Exploring the southern Amadeus Basin with 2D Seismic

Sandra Menpes[1,2], Paul Walshe[1], Francois Bache[1], Juergen Gusterhuber[1] and Mattilda Sheridan[1]

Background

Santos Limited entered into the southern Amadeus Basin via a partnership with Central Petroleum Limited in 2012 to explore the Neoproterozoic Heavitree–Gillen play. A central basin high (and focus for regional migration) was postulated to be a result of both deformation and loading of the basin to the south from the Petermann Orogeny and deformation and loading to the north from the later Alice Springs Orogeny. The primary objective was the Heavitree Formation, a fluvio-marine sandstone that flowed gas from Magee-1 (drilled 1992), at that time the only well to test the Neoproterozoic sub-salt play in this frontier basin (**Figure 1**). Subsequently, a second test of the play, the Southern Amadeus Joint Venture's (SAJV) Mt Kitty-1 well, flowed gas from fractured granitic basement. This test confirmed the existence of an extensive sub-salt petroleum system as well as the excellent sealing capacity of the Neoproterozoic evaporites.

Since 2013, Santos has acquired over 2500 km of both regional and infill 2D seismic across the SAJV permits. Prior to 2013, there were no regional seismic lines and a poor understanding of the structural complexity related to salt mobilisation. A high-resolution depth-to-basement model created for Santos by FROGTECH (Debacker *et al* 2015) was used as a guide for planning the infill seismic program over key leads. A second infill seismic program over the Dukas Prospect and new leads will be acquired in 2018.

1 Santos Ltd, 60 Flinders Street, Adelaide, SA 5000, Australia.
2 Email: sandra.menpes@santos.com

2D seismic interpretation and depth conversion

The SAJV's seismic dataset illustrates the dominantly thin-skinned nature of deformation associated with the ~600–520 Ma Petermann Orogeny, in addition to local basement-involved deformation. Evaporites of the Gillen Formation form a detachment zone, above which folds and thrusts have developed, whilst the basement remains relatively undeformed (**Figure 2**). Poor data zones, which broadly correlate with high gravity values, are attributed to steeply dipping beds at or near surface, and/or the presence of relatively shallow Bitter Springs Group carbonates and evaporites.

Structural orientations and associated tectonic events

Analysis of the seismic profiles, constrained with structural trends observed on gravity and magnetic maps, allows the identification of three main structural orientations:

- WNW–ESE thrusts generally affect the whole stratigraphic succession and are commonly associated with poor seismic imaging to surface. WNW–ESE trends are also a feature of the surface geology north of the Dukas Arch. In our study area, they do not clearly involve the basement and seem rather to be connected to a decollement surface at the base of the Gillen Formation evaporites. These structures are the result of contraction during the Alice Springs Orogeny.
- NW–SE structural features have been mapped exclusively south of the Dukas Arch. Associated thrusts

