Government of Western Australia
Department of Mines and Petroleum

RECORD 2017/5

CANNING COASTAL SEISMIC SURVEY — AN OVERVIEW OF THE CANNING BASIN

by
Y Zhan

Geological Survey of Western Australia

EXPLORATION INCENTIVE SCHEME

Government of **Western Australia**
Department of **Mines and Petroleum**

Record 2017/5

CANNING COASTAL SEISMIC SURVEY — AN OVERVIEW OF THE CANNING BASIN

by
Y Zhan

Perth 2017

Geological Survey of Western Australia

MINISTER FOR MINES AND PETROLEUM
Hon Bill Johnston MLA

ACTING DIRECTOR GENERAL, DEPARTMENT OF MINES AND PETROLEUM
David Smith

EXECUTIVE DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
Rick Rogerson

REFERENCE
The recommended reference for this publication is:
Zhan, Y 2017, Canning Coastal seismic survey — an overview of the Canning Basin: Geological Survey of Western Australia, Record 2017/5, 29p.

National Library of Australia Card Number and ISBN 978-1-74168-735-4

Grid references in this publication refer to the Geocentric Datum of Australia 1994 (GDA94). Locations mentioned in the text are referenced using Map Grid Australia (MGA) coordinates, Zone 51. All locations are quoted to at least the nearest 100 m.

EXPLORATION
INCENTIVE SCHEME

Published 2017 by Geological Survey of Western Australia
This Record is published in digital format (PDF) and is available online at <www.dmp.wa.gov.au/GSWApublications>.

Further details of geological products and maps produced by the Geological Survey of Western Australia are available from:
Information Centre
Department of Mines and Petroleum
100 Plain Street
EAST PERTH WESTERN AUSTRALIA 6004
Telephone: +61 8 9222 3459   Facsimile: +61 8 9222 3444
www.dmp.wa.gov.au/GSWApublications

Cover image: Elongate salt lake on the Yilgarn Craton — part of the Moore–Monger paleovalley — here viewed from the top of Wownaminya Hill, 20 km southeast of Yalgoo, Murchison Goldfields. Photograph taken by I Zibra for the Geological Survey of Western Australia

Contents

Figures

Table

Plate

Canning Coastal seismic survey — an overview of the Canning Basin

by

Y Zhan

Abstract

The northeasterly striking Canning Coastal seismic survey is broadly normal to the strike of the major tectonic elements of the Canning Basin. In order to investigate the full spectrum of structural features along the profiles, seismic interpretation was integrated with drillhole data, nearby seismic profiles and gravity and aeromagnetic data. The Phanerozoic of the Canning Basin has been divided into four megasequences based on several major angular unconformities: 1) the Ordovician to Middle Devonian megasequence is generally extensive in the southern Canning Basin but only locally preserved in the north; 2) the Middle Devonian to mid-Carboniferous megasequence is only present in the northern Canning Basin and varies significantly in thickness from the Jurgurra Terrace to the Lennard Shelf; 3) the overlying mid-Carboniferous to Triassic megasequence is laterally extensive across the basin and was truncated by the Late Triassic to Jurassic Fitzroy Transpression unconformity; and 4) the Jurassic to Cretaceous megasequence has a relatively uniform thickness in the southern part of the survey area, but regionally thins towards the inland and pinches out in the Fitzroy Trough.

The Canning Coastal seismic profiles provide the necessary dataset to interpret and describe previously ambiguous aspects of Canning Basin stratigraphy and structures. The Wallal Embayment in the southwest of the Canning Basin is possibly an outlier to the main basin depocentre. The Samphire Graben was historically interpreted to be bounded by a northwest-trending fault and filled with Ordovician to Devonian deposits; however, such a boundary fault and graben infill are not apparent on the Canning Coastal seismic data. The Samphire Graben is here interpreted to be a transitional element between the Wallal Platform and Willara Sub-basin that is filled mostly by Permian to Mesozoic sedimentary rocks. The Willara Sub-basin and Broome Platform are interpreted to have been uplifted before deposition of the Grant Group, causing increased erosion of the Mid-Ordovician to Mid-Devonian succession towards the northern margin of the Broome Platform. In the Jurgurra Terrace, both the Ordovician to Middle Devonian and the Middle Devonian to mid-Carboniferous megasequences are present and overlap; this differs from elsewhere along the seismic profile where one or the other is found. The terrace deepens to the northeast, towards the Fenton Fault, and forms a transitional tectonic unit between the Broome Platform and the Fitzroy Trough.

Two alternative interpretations are suggested for depth to basement in the Fitzroy Trough: the deep option is characterized by a strong acoustic response below a thick interval that lacks internal reflections, and the shallow option is based on correlation with adjacent seismic profiles and the intersection of metasedimentary rocks in Padilpa 1. Both shallow and deep interpretations imply a considerable amount of reverse movement along the Fenton Fault and a complex history of fault movement. Basement depth generally decreases from the Fitzroy Trough to the Lennard Shelf, and fluctuates near the northeastern margin of the basin, forming a small-scale depression mainly filled with Middle Devonian to Carboniferous sedimentary rocks.

KEYWORDS: Phanerozoic, seismic interpretation, seismic survey, stratigraphic correlation, stratigraphic succession

Introduction

Canning Basin

The Canning Basin covers an area of 640 000 km^2 in northern Western Australia (Fig. 1). It comprises an Ordovician to Cretaceous sedimentary succession that reaches an estimated maximum thickness of 15 km within the Fitzroy Trough (e.g. Forman and Wales, 1981; Towner and Gibson, 1983; Kennard et al., 1994). The principal subdivisions of the basin are: 1) an elongate, northwesterly trending depocentre (the contiguous Fitzroy Trough and Gregory Sub-basin); 2) a mid-basin platform (the Broome and Crossland Platforms); and 3) two southern depocentres (the Willara and Kidson Sub-basins). The Fitzroy Trough and Gregory Sub-basin transition into the Broome and Crossland Platforms via a series of terraces that have basement depths intermediate between the troughs and the mid-basin platforms (Fig. 1). The Canning Basin is flanked by a series of shelves, including the Lennard Shelf in the north and Anketell and Tabletop Shelves in the south (Hocking et al., 1994a,b).

This study adopts the stratigraphic revisions of Haines (2009), Mory (2010), Mory and Haines (2013) and Haines et al. (2013), as illustrated in Figure 2. The Phanerozoic succession in the Canning Basin has now been divided into four megasequences, separated by major angular unconformities; this division facilitates seismic interpretation and description. These megasequences were each deposited over intervals varying from 70 to 100 million years. The Ordovician to Middle Devonian megasequence includes the succession from the Nambeet Formation to Mellinjerie Formation, and is extensive in the southern Canning Basin but only locally preserved in the north (Fig. 2). The Middle Devonian to mid-Carboniferous megasequence consists of the Devonian reef complexes, the Fairfield Group and the Anderson Formation. To date, it is only known to be present in the northern Canning Basin, based on examination of drillhole intersections throughout the basin. The mid-Carboniferous to Triassic megasequence extends across the basin, and incorporates the succession from the base of the Reeves Formation and Grant Group up through the Erskine Sandstone (Fig. 2). In general, this megasequence unconformably overlies the Middle Devonian to mid-Carboniferous megasequence in the north and the Ordovician to Middle Devonian megasequence in the south. The Jurassic to Cretaceous megasequence unconformably overlies the middle Carboniferous to Triassic megasequence, and extends from the Wallal Sandstone to the Anketell Formation (Fig. 2); this megasequence has a relatively uniform thickness from north to south along the survey area, but generally thins southeastwards from the coast to the centre of the basin.

Surrounding Precambrian tectonic units

The Phanerozoic sedimentary section within the Canning Basin is so thick that only a limited number of drillholes has intersected Precambrian basement; as a result, the nature of the underlying basement is poorly constrained. Surrounding basement includes the predominantly Paleoproterozoic North Australian Craton to the northeast (Tyler et al., 2012) and the Archean to Proterozoic West Australian Craton to the southwest (Williams and Trendall, 1998; Smithies, 2004). The basin is bounded to the east by the Paleoproterozoic Arunta and Tanami Orogens (Maidment et al., 2005; Cawood and Korsch, 2008), the Paleoproterozoic to Mesoproterozoic Musgrave Province (Smithies et al., 2009; Howard et al., 2015), and the mostly Neoproterozoic Amadeus, Ngalia and Murraba Basins (Haines et al., 2015; Haines and Allen, 2016). These terranes are included in either the North Australian or West Australian Cratons (Bagas, 2004; Cawood and Korsch, 2008), which both extend beneath the Canning Basin. The temporal and spatial records of Proterozoic rock units and orogenic events suggest that the North Australian and West Australian Cratons were assembled into a proto-Australia along the Paterson Orogen during the late Proterozoic Yapungku Orogeny (Cawood and Korsch, 2008).

Deep crustal seismic surveys

In order to investigate the tectonic architecture and stratigraphy of the Canning Basin, two major deep seismic reflection surveys were conducted across the basin. The first was by the Bureau of Mineral Resources (now Geoscience Australia) in 1988 and the second was by the Geological Survey of Western Australia (GSWA) and Geoscience Australia (GA) in 2014. The early survey incorporated three traverses (BMR88-01, BMR88-02 and BMR88-03, Fig. 1) totalling 650 km with 12 folds, a station spacing of 50 m, and a shot interval of 200 m using dynamite as the energy source (Taylor, 1990). In general, the data were not of sufficient quality to image the full basin stratigraphy and basement structure, even though the survey recorded reflection data to 20 seconds (s).

The 2014 Canning Coastal seismic survey recorded a total of 705 km of 20-second reflection data in two contiguous lines (14GA-CC1 and 14GA-CC2; Fig. 1) along a regional northeast–southwest profile from the Pardoo Roadhouse on the Great Northern Highway to Stumpy's Jump-up on the Gibb River Road in the northwest. This survey utilized a vibroseis source and averaged 150-fold coverage with 20 m station interval and 40 m shot interval (Campbell and Coleshill, 2014; DownUnder Geosolutions, 2015). The coastal survey provides good-quality, basin-scale profiles that enhance the understanding of Canning Basin architecture.

Seismic interpretation of the Canning Coastal profiles

The Canning Coastal seismic data were processed with a minimum phase and normal SEG* polarity (DownUnder Geosolutions, 2015). These settings determine that reflection off the upper surface of a high acoustic

