Looking beneath the Canning Basin: new insights from geochronology, seismic and potential-field data

by

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The onshore Phanerozoic Canning Basin covers an extensive area of northern Western Australia. Although there has been some mineral exploration under thin cover around the margins of the Canning Basin, mainly near Telfer, the nature and age of basement beneath the deeper parts of the Canning Basin is speculative. A few deep petroleum exploration wells do penetrate basement, mainly on the Lennard Shelf, Broome Platform and Barbwire Terrace. Recent advances in knowledge of the basement include new geochronology from selected wells, and new deep crustal seismic data, with further seismic acquisition planned. Extensive coverage by new airborne gravity surveys will be available early in 2018. Currently available data have been used to update the Canning Basin SEEBASE (**S**tructurally **E**nhanced view of **E**conomic **BASE**ment) model including basement topography (depth to basement) and interpretations of basement composition and structure (Fig. 1).

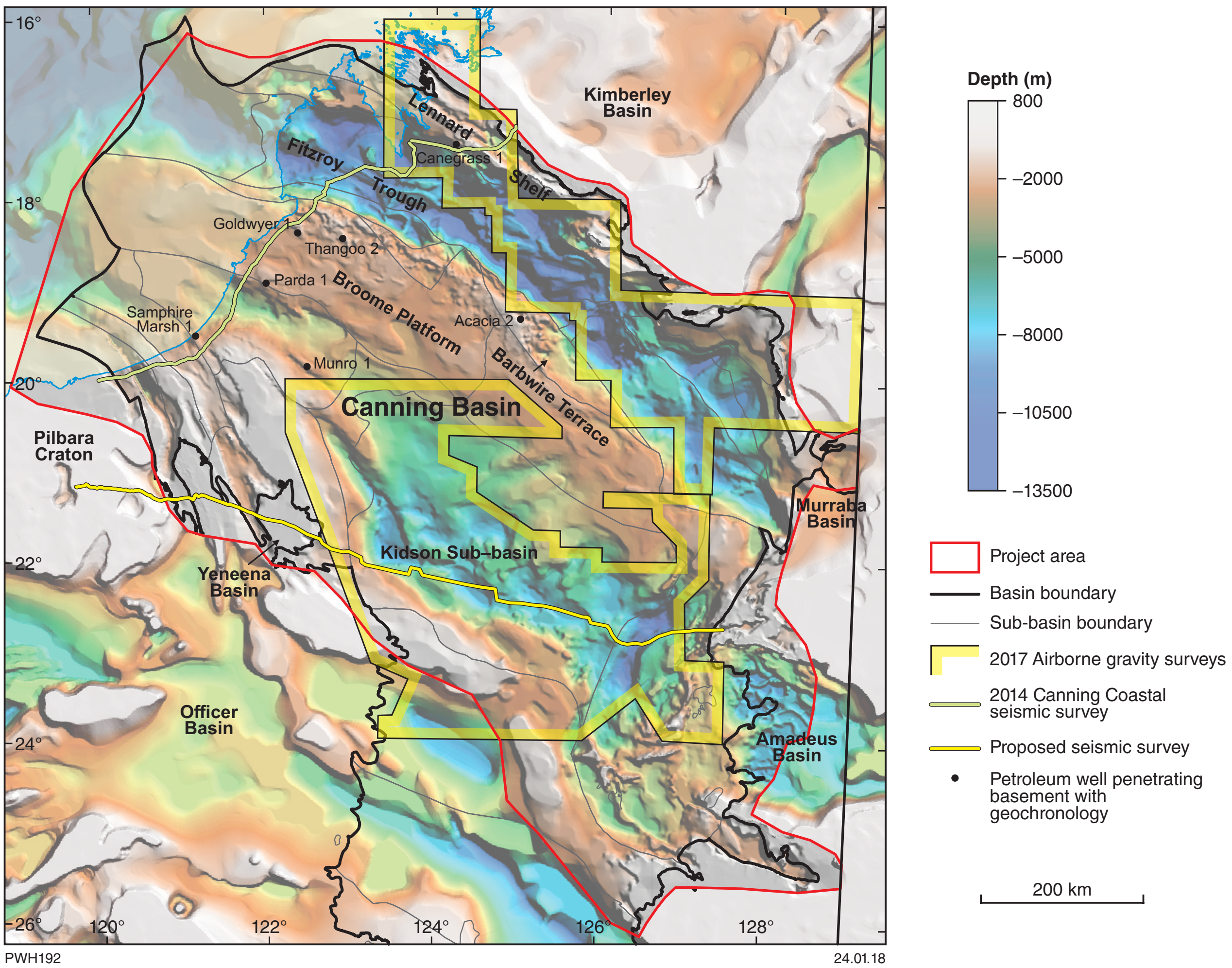

Figure 1. **2017 SEEBASE image for the Canning Basin project area with 2005 SEEBASE image as background. The image is coloured for modelled basement depth (sediment thickness). Thin extensions of the Canning Basin over older sedimentary successions in the south were excluded from the study. Map includes outline of 2017 airborne gravity surveys, the 2014 Canning Coastal seismic survey, the proposed survey across the southern Canning Basin, and locations of petroleum wells with basement geochronology**

Basement geochronology

Although mineral exploration drillholes locally intersect relatively shallow basement near the edge of the Canning Basin, only petroleum exploration wells intersect deeper basement farther inboard. Recent SHRIMP U–Pb zircon geochronology on magmatic and metasedimentary basement rocks penetrated in selected petroleum wells near the Canning Coastal seismic survey (Fig. 1) provides