and exhumed the Fregon (Musgraves) basement
- West Thomson basement is Neoproterozoic to Cambrian
- Irindina-Harts Range - Neoproterozoic to Cambrian metasediments metamorphosed in Ordovician and deformed/exhumed during ASO
- Hale River interpreted to have originally been part of West Thomson that was deformed and metamorphosed during the Alice Springs Orogeny

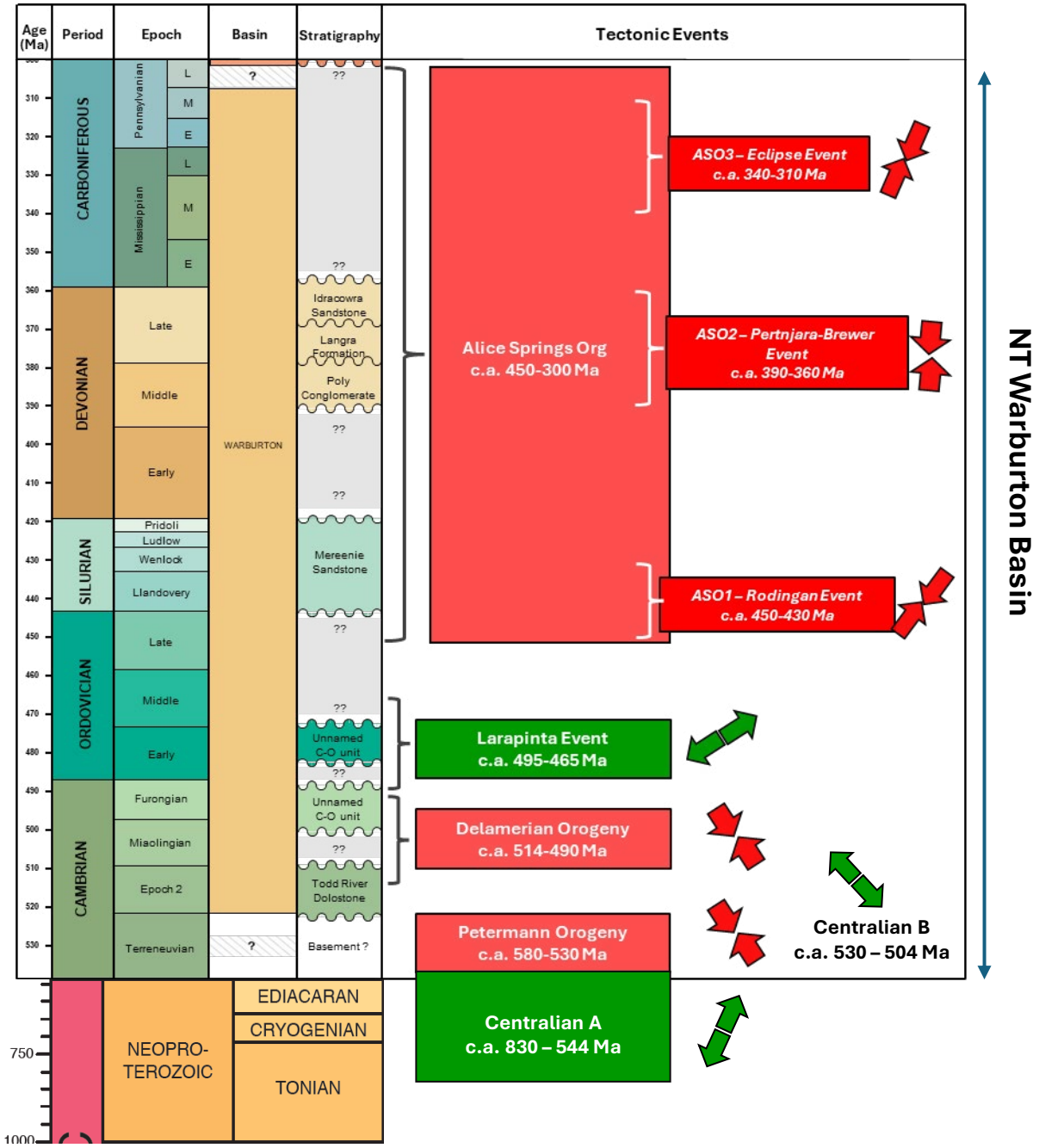


SEEBASE with basement terranes



Tectonic Events

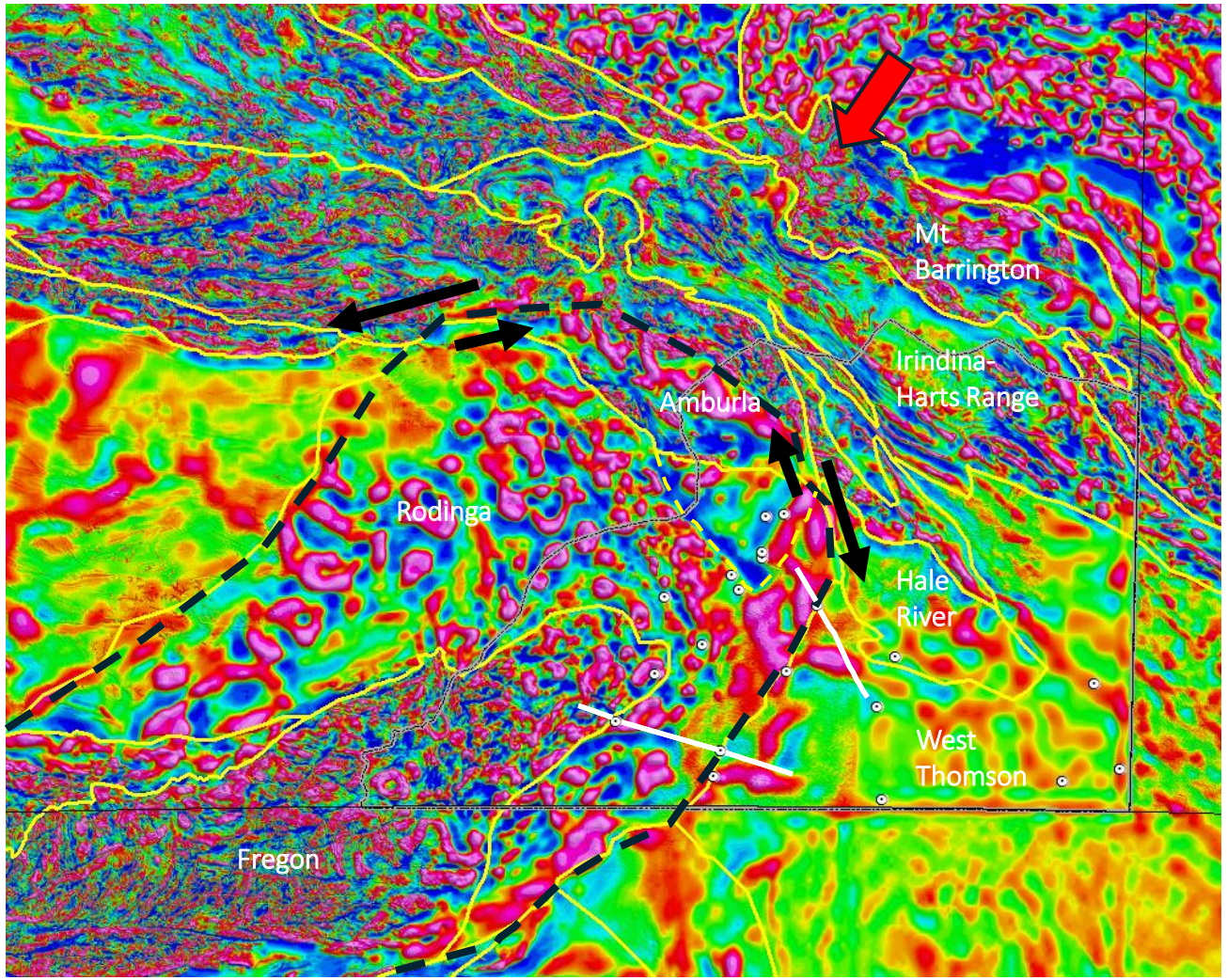