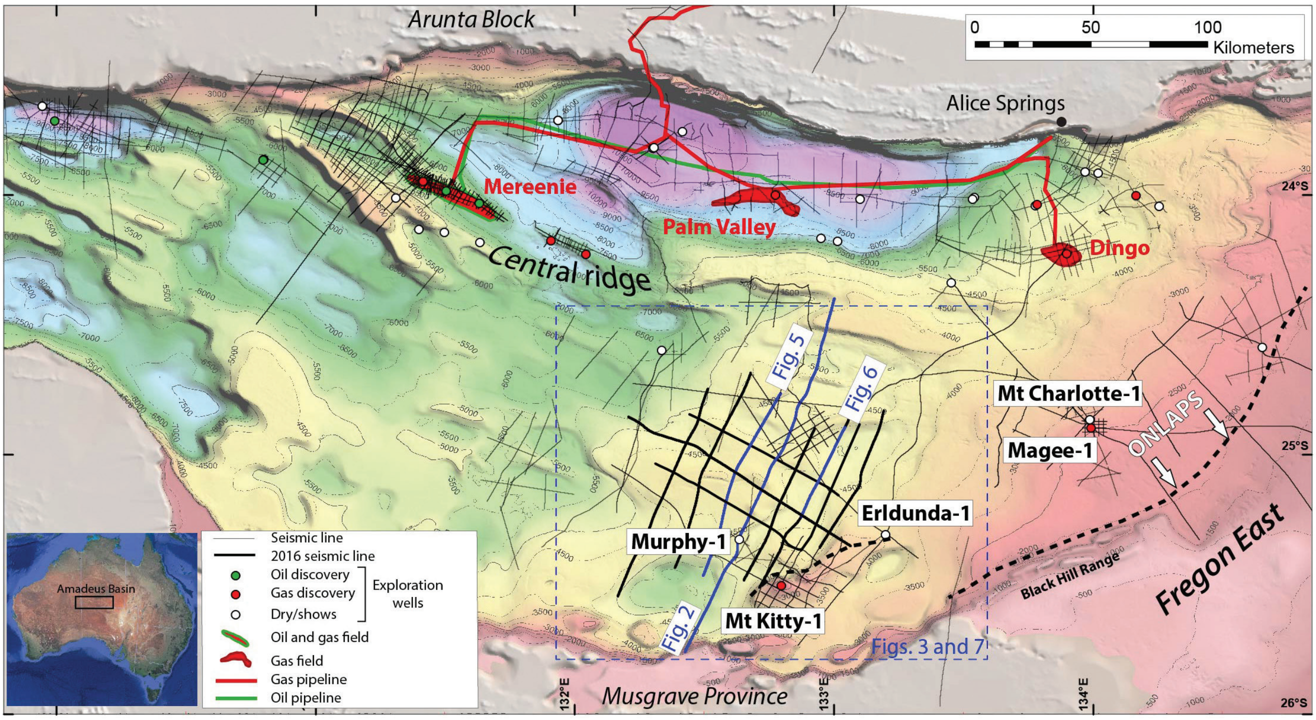

Figure 1. Overburden map (in metres) of the Amadeus Basin derived from SEEBASE® depth-to-basement model (FROGTECH 2015, Debacker *et al* 2016) showing seismic and wells.

show the same characteristics as the WNW–ESE thrusts with the difference that they mainly affect pre-Petermann unconformity sediments. The NW–SE orientation is confirmed by trends in the gravity and magnetic data (**Figure 3**). These structures are the result of contraction during the Petermann Orogeny.

- The SW–NE Mt Kitty structure is unique in our study area. The basement is clearly involved in a thick-skinned deformation-style; the SW–NE structural trend also coincides with the general orientation of the southeastern flank of the Amadeus Basin where onlap of the oldest seismic reflectors onto the Fregon East basement suggest a long-lived SW–NE basin margin (Plummer 2015; **Figure 1**). The SW–NE trend is attributed to reactivation of Albany-Fraser Orogen basement architecture (Aitken and Betts 2008, FROGTECH 2015).

Time to depth conversion

Significant lateral and vertical seismic velocity changes resulting from the complex structures in fold and thrust belt terranes can distort seismic time images. The complex structure, poor seismic imaging, sparse well control and coarse 2D seismic line spacing (10–15 km) in the southern Amadeus Basin has required the construction of a 3D structural framework using the time horizons and interpreted faults (**Figure 4**). In areas of poor data, balanced cross-sections were generated to ensure structurally plausible interpretations were used in the framework model. The model was further constrained with surface geology (**Figure 5**) and trends from gravity/magnetic data (**Figure 3**). The framework model then was populated with interval velocities from the available well data; the resulting velocity model was used to depth convert the time structural framework model.

The interval velocity model suggests that in the region of the Dukas Arch, average velocity to basement varies by as much as 20% (**Figure 6**). Compared to the time closure, basement depth closure at the Dukas Arch moved laterally to the northwest by approximately 3 km after depth conversion.

Petroleum prospectivity of the greater Dukas Arch regional high

The greater Dukas Arch is a regional basement high with a SW–NE trend suggesting it may be a long-lived high related to Albany-Fraser Orogen basement trends pre-dating the Amadeus Basin succession (**Figure 7**). Later loading of the southern and northern margins of the Amadeus Basin during the Petermann and Alice Springs orogenies resulted in the present-day morphology of the Arch. The greater Dukas Arch is therefore considered a long-lived focus for hydrocarbon migration beneath the Gillen Formation evaporites.