* Society of Exploration Geophysicists

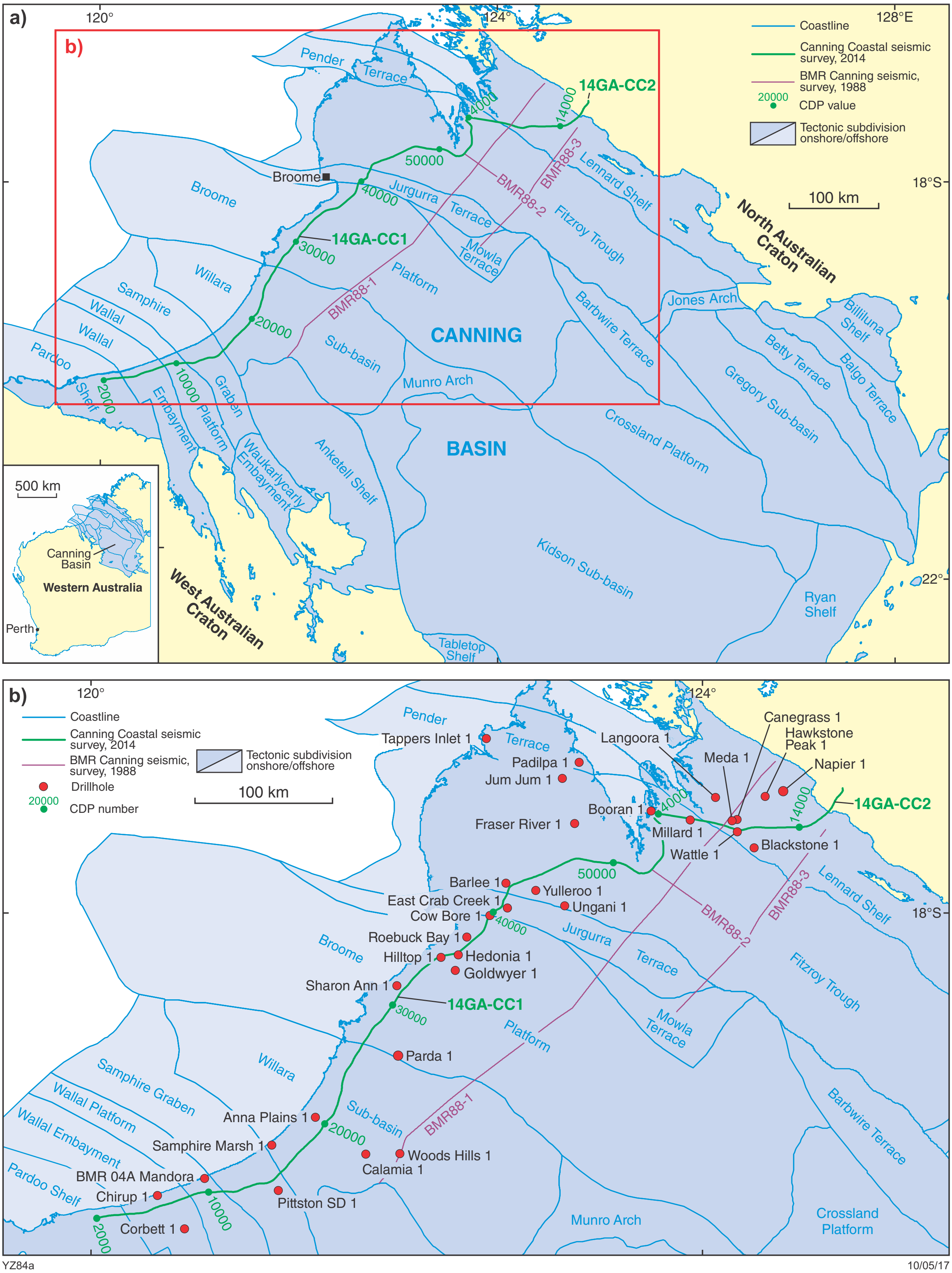


Figure 1. Location map of the Canning Coastal seismic survey showing: a) tectonic elements of the Canning Basin and locations of illustrated seismic profiles; b) drillholes adjacent to the Canning Coastal seismic survey. There are slight differences between these tectonic boundaries, defined by basement faults on pre-existing seismic profiles, gravity and magnetic anomalies (Hocking, 1994a,b; Martin et al., 2015), and the location of labelled tectonic elements on the interpreted seismic profiles

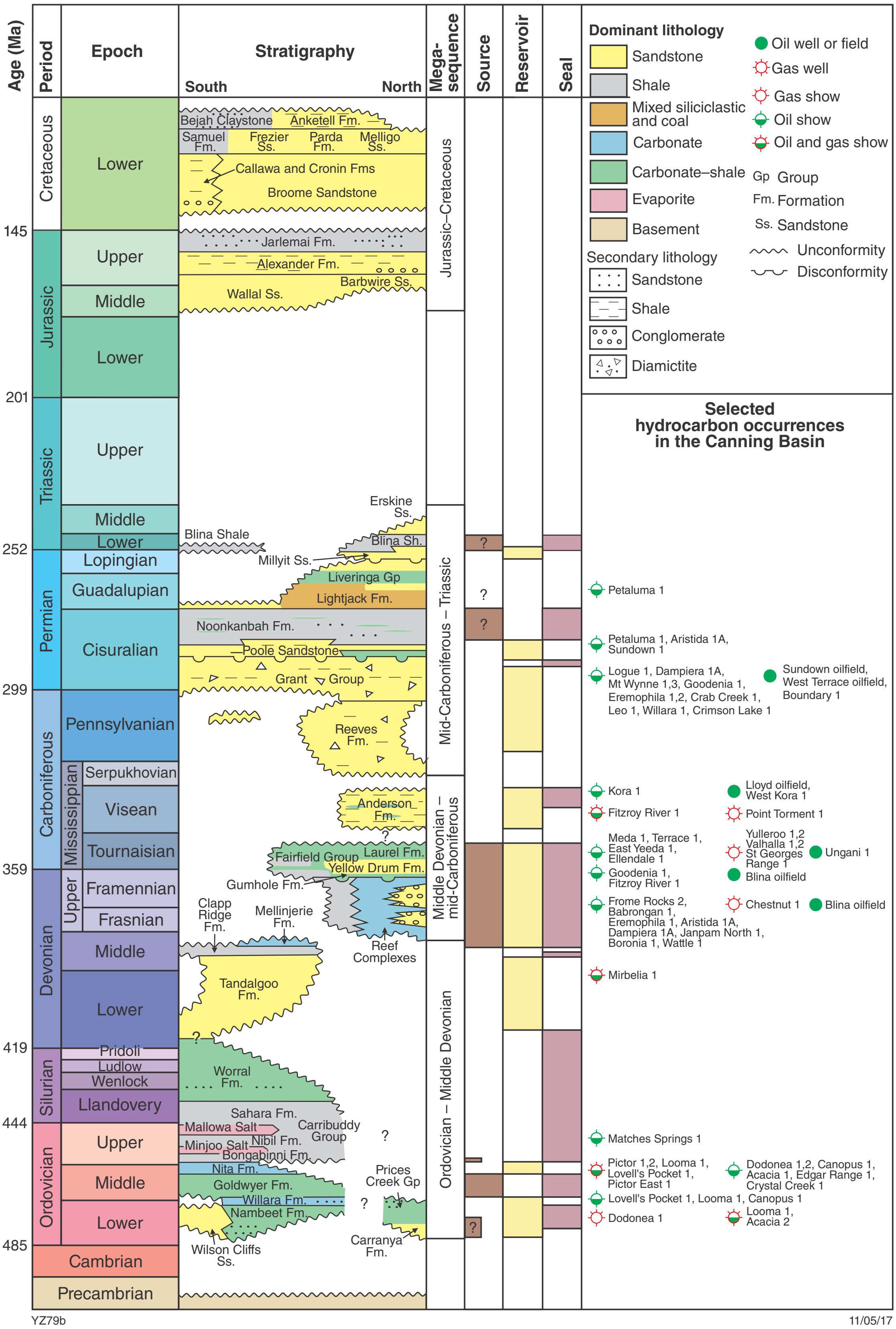


Figure 2. **Stratigraphy of the Canning Basin, modified from Haines (2009), Mory (2010), Haines et al. (2013), and Mory and Haines (2013)**

impedance layer, such as the interface between shale and underlying carbonate, is represented by zero amplitude from a positive peak above to a negative trough below. Final time migration data were corrected from a floating datum to the final datum of 200 m above mean sea level (DownUnder Geosolutions, 2015). The final data required a bulk shift of 200 ms upwards, based on the final datum and replacement velocity of 2000 m/s. This enabled the Canning Coastal survey lines to be correlated with other nearby seismic profiles for which the variable datum has been corrected to mean sea level. In this Record, two-way travel time is abbreviated as TWT and common depth point is abbreviated as CDP.

In general, the Canning Coastal profiles are of reasonable quality across the basin, particularly in the southwest where 14GA-CC1 images the lowermost stratigraphic units within the Canning Basin. Data quality is poor near the centre of the line, which reduces confidence in interpretations. Locally, the survey shows that the Precambrian basement is highly deformed internally; however, across both lines the basement data are generally low amplitude or display few reflections, leading to difficulty in interpreting the structure below the base of the Canning Basin.

An essential precursor to seismic interpretation is the establishment of precise well–seismic ties along the Canning Coastal seismic lines. Sonic logs and velocity profiles from 28 drillholes that penetrated below the prominent basal Jurassic unconformity (Table 1, follows the reference list) were used to tie the seismic profiles and constrain the seismic interpretation of the Canning Basin. Some of the wells (e.g. Hilltop 1, East Crab Creek 1, Millard 1) are close enough to the Canning Coastal seismic line that they can be directly used to calibrate the seismic profile (Fig. 1; Table 1). Other drillholes (e.g. Samphire Marsh 1, Parda 1 and Canegrass 1) are either too distant from the Canning Coastal seismic lines or are located in structurally complicated areas. As these drillholes cannot be tied directly to the survey, they are instead tied to nearby seismic lines. All seismic lines discussed in this Record are available through the Western Australian Petroleum and Geothermal Information Management System (WAPIMS; https://wapims.dmp.wa.gov.au/wapims). Synthetic seismograms were generated for each well (see Figs 3–5 for representative examples) to assist with well–seismic ties, ensuring that the seismic picks of key horizons were unambiguous. Significant structural features within and between Canning Basin subdivisions have then been interpreted on the Canning Coastal seismic profiles and nearby seismic profiles, and do not necessarily coincide with previously defined tectonic boundaries (Fig. 1), due to offsets or differences observed on the seismic profiles. In this Record, the structural contact between the Broome Platform and the Jurgurra Terrace provides a structural and stratigraphic separation of the survey into southwestern and northeastern areas.

Interpretation of the southwestern area

Seismic horizons interpreted in the southern part of the Canning Coastal survey, from the Pardoo Shelf to the Broome Platform, include, in ascending order: Top basement, Top Willara Formation, Top Goldwyer Formation, Base and Top Grant Group, Fitzroy Transpression unconformity, and Cretaceous breakup unconformity (Plate 1). These horizons provide sufficient constraints to subdivide the Phanerozoic succession in order to recognize parts of three of the megasequences in this area: Lower to Upper Ordovician, Permian to Lower Triassic, and Jurassic to Cretaceous packages. The entire Middle Devonian to mid-Carboniferous megasequence is missing, as are Silurian to Middle Devonian and middle to upper Carboniferous packages.

Pardoo Shelf and Wallal Embayment

The Canning Coastal seismic survey extends 7 km into the northeastern Pardoo Shelf (Fig. 1; Martin et al., 2015). This westernmost tectonic element of the Canning Basin was originally incorporated into the Lambert Shelf of the Northern Carnarvon Basin (Hocking, 1994a). The Pardoo Shelf is mostly covered by approximately 300 m of Mesozoic sedimentary rocks that overlie the Precambrian basement of the Pilbara Craton and presumably pinch out to the south (Fig. 6). The Pardoo Shelf is fault-bounded to the north, against the Wallal Embayment (Geophysical Service International Party 852, 1967; Hocking, 1994a,b).

The Wallal Embayment comprises two asymmetric grabens (Fig. 6) containing mostly Permian to Lower Triassic strata as indicated by data from Chirup 1. The unconformable contact with the flat-lying Jurassic succession ranges from 200 to 350 m below the surface and gradually deepens to the northeast. The Permian strata are underlain in both grabens by relatively thin successions of unknown age (possibly Ordovician) that thicken to the southwest, towards graben boundary faults. The succession in the northeastern graben unconformably overlies a package of markedly continuous reflections dipping to the fault. This deeper reflective package has a relatively uniform thickness and was truncated by the basal Permian unconformity in the northeast. There has been no drilling into this isolated graben, and the age of this package is uncertain. It could be either Early Ordovician in age, or a Neoproterozoic succession equivalent to the Yeneena Basin in the Paterson Orogen (Williams et al., 1976; Williams, 1990), located between the Wallal and Waukarlycarly Embayments about 100 km south of the Canning Coastal survey (Fig. 1).