Alice Springs Orogeny

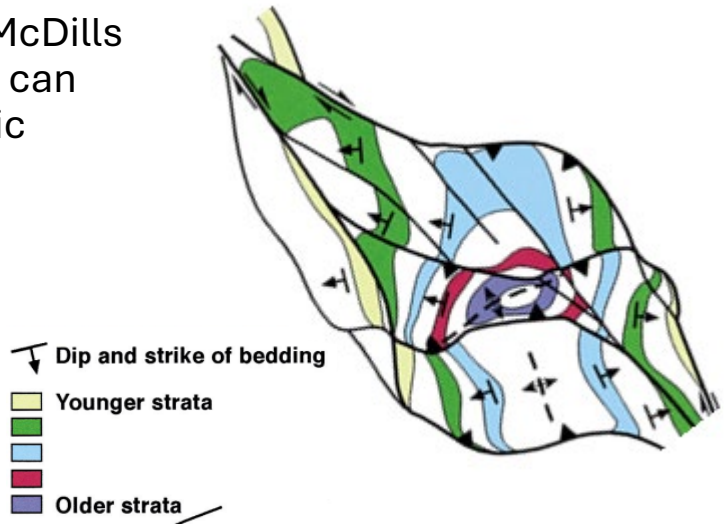
c.a. 450-300Ma

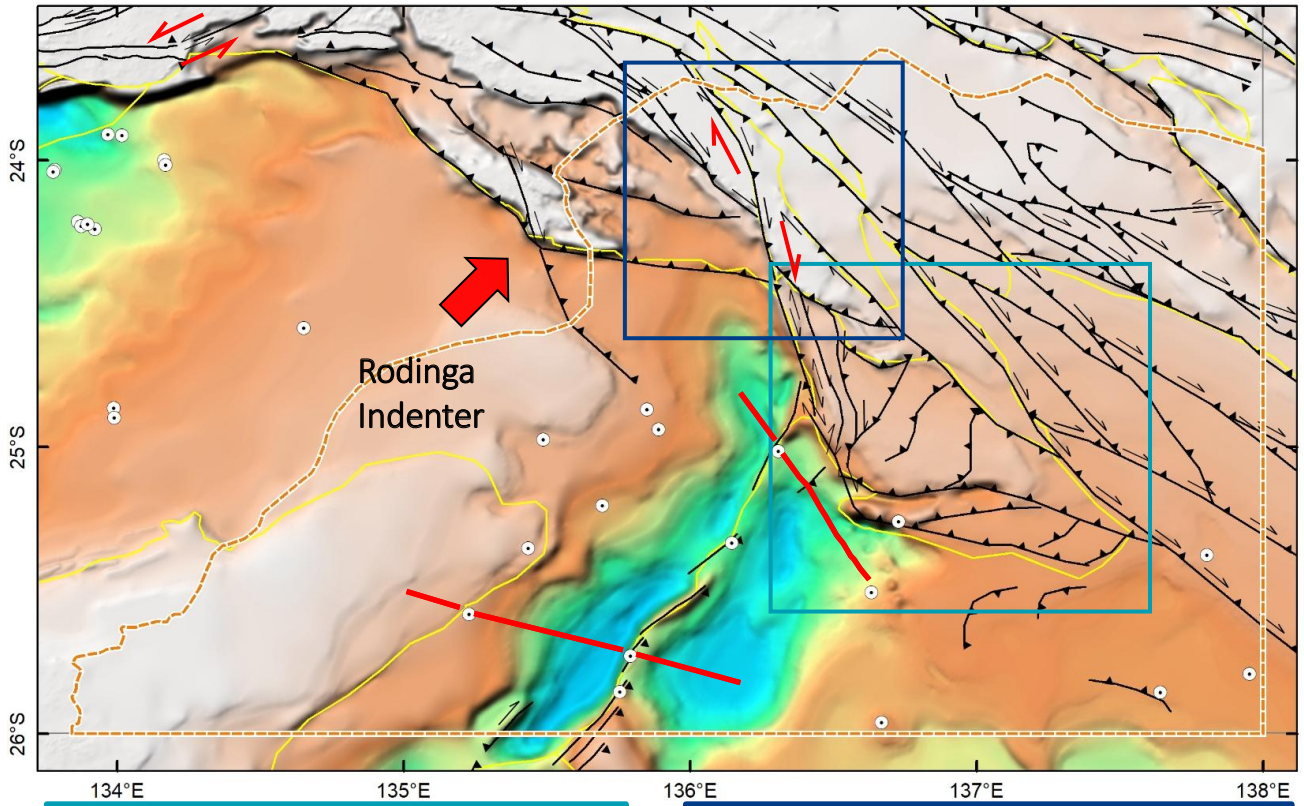
- Rodinga and Fregon were heavily intruded by Pitjantjatjara suite (1220-1120Ma) increasing basement strength
- Compression during ASO concentrated at the nose of Rodinga “indenter”
- Ambrula (Aileron) compressed against Rodinga
- Intense inversion/deformation in Irindina-Harts Range
- Bivergent strike-slip at indenter shoulders
- Deformation dies out to the SE