new insight into the age of the basement directly below the basal unconformity (Figs 2, 3; Table 1). An igneous crystallization age of 654 ± 3 Ma (Fig. 2b) for granitic rock in Goldwyer 1 is within the age range reported for granitic rocks of the O'Callaghans Supersuite (678–607 Ma; Maidment, 2017) in the Telfer area of the Paterson Orogen. However, this well is more than 300 km north of the northernmost outcrops of O'Callaghans Supersuite along the southwestern edge of the Canning Basin. Granitic rock in Samphire Marsh 1 has an igneous crystallization age of 505 ± 4 Ma (Fig. 2a), whereas the dominant group of inherited zircons in the same rock yields a weighted mean age of 653 ± 7 Ma, similar to the age of the granitic rock in Goldwyer 1. A pegmatite vein intruding schist in Parda 1 yields a ^{207}Pb/^{206}Pb age of 537 ± 13 Ma (Fig. 2c).

These Cambrian ages are significantly younger than previously known felsic igneous events in the region, with the possible exception of the 512.5 ± 4.3 Ma U–Pb baddeleyite date reported by Jourdan et al. (2014) for granodiorite basement in Munro 1. The baddeleyite is presumably hosted within the abundant mafic enclaves in this rock, and Jourdan et al. (2014) suggested a connection with the 510.7 ± 0.6 Ma mafic Kalkarindji Large Igneous Province. Subsidence associated with the Samphire Marsh Extension, which resulted in the initial formation of the Canning Basin, is no younger than early Ordovician (Tremadocian; 485–478 Ma), the biostratigraphic age of the oldest marine sedimentary unit in the Nambeet Formation (Nicoll, 1993). The relatively short period separating mafic–felsic magmatism and sedimentation might indicate that Cambrian magmatism reflects an early phase of extension related to initiation of the basin. In central Australia, bimodal magmatism at c. 520 Ma is interpreted to be related to an early stage of rifting focused between the Amadeus and Georgina Basins that also culminated in the early Ordovician, possibly reflecting a continent-scale extensional event (Maidment et al., 2013).