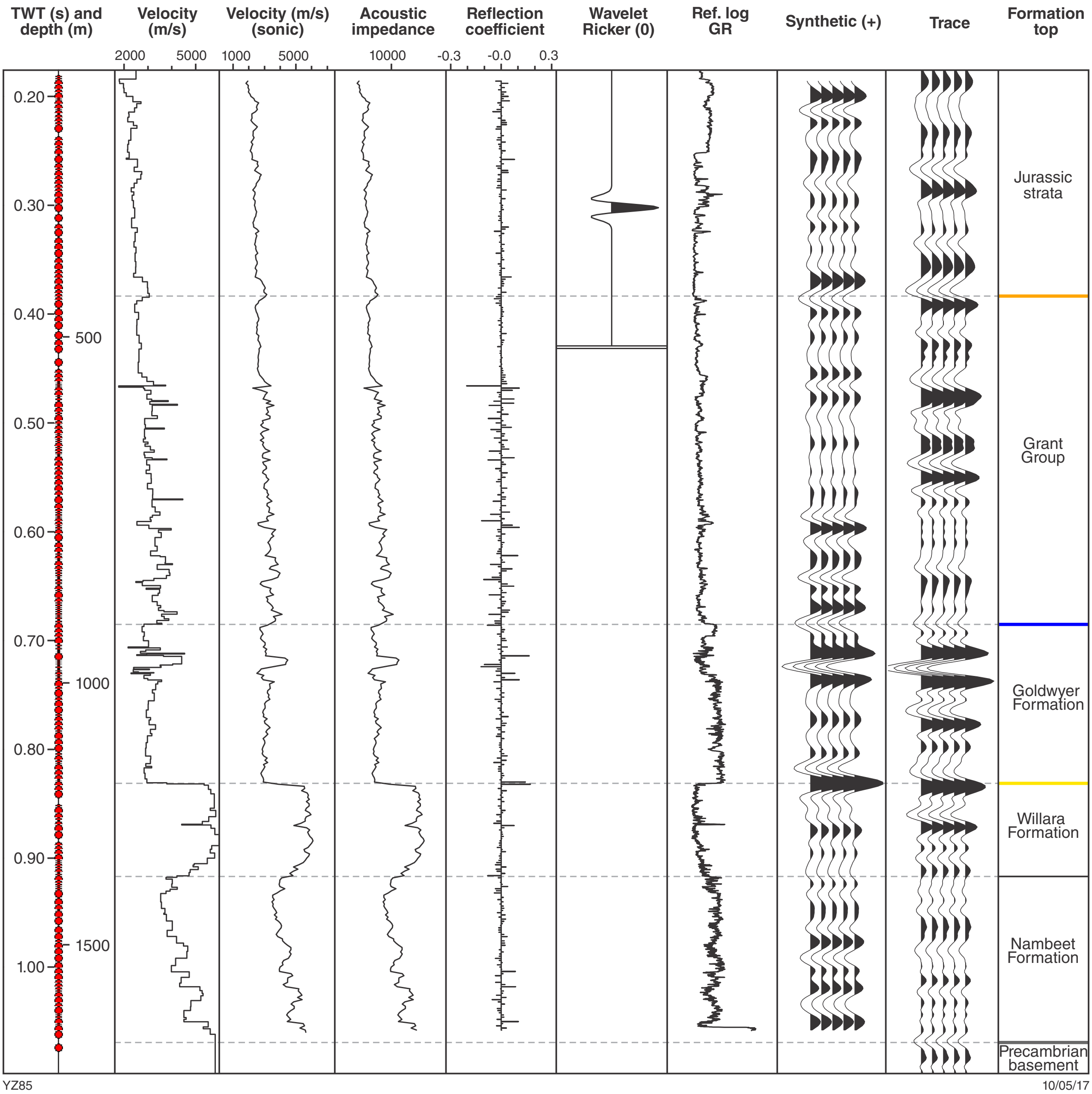


Figure 3. Synthetic seismogram for Hilltop 1, Broome Platform

Wallal Platform

The Wallal Platform is underlain by a north-northwesterly oriented basement ridge (Hocking, 1994a,b), approximately 25 km wide (Fig. 6). It is bounded to the west and east by the Wallal Embayment and Samphire Graben, respectively (Fig. 6). Drillhole BMR 04A Mandora (Bastian, 1963; Table 1), 10 km north of the Canning Coastal seismic profile on the platform, intersected the Phanerozoic succession and Precambrian granitic gneiss basement. The seismic profile shows that the Top basement horizon is characterized by a pronounced high-amplitude seismic reflector from about 400 to 500 ms (at 600–700 m depth), below which reflections are of low amplitude or discontinuous (Fig. 6). A thin Triassic to Permian package lies between the basement and a 400–500 m thick Jurassic succession, as correlated to BMR 04A Mandora (Fig. 1b). The seismic data also show that the Wallal Platform likely bounds the southern extent of the main Paleozoic depocentre in the Canning Basin.

The lower Paleozoic section was probably continuous across the southwestern corner of the Canning Basin, but subsequently was removed by the erosion pre-dating deposition of the Grant Group, especially over basement

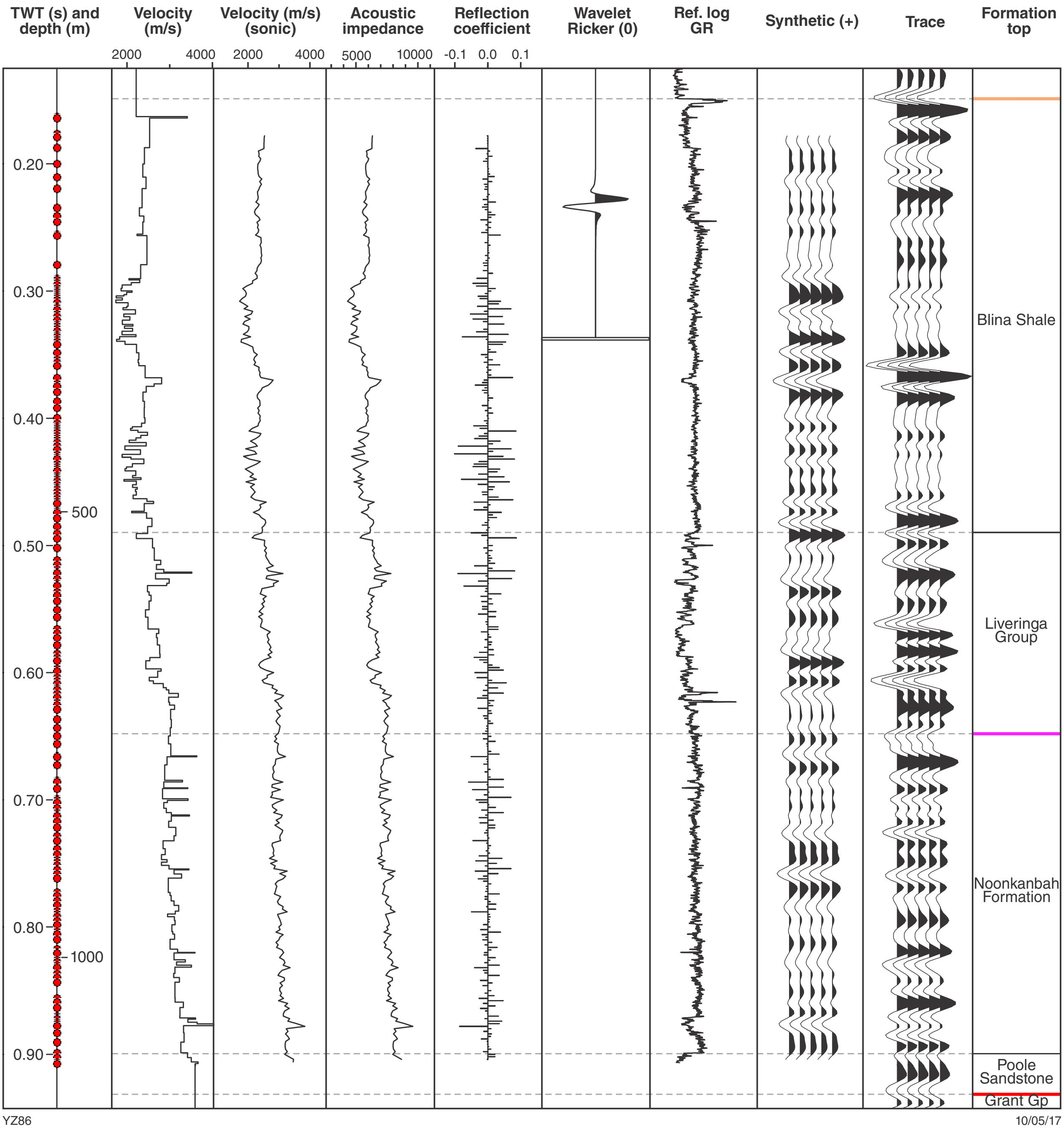


Figure 4. Synthetic seismogram for Millard 1, Fitzroy Trough

highs (e.g. Wallal Platform and Anketell Shelf). The erosion also may have extended down to basement level across some fault blocks, thereby creating discrete outliers such as the Wallal and Waukarlycarly Embayments in the southwestern part of the basin. Alternatively, the basement highs were partly related to earlier tectonic movements and may have been elevated with limited accommodation. Nevertheless, it seems unlikely that the outliers were ever depositionally isolated from the remainder of the basin.

Samphire Graben

The Samphire Graben was recognized firstly as a depression (Veevers and Wells, 1961), based on a vintage aeromagnetic profile (Quilty, 1960; unpublished but referred to in Veevers and Wells, 1961), and then as an embayment through integration of seismic profiles with potential field data (Towner and Gibson, 1983). The tectonic element was then renamed the Samphire Graben

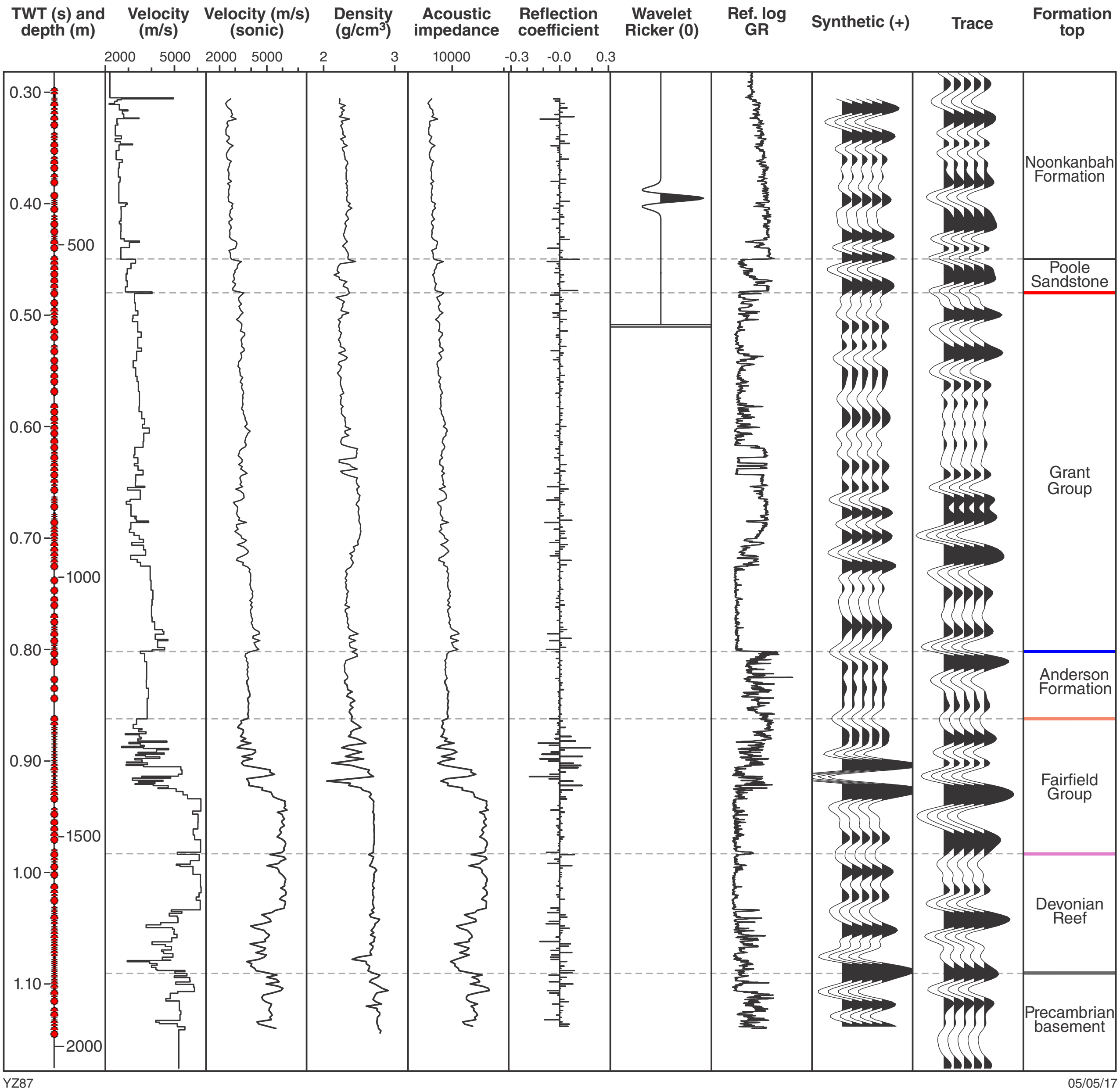


Figure 5. Synthetic seismogram for Canegrass 1, Lennard Shelf

by Hocking (1994b) based on seismic interpretation of the Radi Hills survey data (Santos, 1986; Taylor et al., 1991).