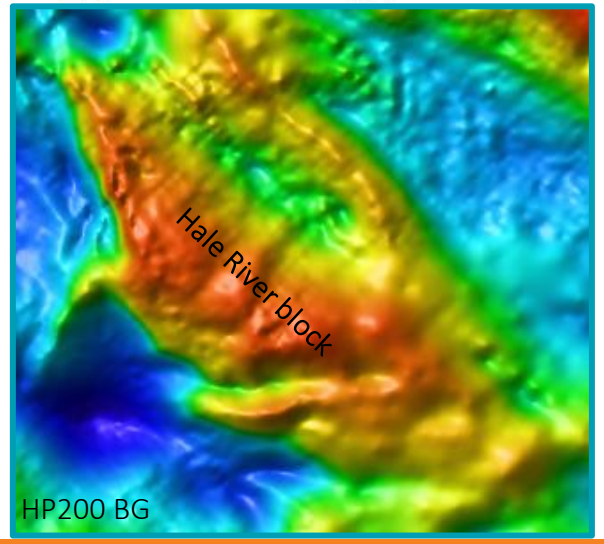


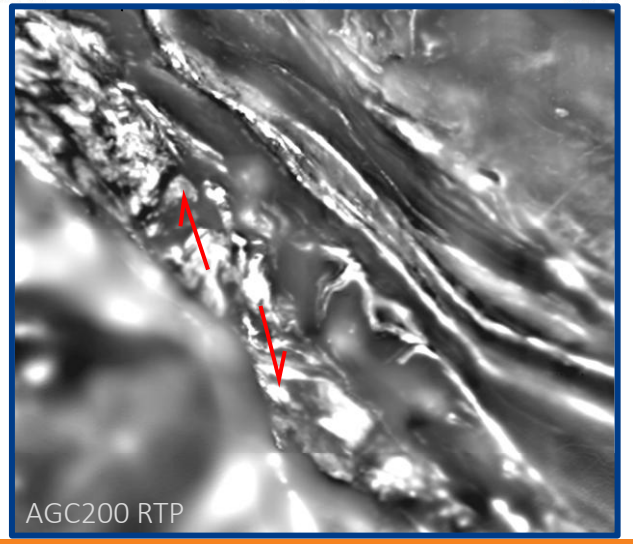
RTP AGC200

- The Warburton lies south of the documented evidence of Alice Springs deformation.
- Rodinga terrane acted as an indenter
- Sinistral strike-slip deformation occurred on the NW side of the indenter
- 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 the dextral strike-slip system
- Pop-up model from McClay and Bonora (2001)
- Deformation on McDills trend during ASO can be seen in seismic