The age of the youngest detrital zircon in metasedimentary rocks in Thangoo 2, 953 ± 21 Ma (1σ), is similar to the youngest date of 961 ± 29 Ma (1σ) previously reported from Acacia 2 (Wingate and Haines, 2009; Fig. 3a,b). Both samples show detrital zircon age spectra similar to those of sedimentary successions of the lower Yeneena Basin (Bagas and Nelson, 2007) and lower Murraba Basin (Haines and Allen, 2017) exposed along the southern and eastern margin of the Canning Basin, respectively. Both are components of the Neoproterozoic–Paleozoic Centralian Superbasin. The granitic rock in Samphire Marsh 1 and pegmatite in Parda 1 contain early Neoproterozoic inherited zircons (Fig. 2a,c) presumably derived from the terrane they intrude. These observations suggest that tectonized components of the Centralian Superbasin may be widespread beneath the Canning Basin, at least south of the Fitzroy Trough. In contrast, a basement metasedimentary breccia from Canegrass 1 on the Lennard Shelf of the northern Canning Basin has no zircons younger than 1791 ± 13 Ma (1σ; Fig. 3c) and an age spectrum similar to those for samples from the Paleoproterozoic Kimberley Basin reported by Phillips et al. (2017). This suggests that the Kimberley Basin directly underlies the Canning Basin in this area and that sedimentary rocks of the Centralian Superbasin were either not deposited there, or were uplifted and eroded prior to the Paleozoic.

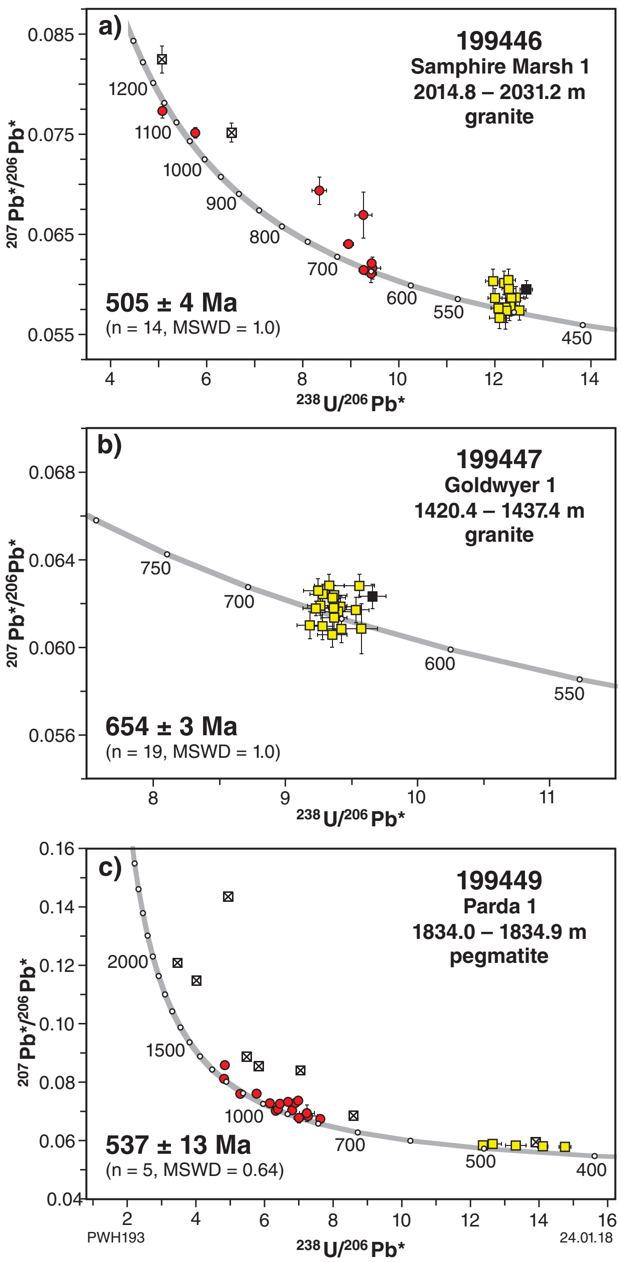

Figure 2. U–Pb analytical data for magmatic zircons (yellow squares) and inherited zircons (red circles) in igneous basement rocks from Canning Basin petroleum wells. Black squares indicate analyses affected by Pb loss and crossed squares indicate data with discordance >5%. Weighted mean ages are quoted with 95% uncertainties; Pb*, radiogenic Pb