The segment of the Canning Coastal seismic profile within the Samphire Graben was tied to the mineral drillhole Pittston SD 1. This hole intersected basaltic rocks within the Permian Grant Group (Fig. 7a; 643–714 m in Douglas McKenna & Partners, 1992). Similar basaltic rocks were also intersected in Corbett 1 within the Permian Liveringa Group in the Wallal Embayment (Fig. 7b; 328–341 m in Boog, 1994). Both basaltic horizons are calibrated to reflections of marked high amplitude on seismic profiles (Fig. 7a,b) and evident negative anomalies in the first vertical derivative of aeromagnetic data for this region (Fig. 8a; GSWA, 2013). These characteristics have been used to recognize basalt occurrences in other parts of the Canning Coastal survey. The basaltic rocks cause interference and mask some reflections from the underlying strata, resulting in relatively low confidence in interpreting the Top basement horizon from the Wallal Platform to this area (between CDP 10800 and 14500, Fig. 9).

Samphire Marsh 1 penetrated granitic basement below the Lower Ordovician Nambeet Formation to the northeast of the Samphire Graben (Fig. 9; below 2015 m in Johnstone, 1961). Based on this intersection of basement and correlation with nearby seismic profiles, the Top basement was picked along the upper boundary of a low-amplitude and chaotic zone with a local relatively

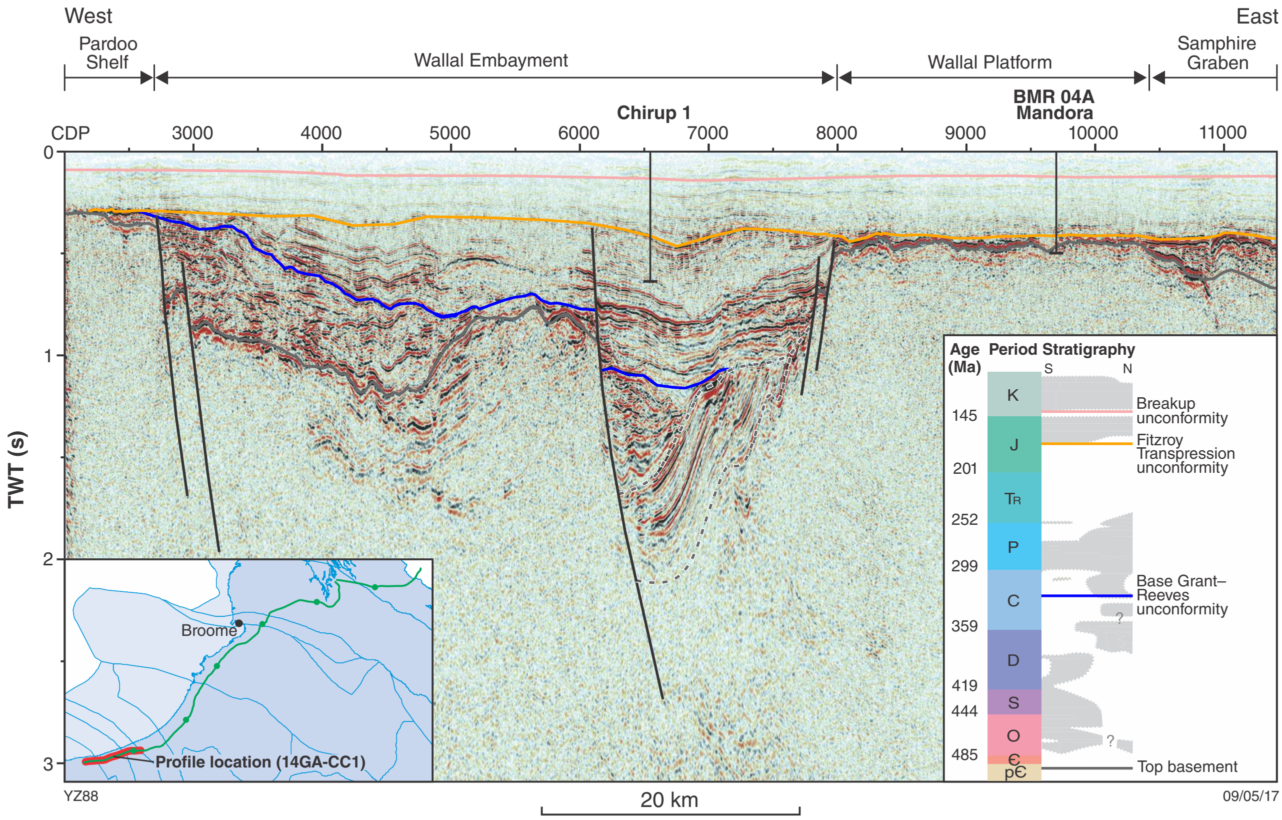


Figure 6. Interpreted seismic section across the southwestern Canning Basin, from the Pardoo Shelf to the Samphire Graben; see Fig. 2 for detailed stratigraphy

strong reflection (about 1.2 s at CDP 16400 in Fig. 9). The seismic profile shows reflections of possible highly deformed Neoproterozoic strata below the Top basement horizon. The gravity signature in the Samphire Graben is characterized by northwest-oriented positive and short-wavelength anomalies that resemble the gravity response of the Wallal Platform, indicating the presence of shallow basement across these areas (Fig. 8b). A previously interpreted graben filled with a thick Paleozoic succession (Alavi, 2013; fig. 12) is not evident in the Canning Coastal seismic profile (Fig. 9). The interpreted Permian to Lower Triassic succession thickens from the Wallal Platform to near Pittston SD 1, and is unconformably overlain by flat-lying Jurassic strata (Fig. 9).

Willara Sub-basin

The southern boundary of the Willara Sub-basin is taken at the edge of preservation of the Ordovician succession below the Base Grant–Reeves unconformity. The Admiral Bay Fault Zone forms the boundary between the sub-basin and the Broome Platform (Fig. 10). Ordovician rocks comprising the lowermost stratigraphy of the Canning Basin (Forman and Wales, 1981; Towner and Gibson, 1983; Kennard et al., 1994) have been intersected in many wells in the Willara Sub-basin, including Samphire Marsh 1, Calamia 1, Anna Plains 1 and Woods Hills 1. These intersections of Ordovician and/or basement rocks provide precise control points for interpreting the complete stratigraphy. The Cretaceous breakup unconformity was interpreted with low confidence due to the very poor-quality seismic data at shallow level, and is mainly constrained by the drillholes to lie at depths of 150–200 m. The Upper Jurassic succession is characterized by a package of flat-lying seismic reflections overlying a nearly horizontal unconformity on Permian strata which generally thicken towards the south (Fig. 10). The bulk of the preserved Paleozoic succession is Lower to Upper Ordovician, and is characterized by intraformational subparallel reflections in seismic data between the angular unconformity at the base of the Permian succession and the top of basement. The Top basement picks in the south were calibrated using data from Samphire Marsh 1 and Calamia 1 (Fig. 1), and interpreted in the centre of the Willara Sub-basin along a relatively continuous reflector above a low-amplitude zone (Fig. 10).

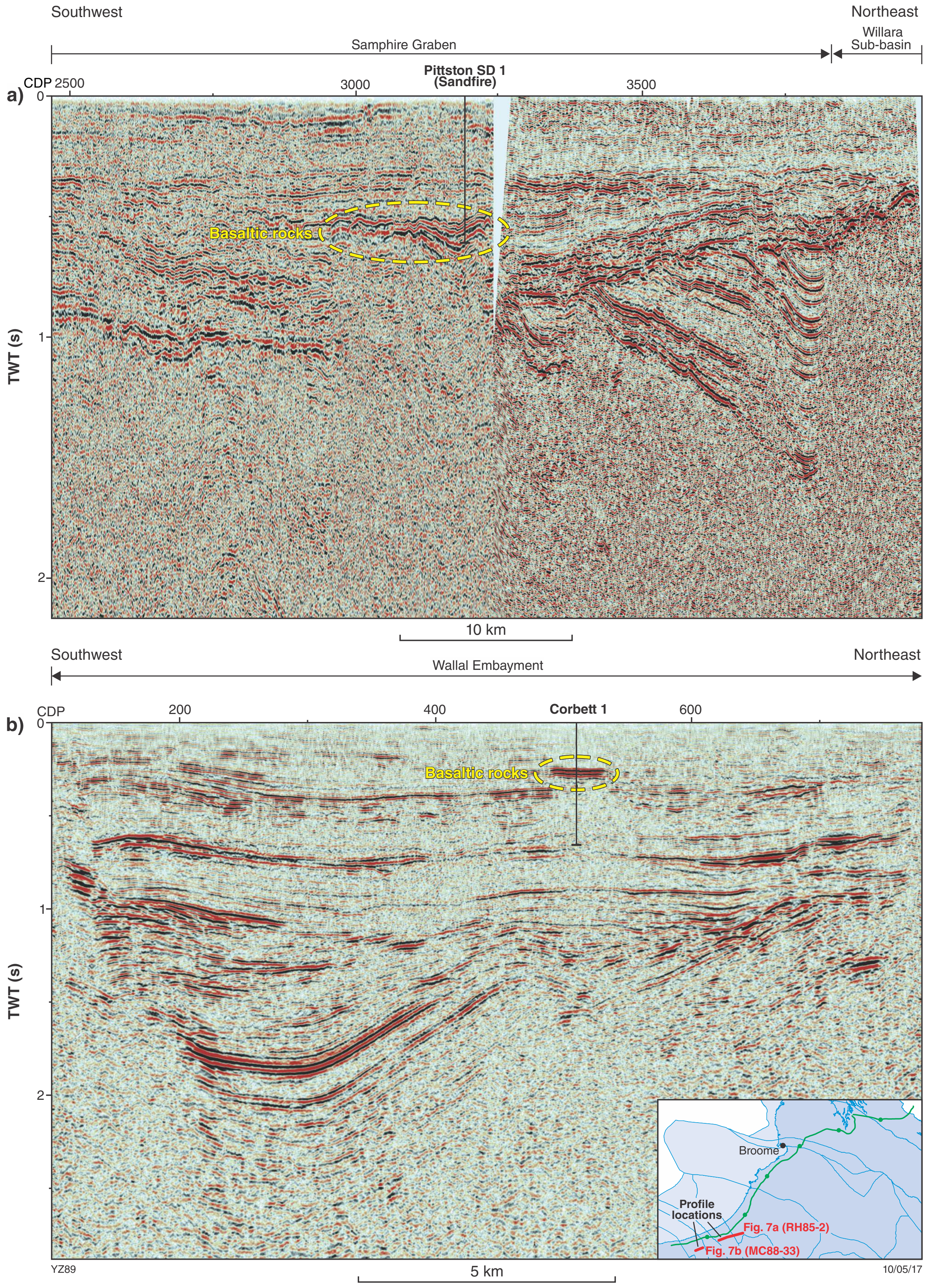


Figure 7. **Interpreted seismic sections of line RH85-2 (a) and line MC88-33 (b); note the seismic signature of basaltic rocks in Pittston SD 1 and Corbett 1**