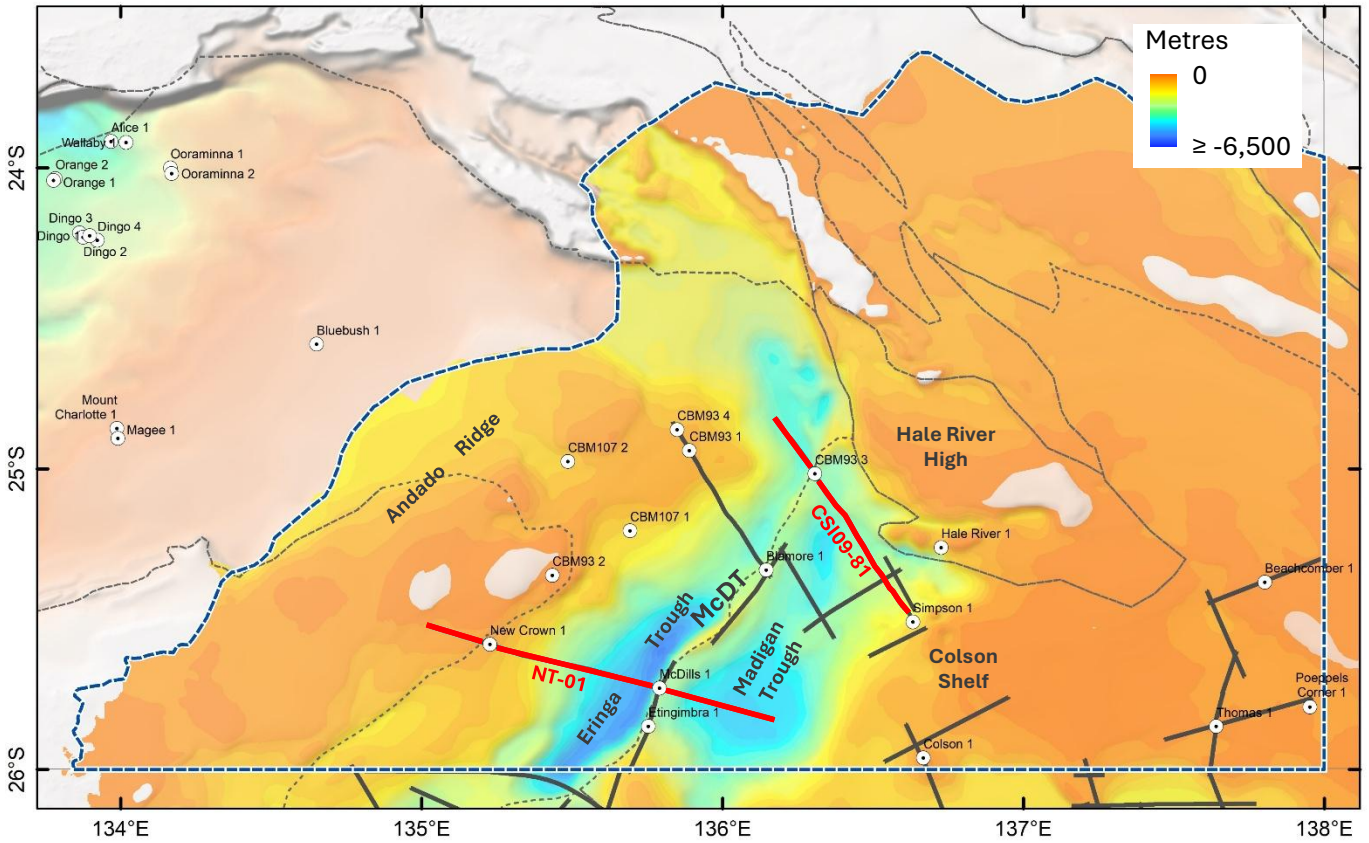






Geognostics Seismic Interpretation:

Basement Calibration, Tectonic Events and Basin Response



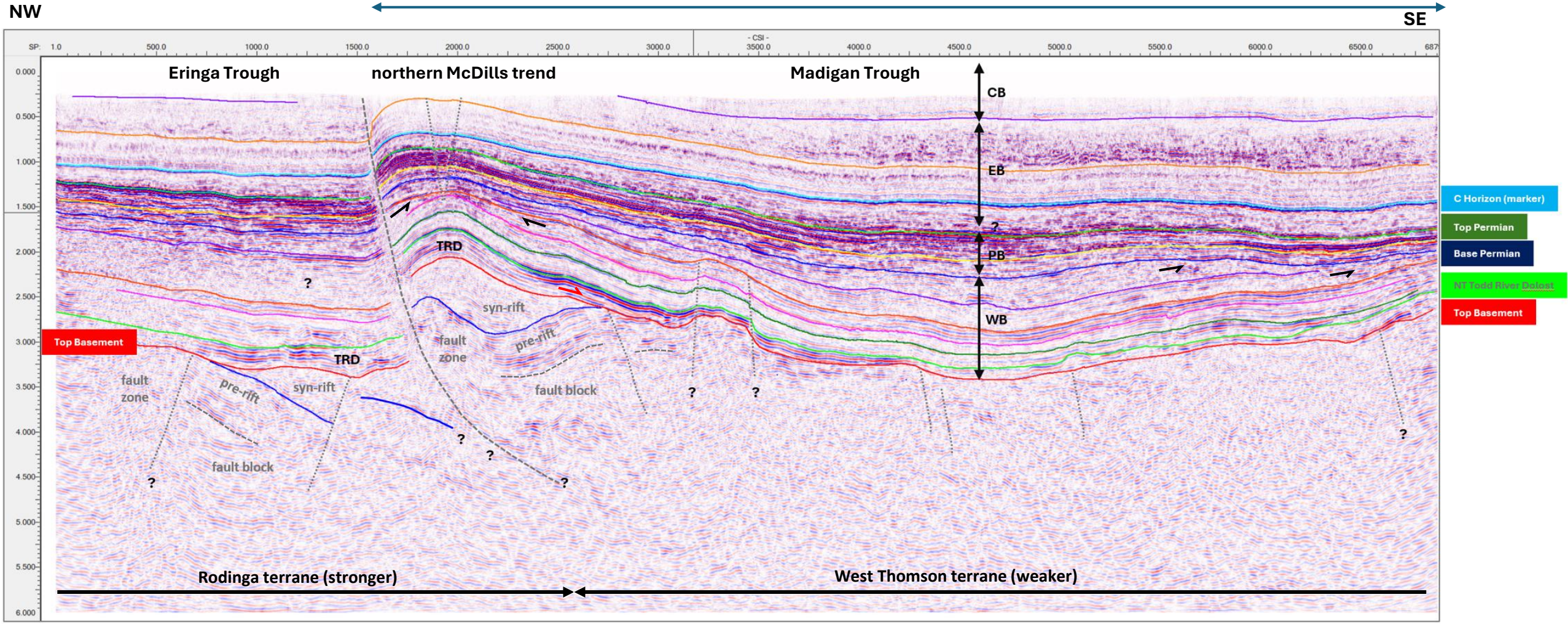
Warburton Basin Sediment Thickness Map

Two key seismic lines that anchor the Warburton Basin and basement regional interpretations:

- **CSI09-81:** Best basement imaging but no deep well tie
- **NT-01:** Ties to McDills-1 well but deep imaging is poor
- **Other issues:** Only one deep well to constrain interpretations and limited velocity data to constrain time-to-depth conversions

Seismic Interpretation: Basement

Line CSI09-81(twt)