The Dukas prospect structural closure as currently mapped is about 250 km^2 at top reservoir with 350 m of vertical relief. Follow-up 2D seismic to be acquired in 2018 will help constrain the structural crest and eastern extension of the closure. The prospect has the potential to host a very

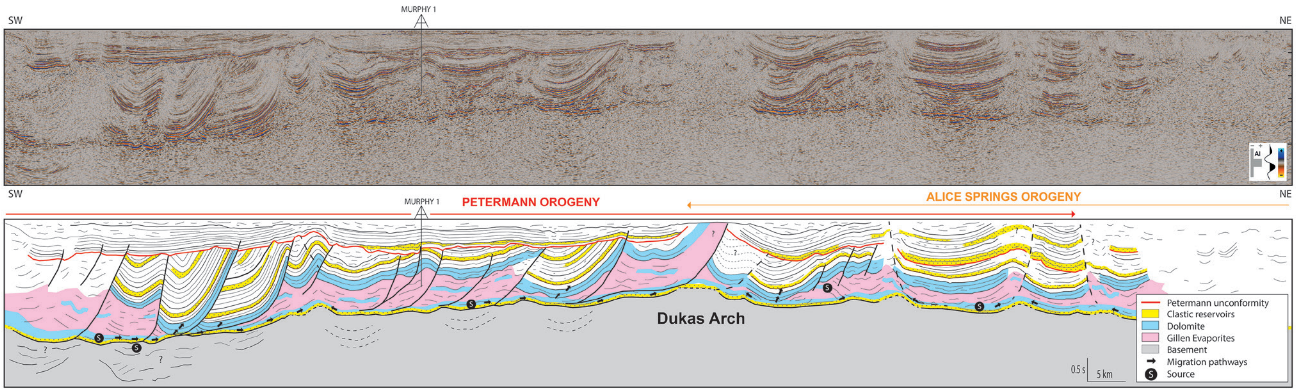

Figure 2. Seismic line AMSAN13-B04 and associated line drawing across the southern Amadeus Basin showing structural detachment in the Gillen Formation evaporites. Seismic line location in **Figure 1**.

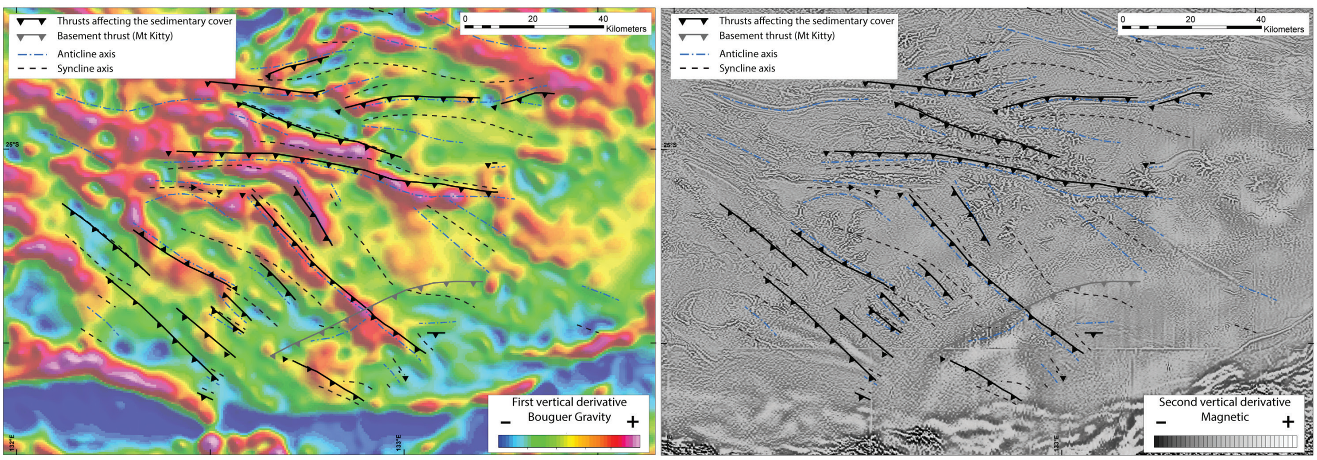

Figure 3. First vertical derivative of Bouguer Gravity (left) and second vertical derivative magnetic (right) maps (FROGTECH 2015). SW–NE (Petermann Orogeny) and WNW–ESE (Alice Springs Orogeny) orientations are both recorded. Map location in **Figure 1**.