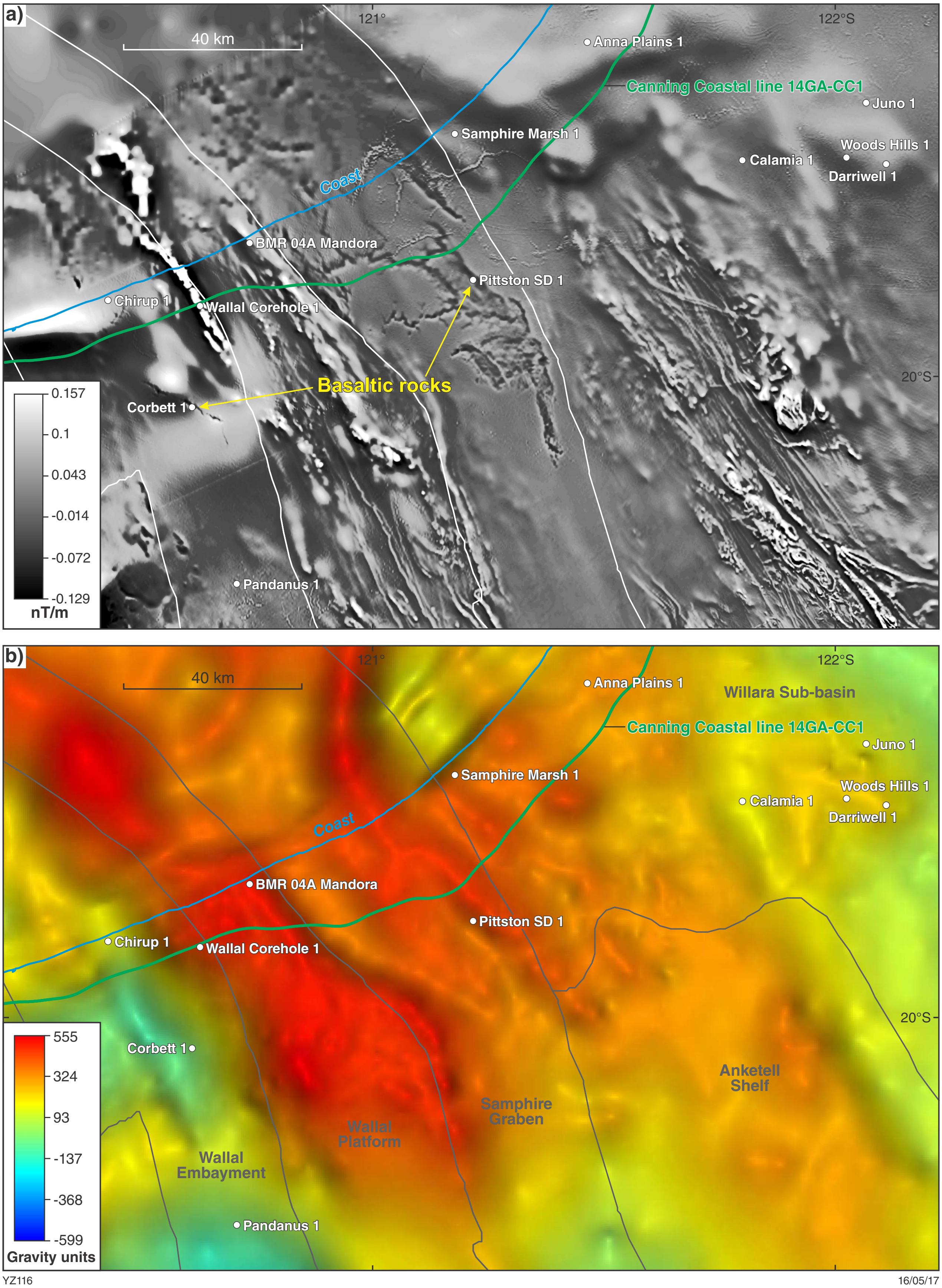


Figure 8. Geophysical images of the southwestern and central Canning Coastal survey area: a) first vertical derivative of aeromagnetic data; b) gravity data. Basaltic rocks in Pittson SD1 (Samphire Graben) and Corbett 1 (Wallal Embayment) are characterized by marked magnetic anomalies. Shallow basement beneath the Wallal Platform and the Anketell Shelf is consistent with a positive gravity anomaly in these areas

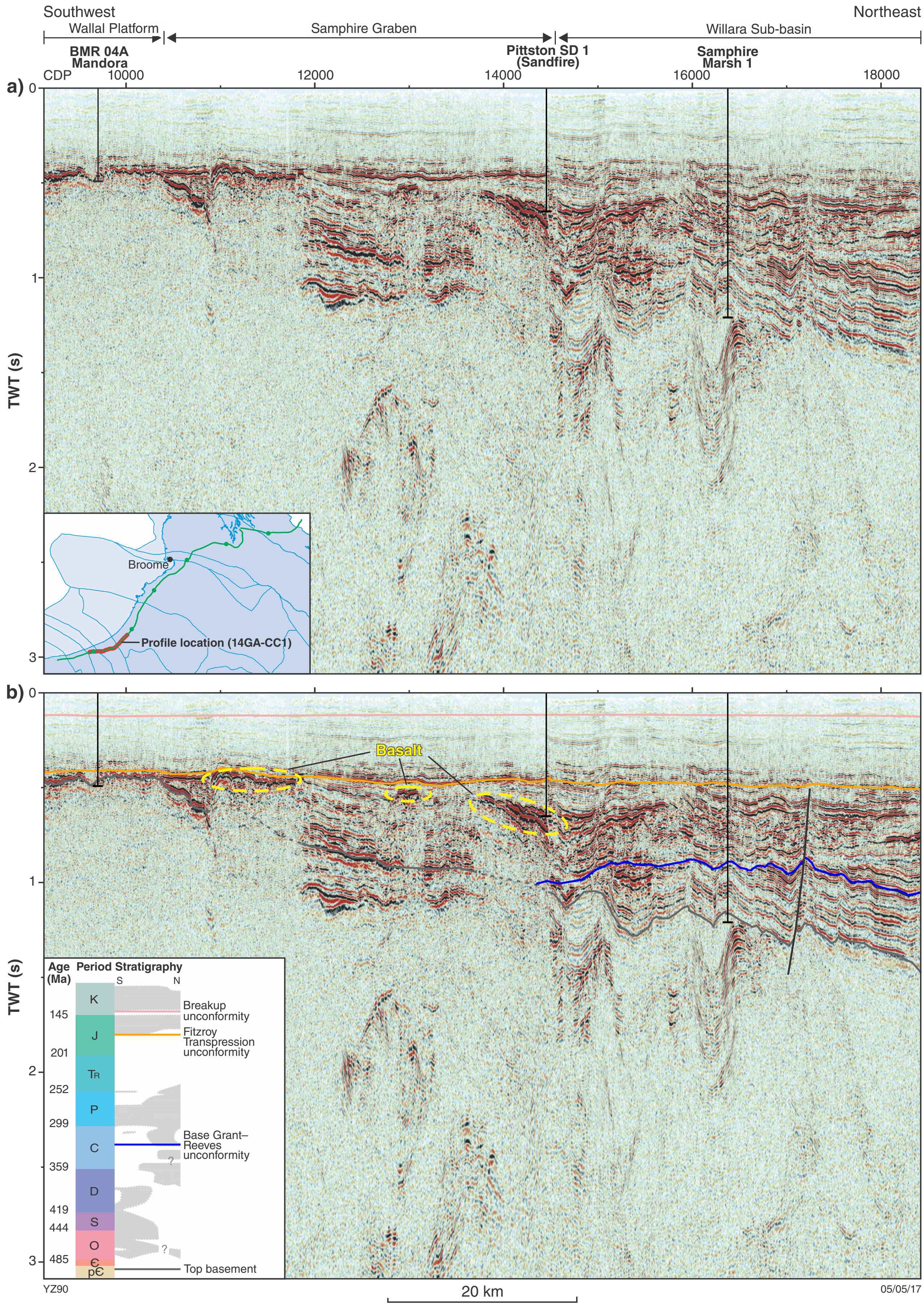


Figure 9. **Seismic sections across the Samphire Graben and part of the Willara Sub-basin (14GA-CC1): a) uninterpreted; b) interpreted; see Fig. 2 for detailed stratigraphy**

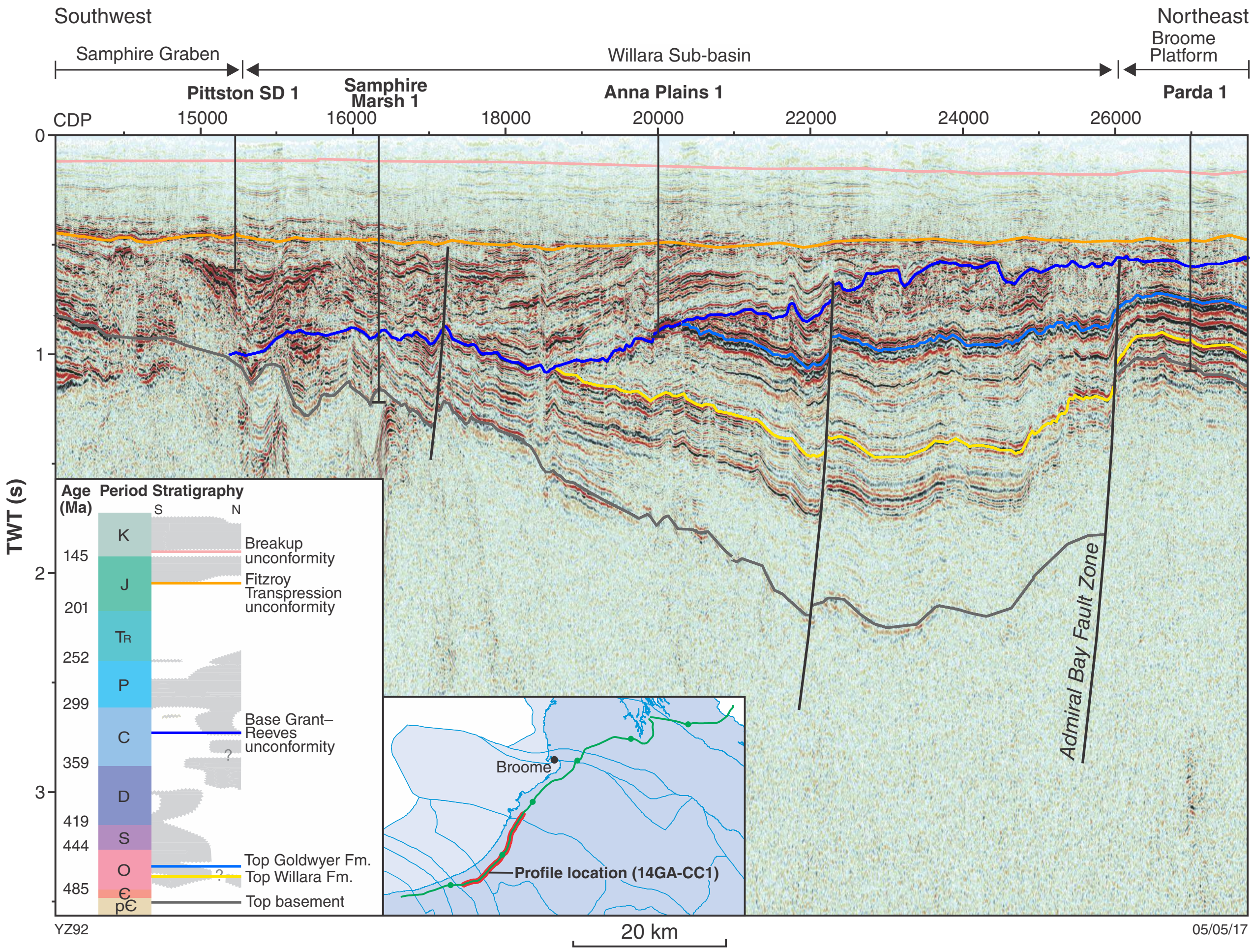


Figure 10. Interpreted seismic section (14GA-CC1) across the Willara Sub-basin; see Fig. 2 for detailed stratigraphy

The Admiral Bay Fault Zone trends west-northwest, dips south-southwest, and shows segmentation and differential vertical displacement along its strike (McCracken, 1994, 1997). This displacement diminishes to the southeast, from a vertical throw of about 1.5 km near the coast to no displacement at its termination northwest of the Kidson Sub-basin. The Ordovician succession in the hanging wall of the Admiral Bay Fault (Fig. 10) does not appear to thicken towards the fault, even though there is significant syndepositional displacement compared to that in the footwall.