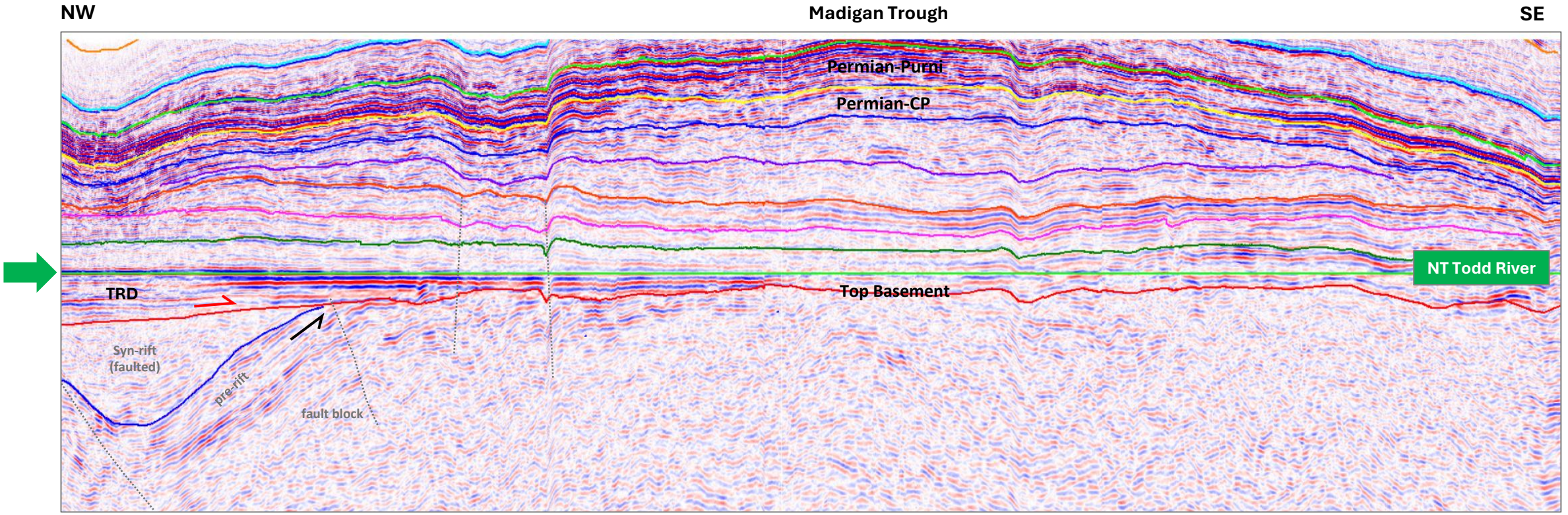


TRD = Todd River Dolostone

WB = Warburton Basin PD = Pedirka Basin EB = Eromanga Basin CB = Cenozoic Basin

Seismic Interpretation

Line CSI09-81 Flattened on (interpreted) Near-Top Todd River Dolostone (approximately 510 Ma)

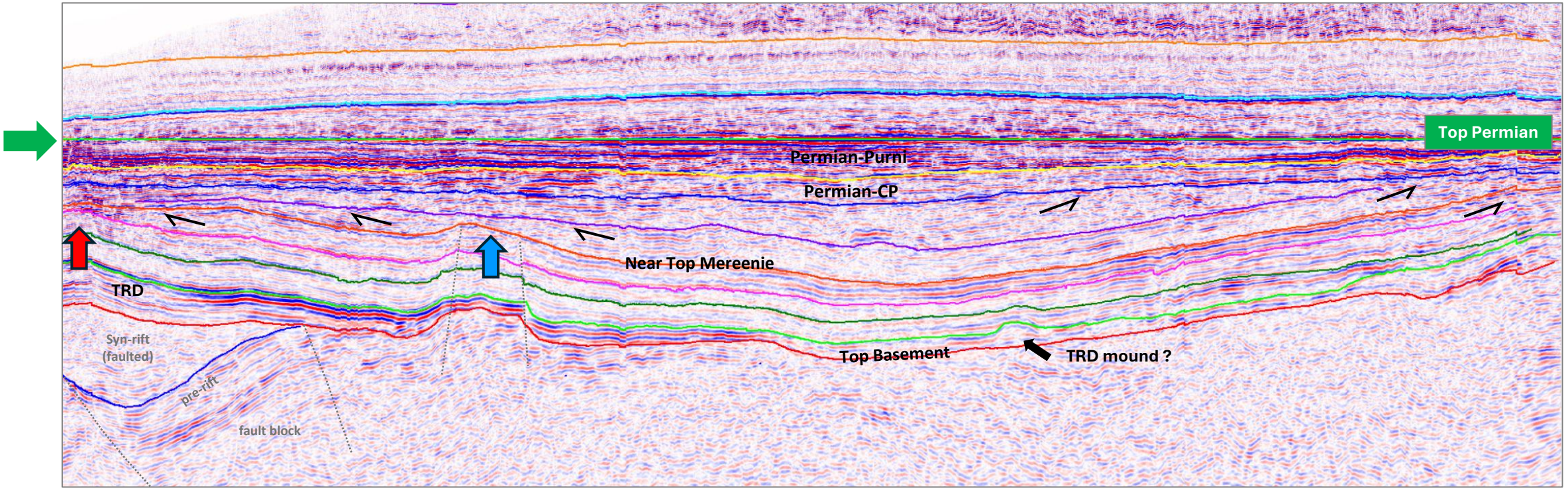


Part Line CSI09-81

Reflections below Todd River Dolostone interpreted to be related to Neoproterozoic-Cambrian Centralian extension – Amadeus Basin equivalents

Seismic Interpretation

Line CSI09-81 Flattened on (interpreted) Top Permian (Purni) (approximately 260Ma)