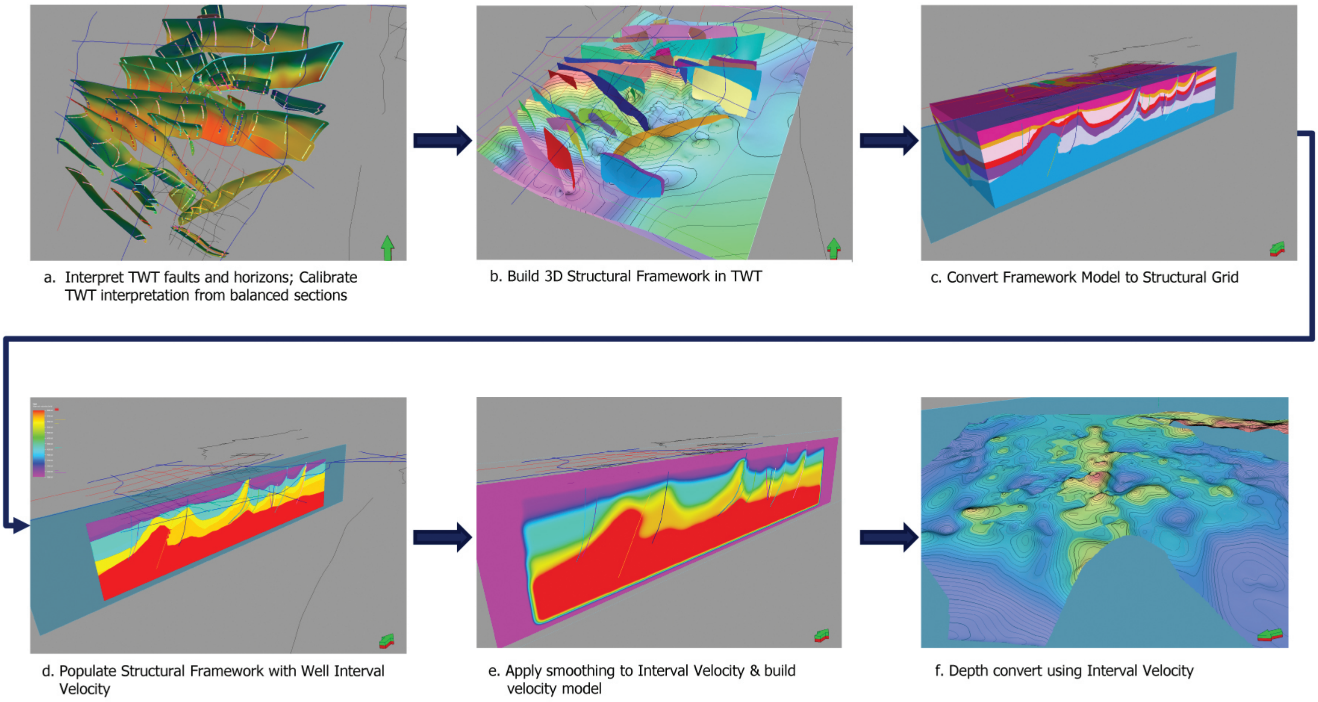

Figure 4. Building the 3D framework model and time to depth conversion workflow.