Broome Platform

The Broome Platform, located between the Willara Sub-basin and the northern Canning Basin, comprises a relatively thin Phanerozoic succession. It is bounded to the south by the Admiral Bay Fault Zone and transitions gradually northwards into the Jurgurra Terrace (Fig. 11). The Phanerozoic succession, as intersected in Hedonia 1, Hilltop 1, Sharon Ann 1 and Parda 1, comprises: 1) less than 200 m of Lower Cretaceous rocks and about 400 m of Upper Jurassic flat-lying strata; 2) 300–500 m of Permian succession generally thickening towards the north; and 3) 600–1200 m of Lower to Middle Ordovician rocks unconformably overlain by the Permian strata.

Towards the northern edge of the Broome Platform, the lower Paleozoic succession beneath the Permian Grant Group is buckled into a series of small-scale folds, possibly related to salt withdrawal or compressional movement before the Permian (Fig. 11). This succession is more deeply eroded to the northeast (Figs 11 and 12), such that the upper Carribuddy Group has been removed in the south (e.g. in Parda 1; Haines, 2009), the upper Nita Formation is absent in the centre (e.g. in Sharon Ann 1; Haines, 2004), and the upper Goldwyer Formation has been eroded in the north (e.g. in Hedonia 1; Haines, 2004). In addition, Figure 11 shows that the Lower to Middle Ordovician succession below the Top Goldwyer Formation also thins or pinches out towards the southern margin of the platform. For example, the Nambeet Formation is absent at Parda 1 in the south but about 240 m thick at Hedonia 1 in the north (plate 1 of Haines, 2004). This northwards-thickening trend suggests that a considerable thickness of the Ordovician to Silurian succession was present near the northern margin of the platform prior to the erosion preceding deposition of the Grant Group. This inference is supported by the significant differences in thermal maturity between the Grant Group (R_o 0.4–0.6%) and the underlying Goldwyer Formation (R_o equivalent >0.8% or even >1%; as seen in Hedonia 1, Hilltop 1, Edgar Range 1 and Thangoo 1 by O'Reilly, 1987; and in Parda 1 by Geotrack International Pty Ltd, 1999). The abrupt change of maturity suggests that maximum burial depth was probably reached after deposition in the Silurian, following which there was removal of about 2–3 km of the section before the deposition of the Grant Group in the Permian.

Interpretation of the northeastern area

The horizons interpreted northeast of the Broome Platform (Plate 1) include, in ascending order, Top basement, Top Willara Formation, Base and Top Fairfield Group, Base and Top Grant Group, Top Noonkanbah Formation, Top Blina Shale, Fitzroy Transpression unconformity, and the Cretaceous breakup unconformity. Three of the Phanerozoic megasequences were recognized: Middle Devonian to mid-Carboniferous, mid-Carboniferous to Triassic, and Jurassic to Cretaceous (Fig. 2).

Jurgurra Terrace

The Jurgurra Terrace (Playford and Johnstone, 1959; Hocking, 1994a,b) lies between the Broome Platform and the Fitzroy Trough (Fig. 1). The northeast boundary of the terrace is marked by the Fenton Fault (Hocking, 1994b), and its southwest boundary is here placed where pre-Permian strata appear to dip and thicken markedly northwards. The terrace strikes west-northwest and is structurally complex, with extensive faulting and basin inversion across the area (Buru Energy, 2009). Major strike-slip displacement along the faults has been associated with right lateral wrenching during the Fitzroy Transpression movement (Zhan and Mory, 2013).

The quality of the coastal survey in the Jurgurra Terrace area is reduced compared with elsewhere along the line. The data deteriorate with depth as a result of both acquisition difficulties and local geological complications. The acquisition line diverges from the Great Northern Highway near East Crab Creek 1 to follow minor tracks that have numerous sharp bends (Fig. 13; Campbell and Coleshill, 2014). This zigzag line geometry reduces the seismic fold coverage for the mid-point positions between source and receiver. In addition, the structural variation in this area, characterized by tight folds and steeply dipping strata (Buru Energy, 2009), resulted in a loss of

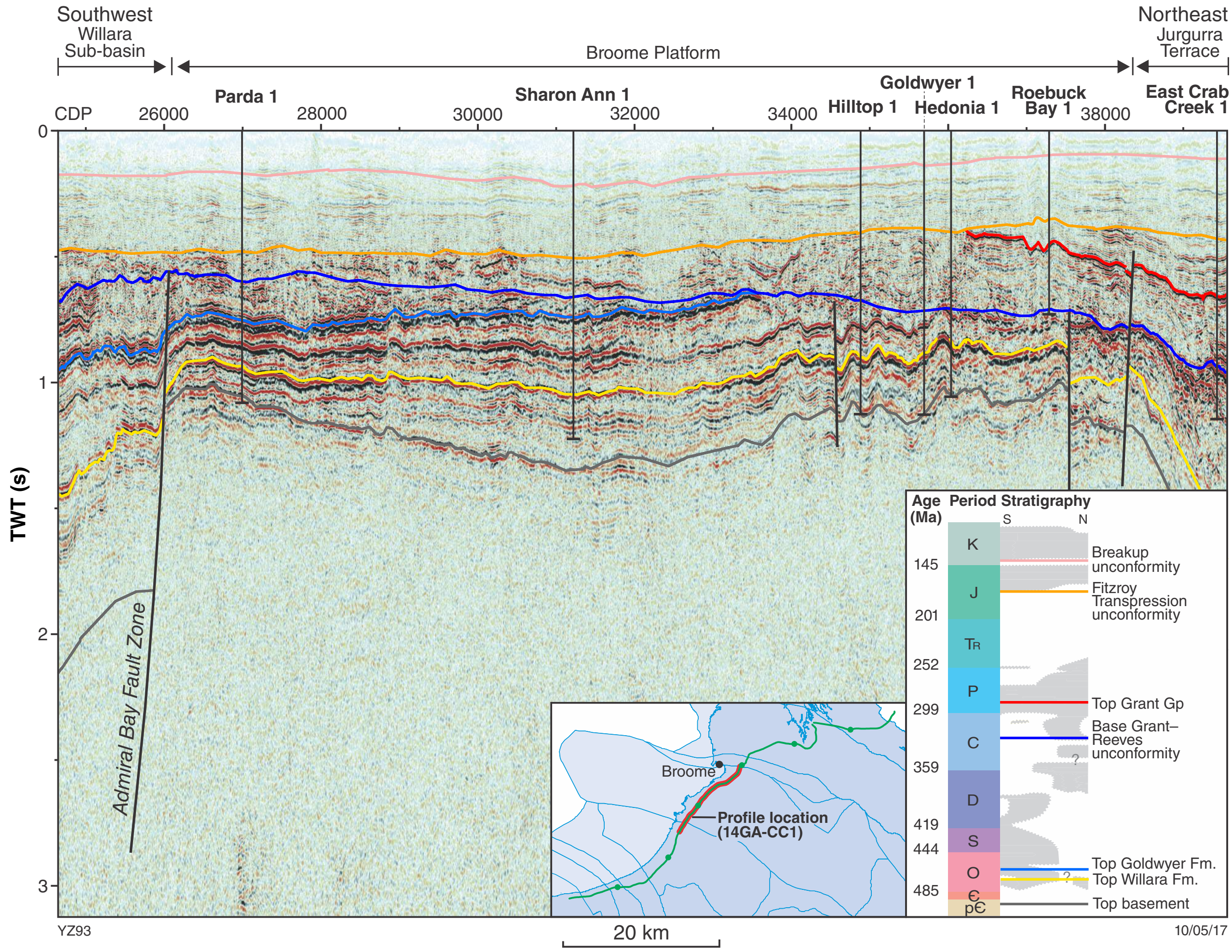


Figure 11. Interpreted seismic section (14GA-CC1) across the Broome Platform; see Fig. 2 for detailed stratigraphy

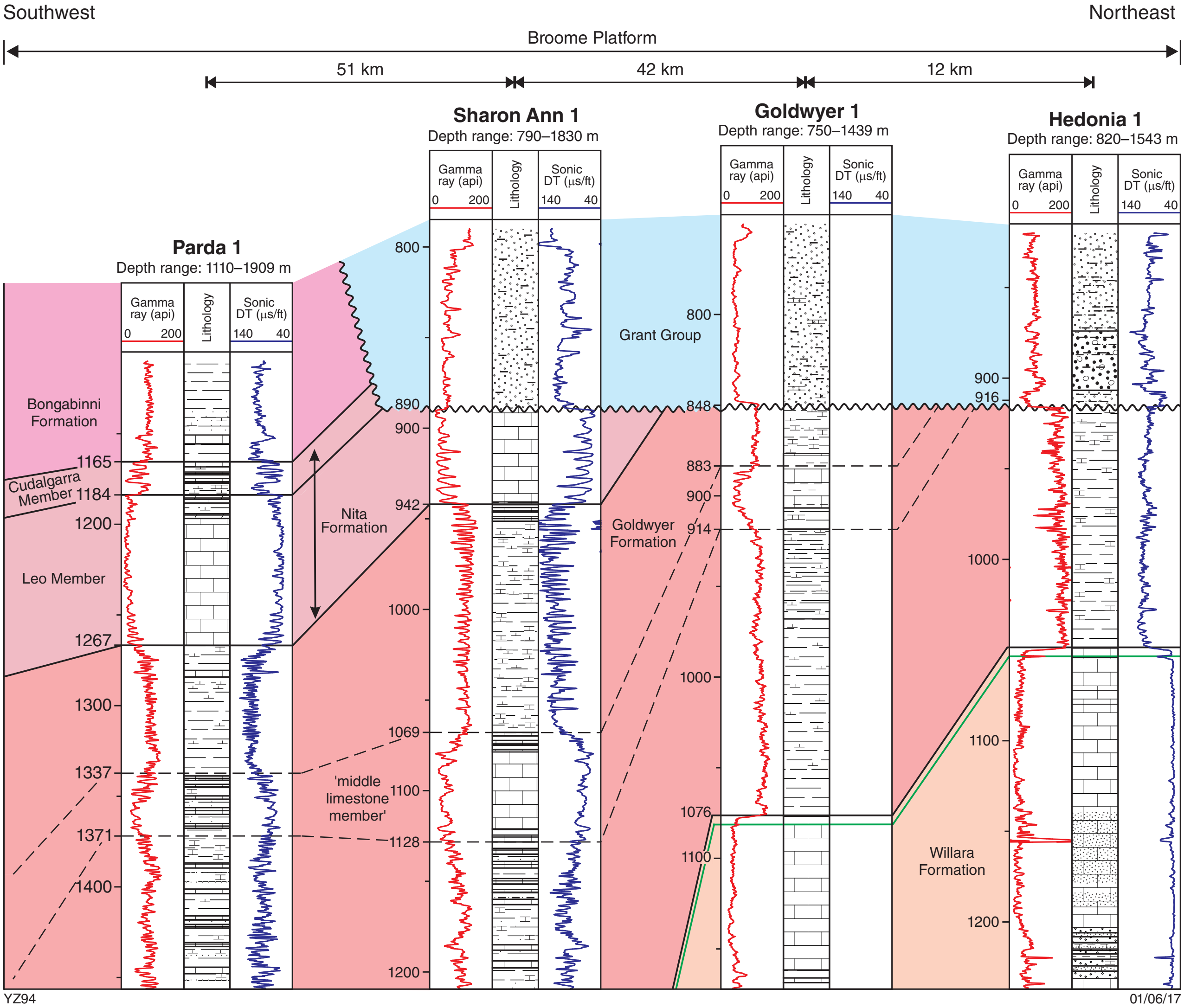


Figure 12. **Stratigraphic correlation across the Broome Platform between drillholes adjacent to the Canning Coastal seismic line (after Haines, 2004); see Fig. 1b for drillhole locations and Haines (2004) for lithological descriptions**

reflection signal from geophones of near to middle offsets, accentuating the lack of seismic fold coverage related to the sharp bends in the seismic line.