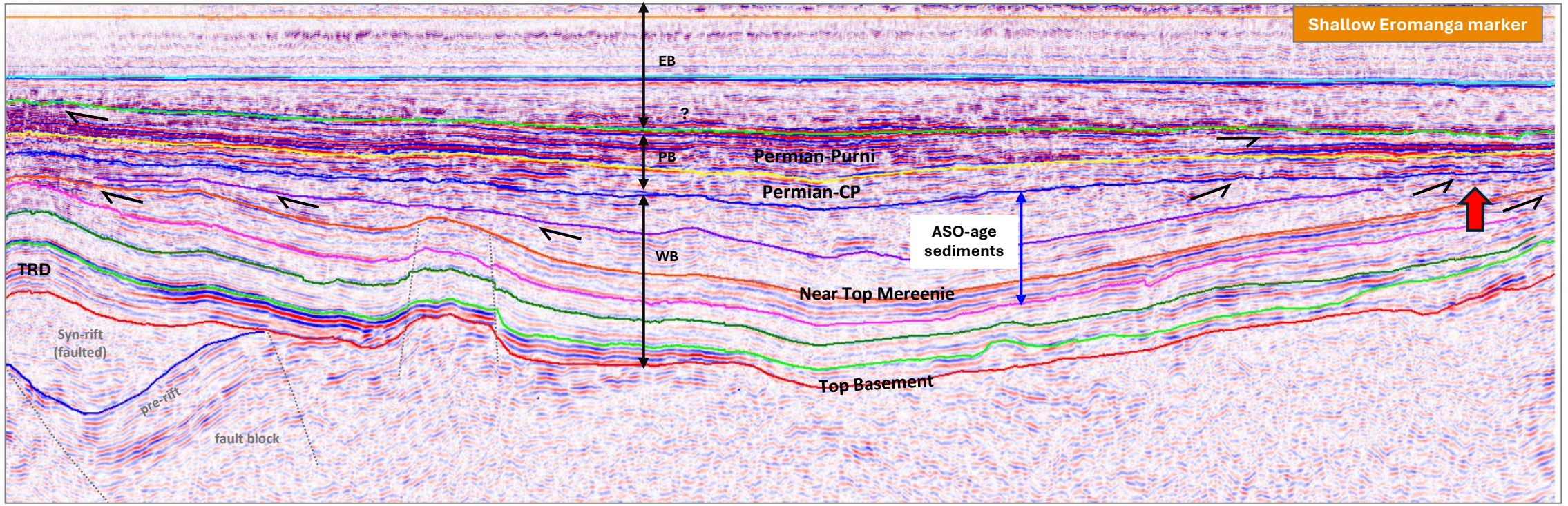
Part Line CSI09-81

Rodingan ASO1
Uplift pre-Mereenie

Pertnjara ASO2 Uplift
pre-Poly Conglomerate

Seismic Interpretation

Line CSI09-81 Flattened on (interpreted) Shallow Eromanga marker (pre-Miocene deformation)