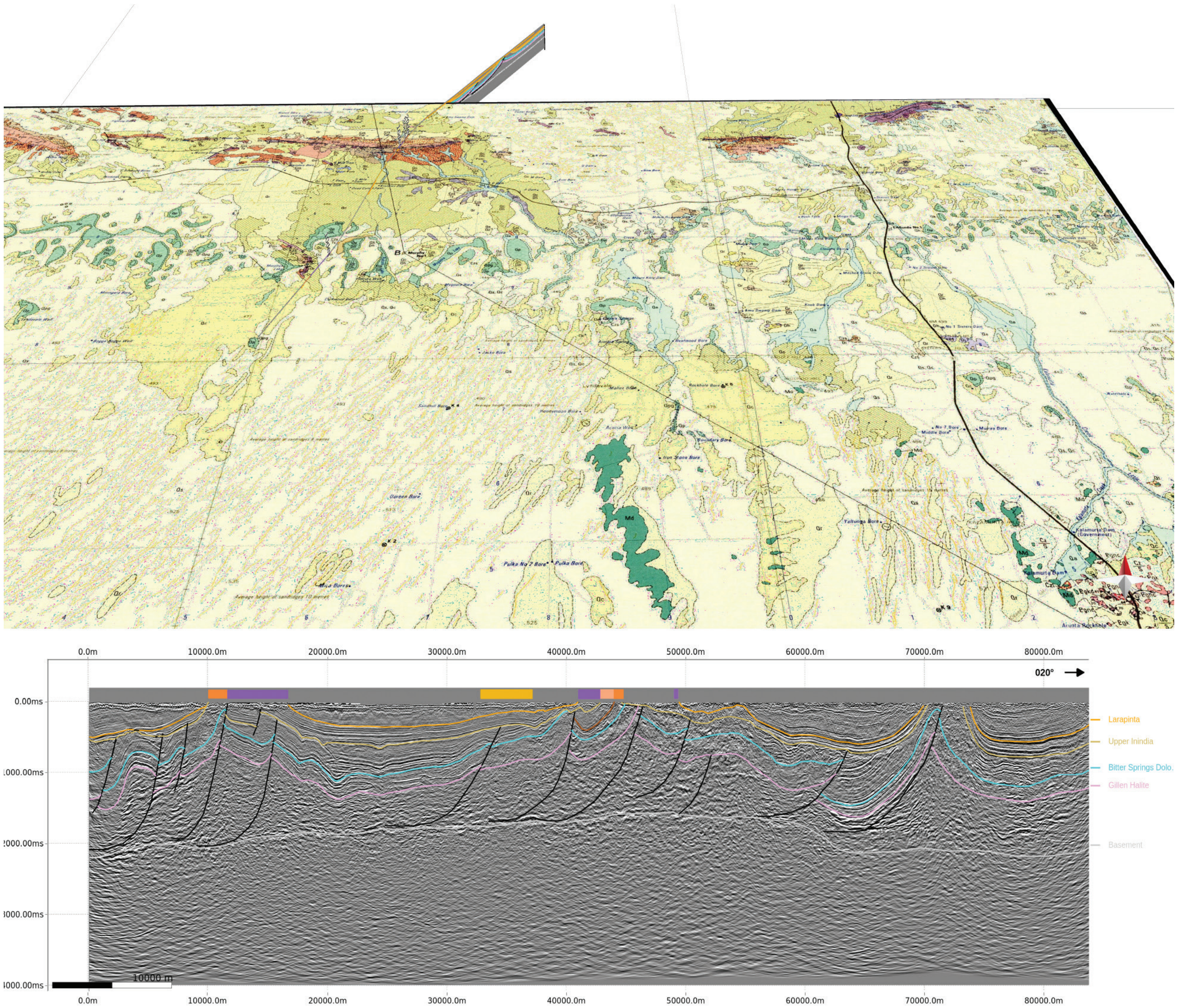

Figure 5. Integration of surface geology into 2D seismic interpretation – AMSAN16-DK03 example.

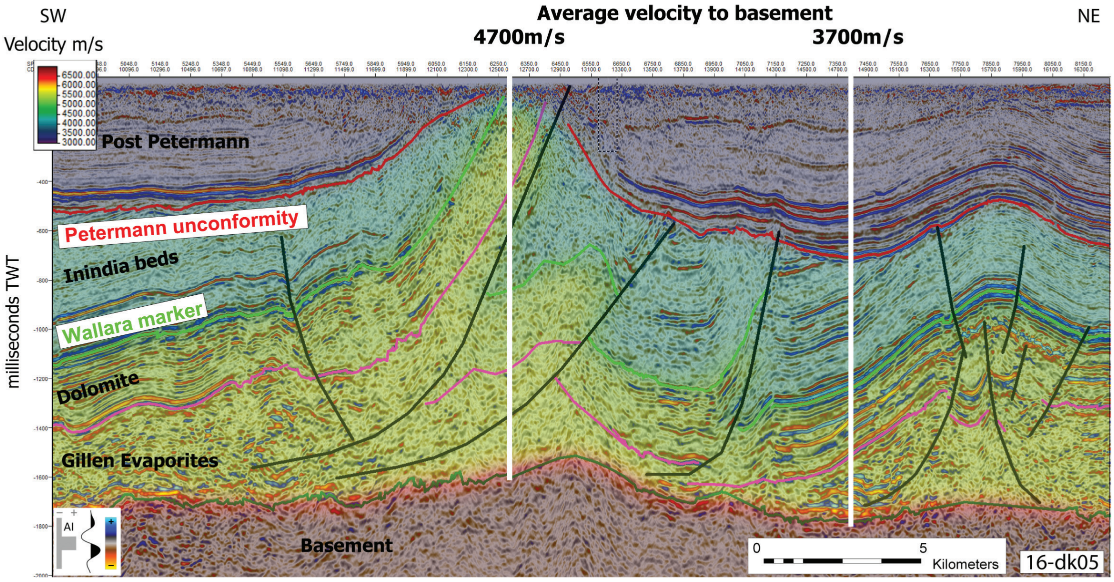

Figure 6. Seismic profile AMSAN 16-DK05 with modeled velocity showing as much as 20% variation in average velocity to basement. Seismic line location in **Figure 1**.