The Ordovician to Upper Devonian succession is only intersected by petroleum exploration wells in the south of Jurgurra Terrace and on the northern margin of the Broome Platform (e.g. Hilltop 1, Hedonia 1, East Crab Creek 1). Drillholes near the north of the terrace, such as Cow Bore 1, Ungani 1 and Yulleroo 1, did not extend deeper than lower Carboniferous to Upper Devonian rocks. The correlation of these wells with the seismic profile (Fig. 14) indicate that pre-Permian strata are increasingly eroded to the southwest: the upper part of Anderson Formation was removed at Cow Bore 1, the Anderson Formation and upper part of Fairfield Group were removed at East Crab Creek 1, and the upper part of Goldwyer Formation was absent at Hedonia 1.

The lateral extents of Devonian to Carboniferous units are believed to vary along the strike of the terrace. This is indicated by the lithological differences between the broadly stratigraphically equivalent tight sands of the lowermost Carboniferous Laurel Formation in Yulleroo 1 and the pervasively dolomitized limestone without tight sands of Late Devonian to early Carboniferous age in Ungani 1, 30 km southwest of Yulleroo 1 (Edwards and Streitberg, 2013). The Permian succession in the Jurgurra Terrace occupies a small-scale syncline centred near East Crab Creek 1, and shallows to either side of the terrace (Fig. 14). This succession is overlain by flat-lying Jurassic strata deposited on an erosional surface (interpreted as the Fitzroy Transpression unconformity). In some places, the Permian section has been completely removed by erosion during this event, as indicated by its absence in Barlee 1 (Mory, 2010).

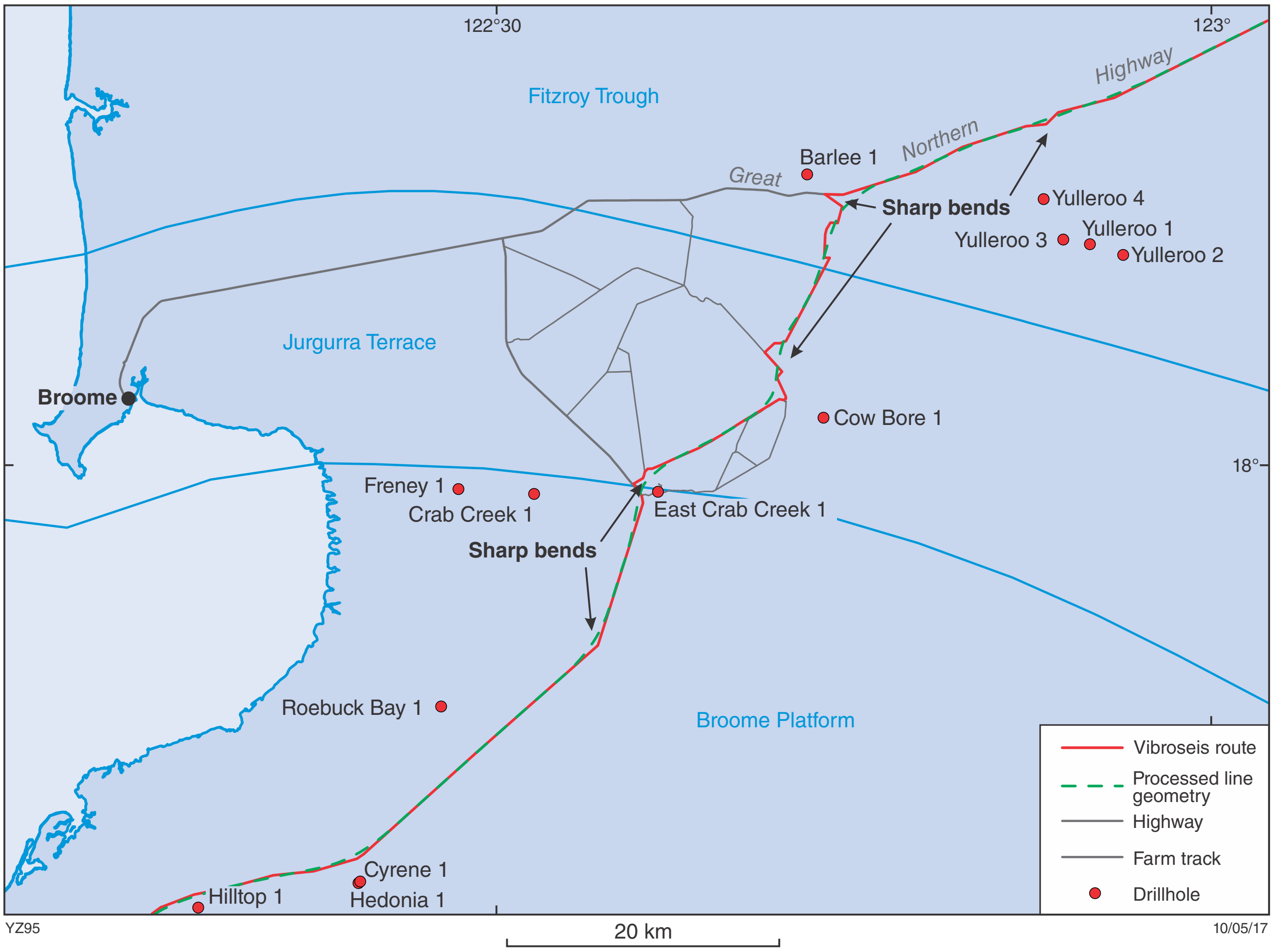


Figure 13. Detailed location of the Canning Coastal seismic line across the Jurgurra Terrace; note the sharp bends along the acquisition line and deviations between it and the final processed line

The seismic data quality is much lower in the Canning Coastal seismic section from 1.5 to 4 s between CDP 39000 and 48000. Only ambiguous, subtle reflections are observable here, making it difficult to interpret the structure and stratigraphy. Top basement beneath the Lower to Middle Ordovician section has been interpreted, using well correlation and nearby seismic profiles, to be at the base of the low-amplitude reflection between 1.2 s TWT at CDP 38500 and 4.3 s TWT at CDP 43500 (Fig. 14). East Crab Creek 1 intersected stratigraphic units ranging from the lower Carboniferous – Upper Devonian Fairfield Group, just below the Base Grant–Reeves unconformity, to the mid-Ordovician Nita Formation below 2741 m (Haines, 2009). These stratigraphic units are much younger than the Precambrian basement in Hedonia 1 at shallow depth (1531 m), implying that the Top basement deepens to the northeast, towards East Crab Creek 1. A nearby, broadly parallel seismic profile (Fig. 15) shows that Lower Ordovician to Carboniferous strata are truncated by the Grant Group and dip to the northeast. The northeasterly dipping seismic reflections (Fig. 15) are believed to be equivalent to the low-amplitude zone beyond the penetration of East Crab Creek 1. Furthermore, the subtle reflections can be correlated with strong continuous reflections on an adjacent profile (Fig. 16), providing additional evidence for interpreting Top basement at depth.

Fitzroy Trough

The Canning Coastal seismic profiles show that the Fitzroy Trough is a deep asymmetric depression filled with a thick Paleozoic succession. The trough is bounded to the southwest by the Fenton Fault, which extends to the surface and exhibits inversion within the Mesozoic succession (Fig. 17) due to fault reactivations. The Devonian to Carboniferous succession in the trough generally shallows to the south, towards the Fenton Fault (Fig. 14). This geometry is opposite to that interpreted on BMR88-03 (Fig. 1a; Drummond et al., 1991). This line is located approximately 100 km southeast of 14GA-CC1 (Fig. 1a) and shows that the trough deepens to the Fenton Fault (Drummond et al., 1991; Kennard et al., 1994; Zhan and Mory, 2013). The difference in trough geometry between the two surveys suggests that a half-graben geometry is not applicable to the entire Fitzroy Trough.

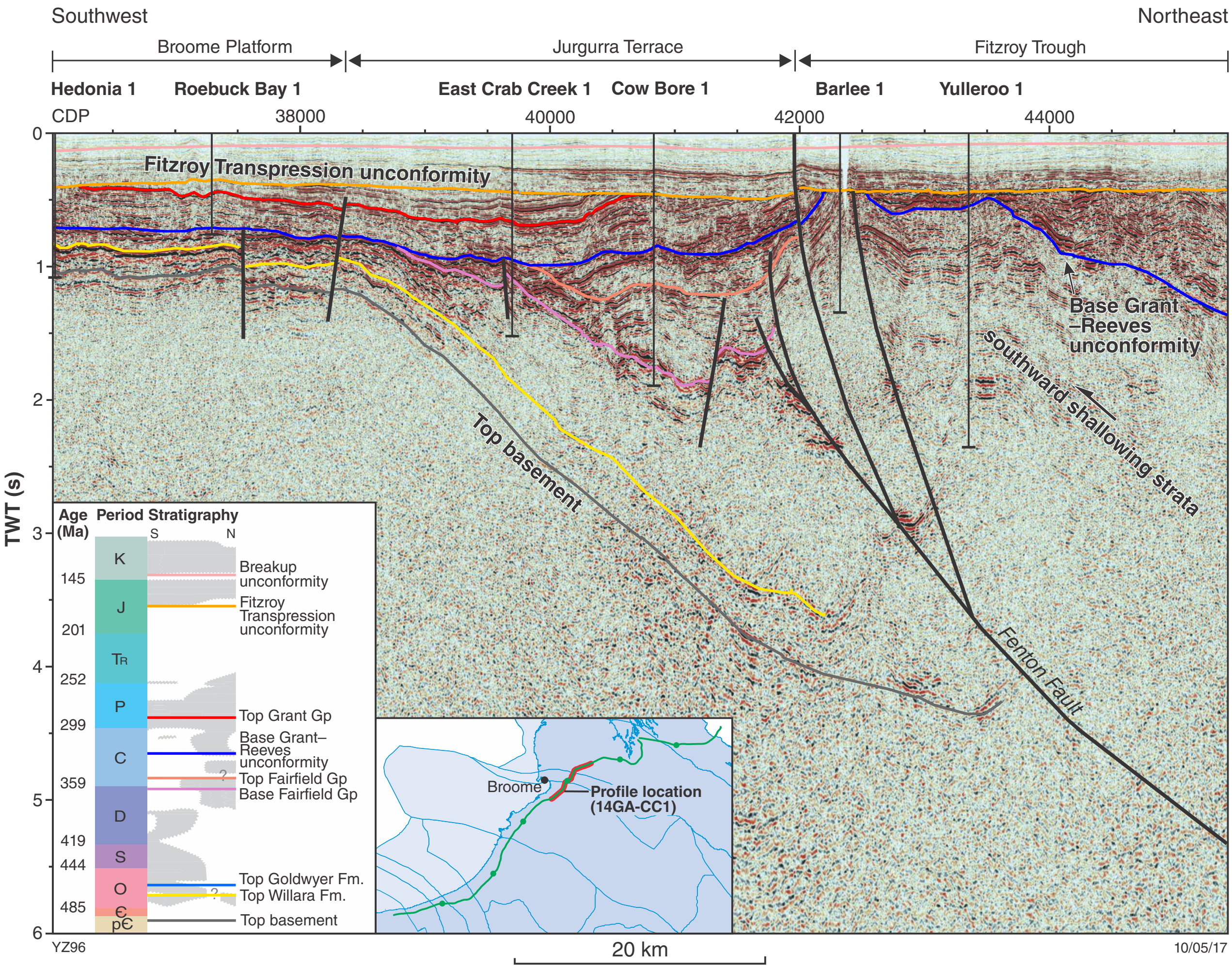


Figure 14. Interpreted seismic section (14GA-CC1) across the Jurgurra Terrace; see Fig. 2 for detailed stratigraphy