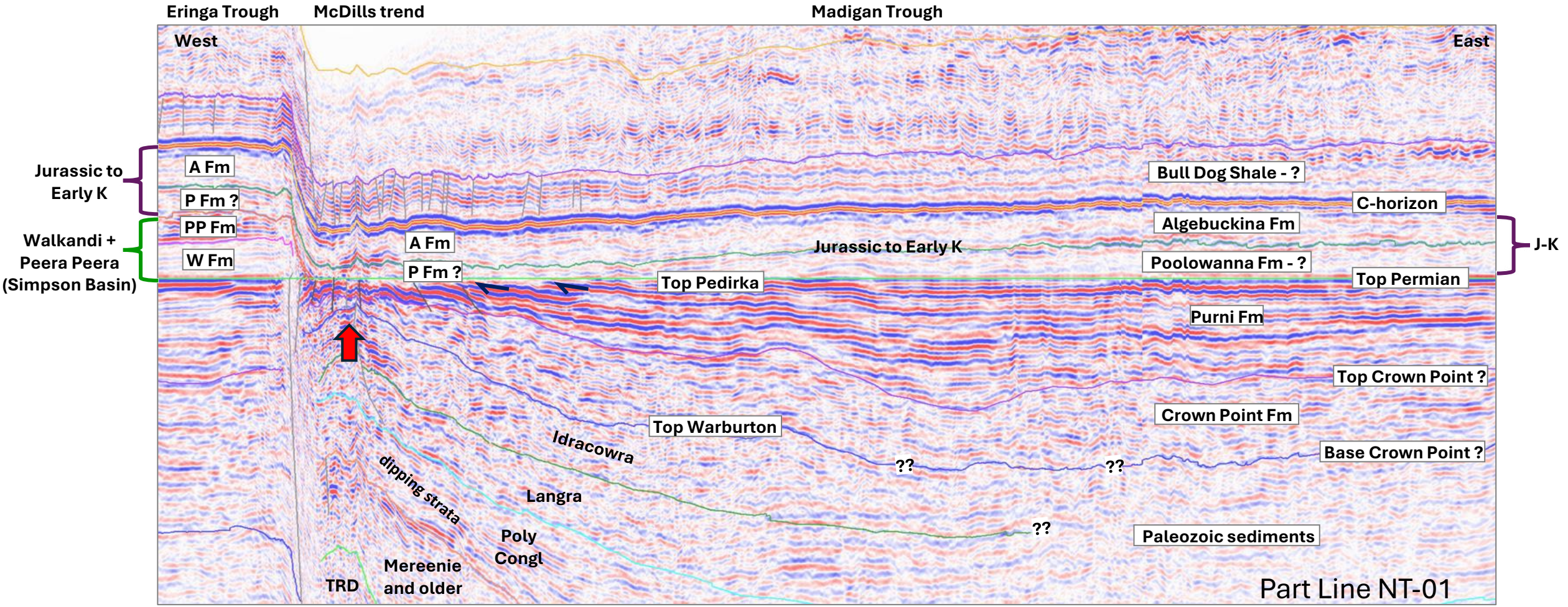


Part Line CSI09-81

Eclipse uplift and erosion pre-Crown Point

Seismic Interpretation

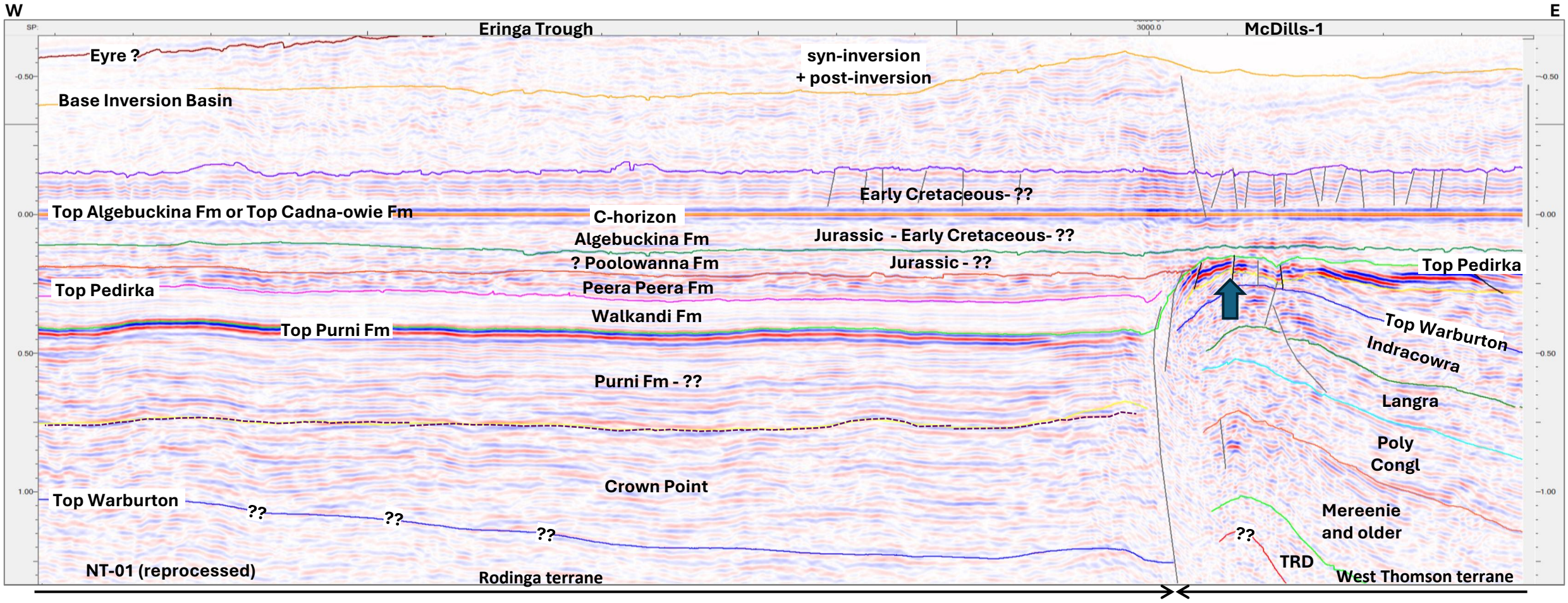
NT-01 Flattened on (interpreted) Top Permian showing Hunter-Bowen Uplift on the McDills trend



Eclipse ASO3 uplift pre-Crown Point

Seismic Interpretation

NT-01 Flattened on (interpreted) C Horizon showing Hunter-Bowen Uplift and increased thickness of Tr-J

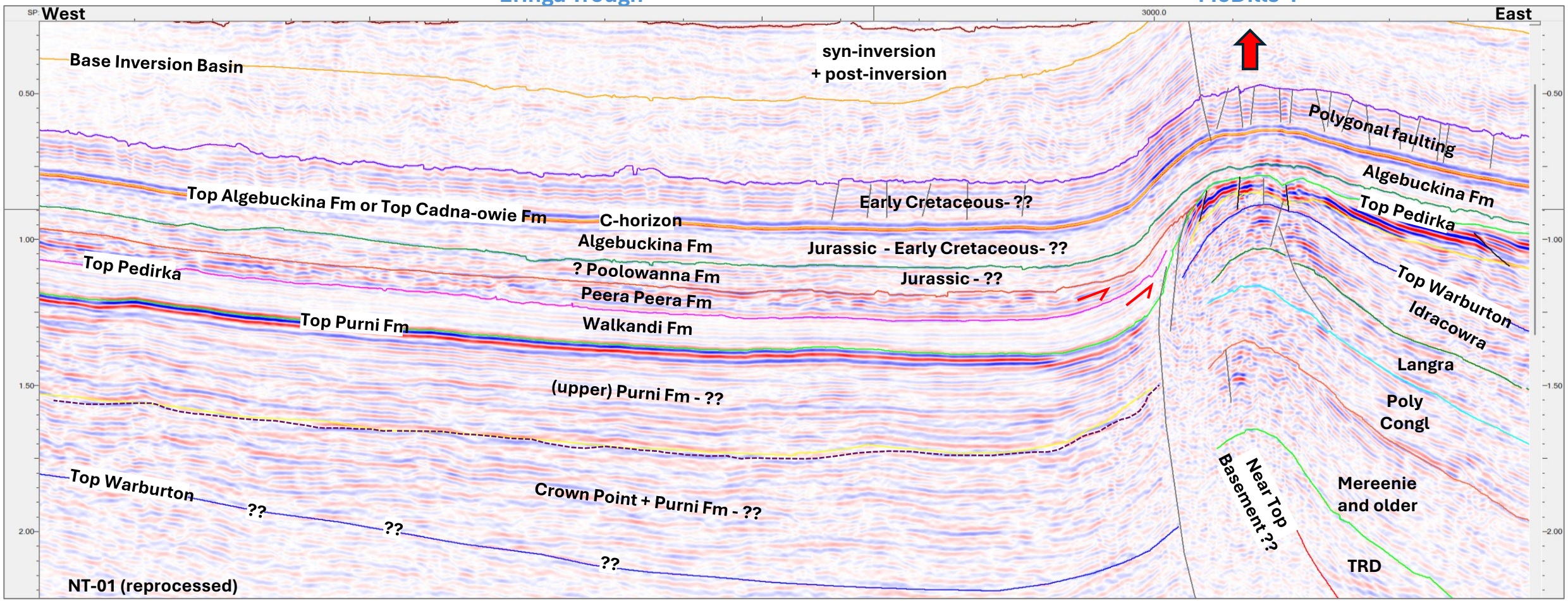


Deposition of Walkandi and Peera Peera west of McDills

Hunter-Bowen uplift/erosion

Seismic Interpretation

NT-01 Unflattened showing the present-day geometry of the basin and effects of Miocene and younger uplift)