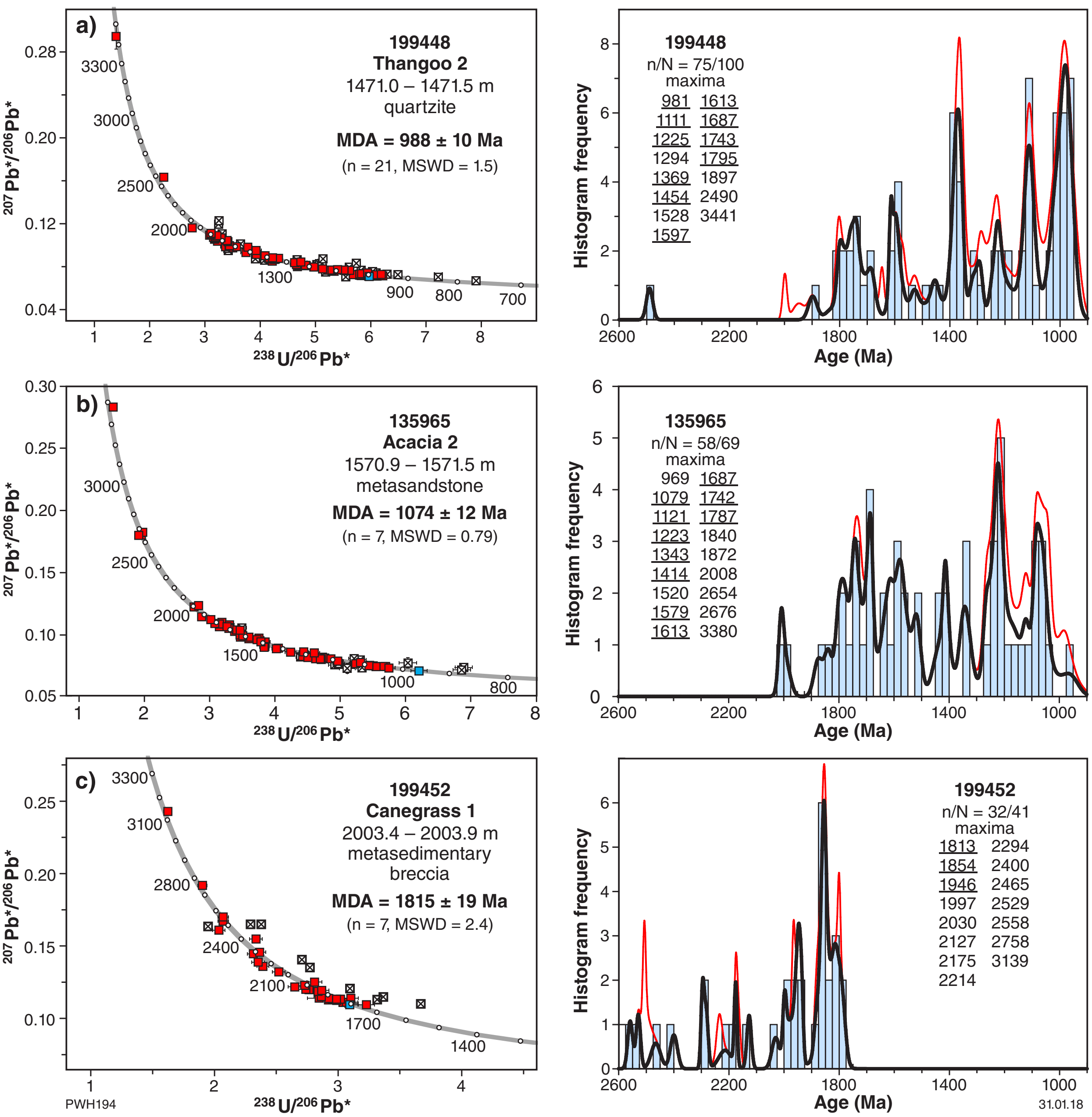

Figure 3. U–Pb analytical data (left) with corresponding probability density diagrams and histograms (right) for detrital zircons in metasedimentary basement rocks from Canning Basin petroleum wells. Crossed squares indicate data with discordance >5%. MDA is maximum depositional age expressed as weighted mean age of the youngest group (uncertainties are 95%, n = number of zircons in youngest group). Thick black probability curve, maxima values, and frequency histograms include only data <5% discordant; thin red curve includes all data (n/N = number of analyses <5% discordant/total number analyses). Significant age components (based on three or more dates) are underlined