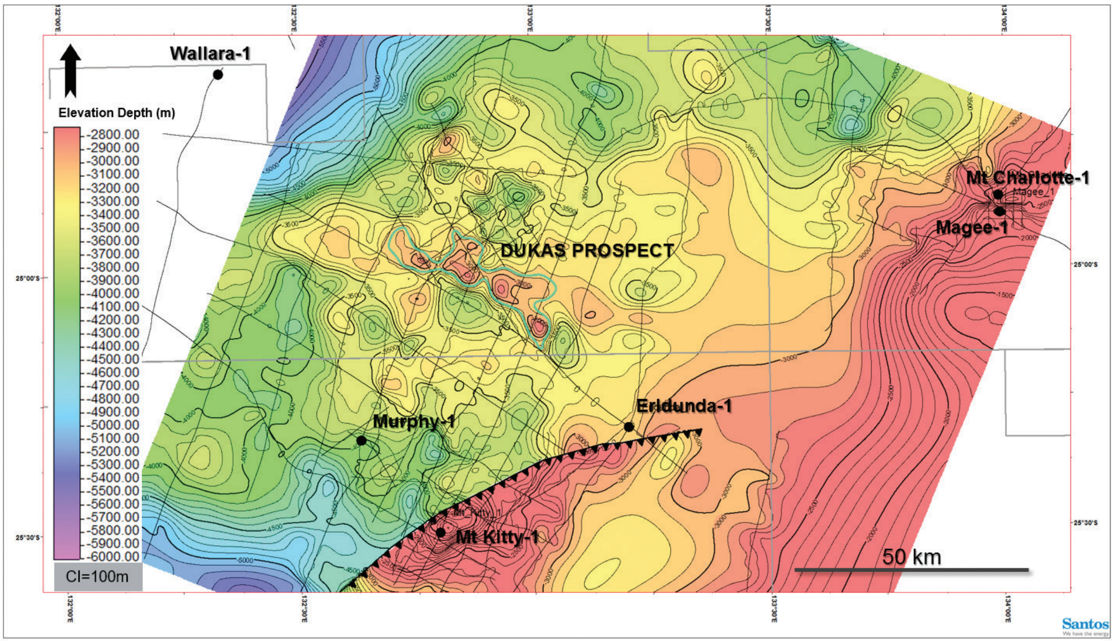

Figure 7. Current depth converted basement map showing Dukas Prospect depth closure polygon.

large gas accumulation, including valuable helium gas. A drill test is planned for the first quarter of 2019.

Acknowledgements

The authors acknowledge Central Petroleum and Santos for allowing us to publish this abstract. We acknowledge Santos staff, and particularly Reinaldo Ollarves, Peter Boult, Saverio Spagnuolo, Rhodri Johns, Sharon Johns, Bill Ovenden and Geoff Wood for helpful discussions and technical support. We acknowledge former Amadeus team members (Sandy Watters, Phil Plummer, Emma Hissey, Jenny Clifford) for their initial work in the Amadeus Basin.

References

Aitken ARA and Betts PG, 2008. High-resolution aeromagnetic data over central Australia assist Grenville-Era (1300–1100 Ma) Rodinia reconstructions. *Geophysical Research Letters* 35, 1–6.

Debacker T, Connors K, Lee J-U, Watters S, Clifford J, Plummer P and Menpes S, 2016. Exploring the sub-salt play in the frontier Amadeus Basin – Insights from potential field data analysis: in '*Proceedings of the Annual Geoscience Exploration Seminar (AGES), Alice Springs, Northern Territory, 15–16 March 2016*'. Northern Territory Geological Survey, Darwin.

FROGTECH, 2015. *Amadeus Basin SEEBASE^{TM} Update – Phases 1–2. Confidential report prepared for Santos QNT Pty Ltd.* FROGTECH Pty Ltd, Canberra, Australia.

Plummer P, 2015. Heavitree Quartzite, Amadeus Basin: its place within the Centralian Superbasin: in *'Proceedings of the Annual Geoscience Exploration Seminar (AGES), Alice Springs, Northern Territory, 17–18 March 2015'. Northern Territory Geological Survey, Record* 2015-002.