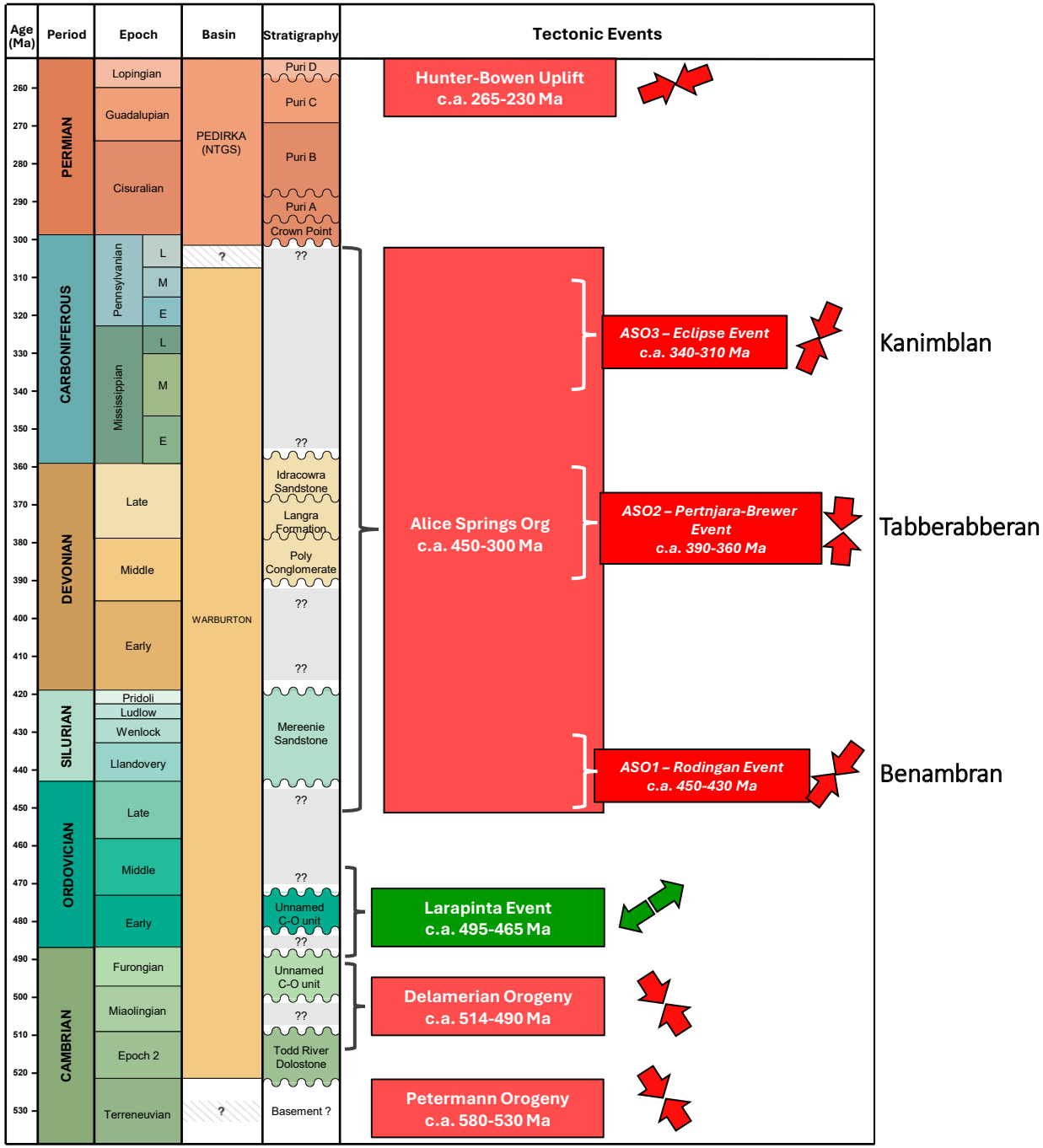


Miocene inversion

Tectonic Events

Basin Response

- Cambrian-age Todd River Dolostone was deposited over metamorphosed basement deformed and eroded during the Petermann Orogeny
- Evidence of deformation during the Delamarian is circumstantial
- Uplift focused on McDills trend and NE basin margin during the episodic ASO and again during the Hunter-Bowen at McDills 1 – a proto-McDills trend was initiated during these events
- Movement on the McDills trend responsible for present day configuration was Miocene and younger due to far-field collision along Australia's northern margin



Conclusions

- Interaction between regional kinematics and deformation/response of basement terranes (terrane boundaries and rheology) controlled deposition and preservation of Warburton and Pedirka basins.
- Boundary between Rodinga and West Thomson terranes (i.e., the McDills trend) has been a repeated focal point of complex, strike/slip and thrusting from Late Ordovician onwards.
- Result is present-day juxtaposition of relatively undeformed sediments overlying competent Rodinga terrane (Eringa Trough), against older and more deformed overthrust sediments of weaker West Thomson terrane (Madigan Trough).
- The boundary of the Madigan Trough and the Colson Shelf is likely to coincide with a deformation front associated with Delamerian deformation to the south and east.
- Late far-field uplift in the mid-Miocene reshaped the entire basin system and accentuated the McDills trend.

Warburton Basin: Sediment Thickness Map