New Canning Basin SEEBASE study

During 2017, Frogtech Geoscience produced an updated SEEBASE study and ArcGIS package of the Canning Basin recently released as Geological Survey of Western Australia (GSWA) Report 182 (Frogtech Geoscience, 2017). SEEBASE is a map of the depth to economic basement (from a petroleum perspective), and this update is based on the latest potential-field, seismic, and other datasets. The result is a substantial increase in the resolution of the Canning Basin depth-to-basement model (Fig. 1) compared to the 2005 OZ SEEBASE (FrOG Tech, 2005). The revised SEEBASE basement topography model provides a new view of basin geometry as a foundation upon which to build basin, petroleum systems, and exploration models. The study also provides an interpretation of underlying basement terranes, their structure and tectonic evolution. This includes maps of basement composition, crustal thickness, depth to Moho, and basement-derived heat flow. The SEEBASE product is designed to be easily reviewed and updated as new data, such as the current and future gravity and seismic survey data discussed below, become available.

Table 1. U–Pb ages from Canning Basin basement in petroleum exploration wells

GSWA sample ID	Well name	Sample depth	Lithology	Age	Reference
Igneous crystallization zircon ages					
199446	Samphire Marsh 1	2014.7 – 2031.2 m cuttings	granite	505 ± 4 Ma	GSWA, in prep.
199447	Goldwyer 1	1420.4 – 1437.4 m cuttings	granite	654 ± 3 Ma	GSWA, in prep.
199449	Parda 1	1834.0 – 1834.9 m	pegmatite	537 ± 13 Ma	GSWA, in prep.
Detrital zircon ages					
199448	Thangoo 2	1471.0 – 1471.5 m	quartzite	953 ± 21 Ma[1] 988 ± 10 Ma[2]	GSWA, in prep.
135965	Acacia 2	1570.9 – 1571.5 m	metasandstone	961 ± 29 Ma[1] 1074 ± 12 Ma[2]	Wingate and Haines, 2009
199452	Canegrass 1	2003.4 – 2003.85 m	metasedimentary breccia	1791 ± 13 Ma[1] 1815 ± 19 Ma[2]	GSWA, in prep.
Igneous crystallization baddeleyite age					
135990 (= B01)	Munro 1	2113.5 – 2115.6 m	granodiorite	512.5 ± 4.3 Ma	Jourdan et al., 2014

NOTES: 1. Age of youngest detrital zircon (1σ)
2. Weighted mean age of youngest detrital age component; all mean ages are quoted with 95% confidence intervals

Deep crustal seismic and airborne gravity

A collaboration between Geoscience Australia and GSWA to acquire a deep crustal reflection seismic survey across the southern Canning Basin and surrounding basement terranes is currently in the planning stage. The survey will ideally extend west from the western edge of the Arunta Orogen, across the southern Canning Basin (mainly Kidson Sub-basin) and Paterson Orogen near Telfer, to the Pilbara Craton (Fig. 1). The proposed survey would use an existing east–west road corridor across central Western Australia, which is well located to investigate southern Canning Basin depocentres interpreted by the new SEEBASE model. Apart from providing an unprecedented transect across the southern Canning Basin, the survey should be capable of imaging major basement structures and provide new insights into the nature of basement through this area. Passive seismic monitoring stations along the line are also proposed. An earlier deep crustal reflection survey was acquired in 2014, also in collaboration with Geoscience Australia. Referred to as the Canning Coastal seismic survey (Fig. 1), it provides a transect normal to major basement structures across the western Canning Basin (Zhan, 2017). In-progress reprocessing of part of this line aims to enhance imaging of basement structure. A passive seismic survey along the same route is currently underway in collaboration with the Institute of Geology and Geophysics of the Chinese Academy of Sciences, Macquarie University, and The University of Western Australia. The survey will yield valuable data about the deep structure of the crust beneath the Canning Basin, and the nature of fundamental terrane boundaries. Data from 2017 airborne gravity surveys over major depocentres of the Canning Basin (Fig. 1) are scheduled for release in early 2018. These should provide further insights into deep crustal terrains beneath the Canning Basin.

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