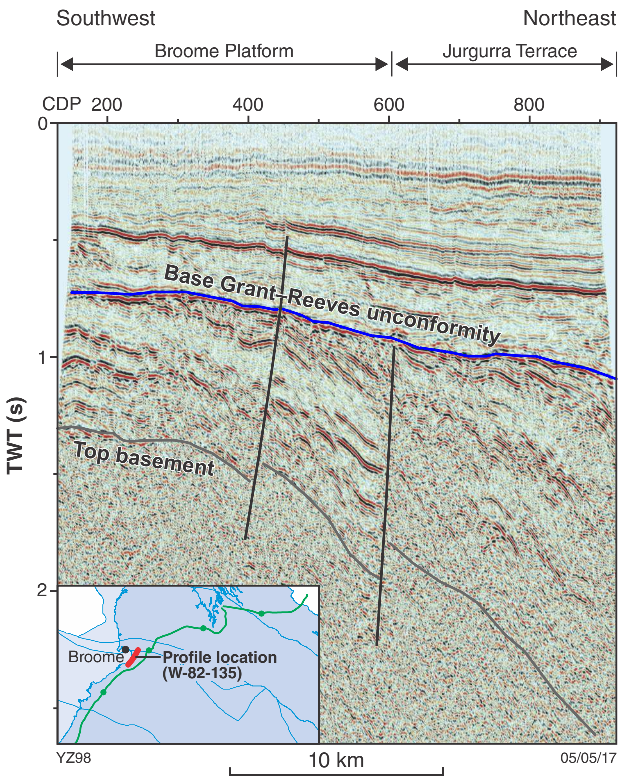


Figure 15. Interpreted seismic section of an adjacent line (W-82-135), showing northeasterly dipping strata below the Base Grant–Reeves unconformity

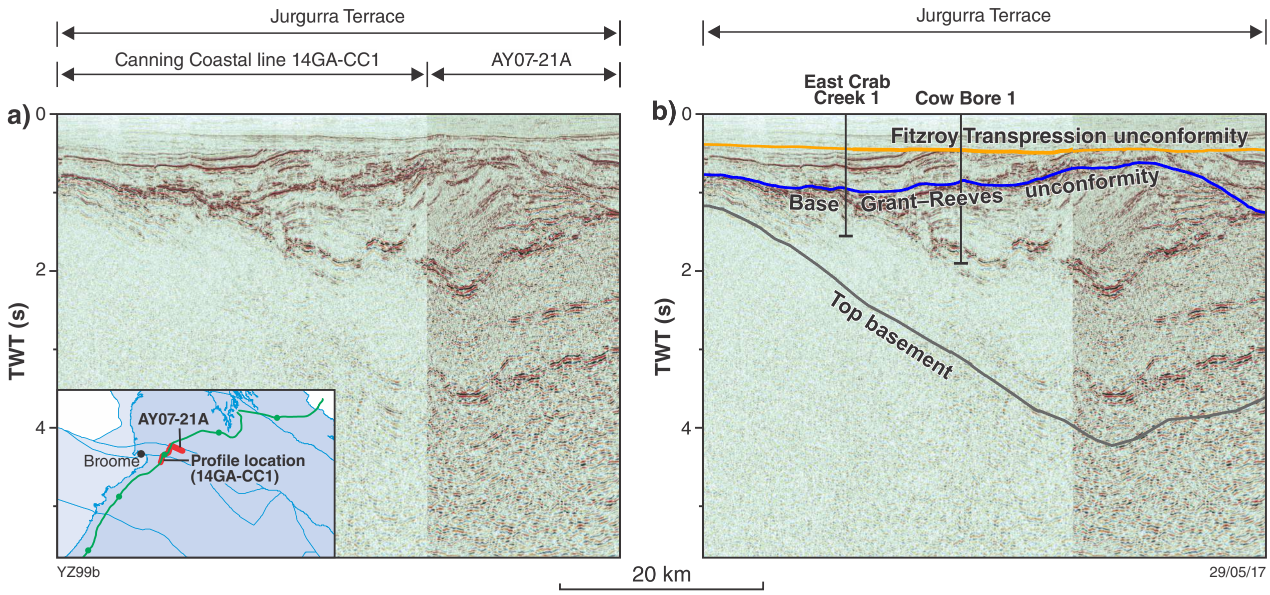


Figure 16. Composite seismic section across the Jurgurra Terrace, incorporating the Canning Coastal line (14GA-CC1) and a nearby profile (AY07-21A): a) uninterpreted; b) interpreted, showing the possible location of Top basement

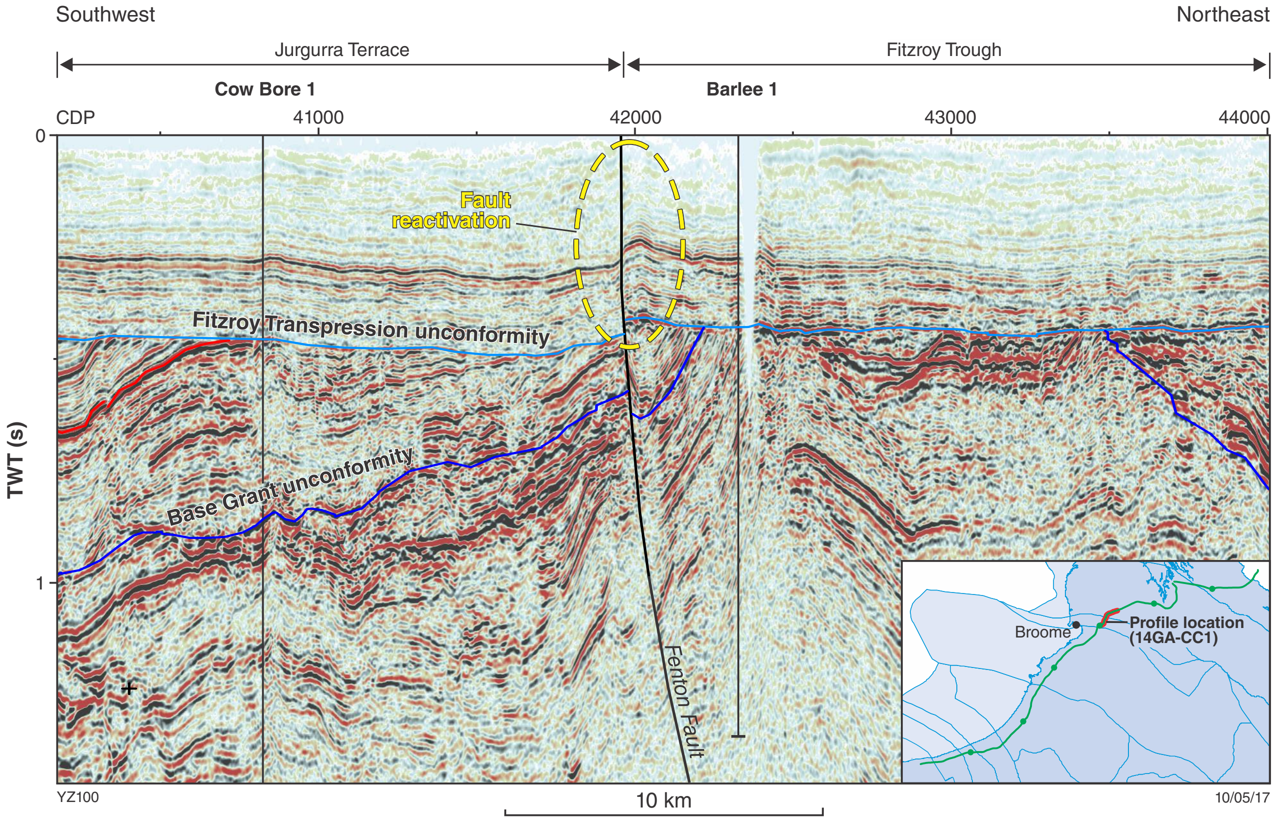


Figure 17. Seismic interpretation across the boundary between the Jurgurra Terrace and Fitzroy Trough, showing Mesozoic–Cenozoic reactivation (inversion) of the Fenton Fault

The depth to basement is uncertain in the deep part of the trough due to the very poor data quality coupled with the lack of well control. Two options for the maximum depth of Top basement around CDP 50500 are presented: about 5 s TWT for the deep option and about 3 s TWT for the shallow option (Figs 18a,b and 19; Plate 1). The deep option for Top basement is characterized by strong reflections beneath a low-amplitude zone spanning an interval of approximately 2 s. The acoustic basement marks the deepest part of the trough, which is then interpreted to shallow towards both the trough margins (Fig. 18b).

The shallow option for Top basement is based on the correlation with offset profiles around the wells Fraser River 1 and Padilpa 1 (Fig. 18a). The former bottomed in 30 m of igneous rocks below the Fairfield Group (3061 m; Hunt, 1956) in the Fitzroy Trough. The latter, on the southern margin of the Lennard Shelf, intersected a 148 m thick metasedimentary succession between two intervals of gabbro underlying the Permian Grant Group (Owad-Jones et al., 1988). The upper gabbro yielded an early Carboniferous K–Ar date (Owad-Jones et al., 1988), although the result is considered unreliable because Ar loss or excess could lead to an erroneously younger or older age, respectively (McDougall and Harrison, 1999). The metasedimentary rocks and lower gabbro are undated but are interpreted to be Precambrian basement. The seismic profile (Fig. 18a) exhibits chaotic and broken signatures for the igneous rocks around Fraser River 1, and a strong coherent interface at about 2 s between the bottom of the well and a deep zone of no reflection. The coherent reflector can be correlated with shallow basement on the Lennard Shelf to the north, indicating that it is reasonable to interpret a shallow basement beneath the Upper Devonian reefs and Fairfield Group in this region (Fig. 18a).

The Top basement and Lower Ordovician strata in the Jurgurra Terrace, south of the Fenton Fault, dip to the northeast and extend down to about 4.5 s TWT (Figs 14 and 19). This contrasts with southwards shallowing basement north of the Fenton Fault along the southeastern margin of the Fitzroy Trough (Fig. 19). Both the deep and shallow options for Top basement in the trough inevitably require a certain amount of reverse movement along the Fenton Fault (Fig. 19). North of the Fenton Fault, there is an abrupt change in strata dip from approximately 5° at 1 to 2.5 s TWT (CDP 44000 to 45000) to ~20° at 1.5 to 3 s TWT (CDP 45000 to 46000), suggesting that a northeasterly dipping fault is present (Fig. 19). Exploration well Yulleroo 1 was drilled between this inferred fault and the Fenton Fault, and intersected over 700 m of alternating limestone and shale of Devonian age to its total depth of 4572 m (Bischoff, 1968), indicating relatively deep basement at this well location. The contrast between the relatively deep basement below Yulleroo 1 and the southwards shallowing trend in basement at a similar level from CDP 46000 to 45000 (Fig. 19) indicates a considerable amount of reverse movement across this inferred fault, possibly of a similar order of magnitude of vertical displacement to the Fenton Fault.

The shallow basement option requires significant vertical displacement (~1.5 s TWT, approximately 3.2 km at this level) along both the Fenton Fault and the inferred fault to the north. Canning Coastal line 14GA-CC1, flattened to the base of the Grant Group (Fig. 20), shows that the displacement of basement across these two faults is too large to be exclusively related to Fitzroy Transpression movement. The reverse movements along the faults shown on the shallow basement option require additional increments prior to the deposition of the Grant Group. This is consistent with pre-Permian structural inversion and reverse movement observed at the southeastern margin of the trough on a nearby seismic profile (Fig. 21).

The continuous reflectors of the Devonian to mid-Carboniferous succession are interrupted by a dome-like feature in the south of the Fitzroy Trough (Fig. 18a,b). This feature comprises some low-amplitude and chaotic reflections that pass into continuous reflections to the west; there is a more abrupt change of amplitude to the east. The dome-like geological body also coincides with a nearly circular, long-wavelength, positive gravity anomaly which is about 40 km in diameter (Fig. 22). The variations in seismic signature and the broad gravity anomaly may indicate lithological differences across the dome-like feature, and suggest a possible large igneous intrusion at depth.

The seismic profile crossing the northern part of the Fitzroy Trough (Fig. 23) clearly shows a westwards-prograding complex between CDP 9900 and 6200 (1.3 – 1.8 s TWT). Although this feature may extend farther westwards, the relatively poor quality of the seismic data prevents interpretation of its lateral extents. This progradational package deepens basinwards, away from the trough-bounding Pinnacles Fault, and is correlated with part of the Upper Devonian to lower Carboniferous Fairfield Group in Wattle 1. The lack of a growth component, or any substantial normal displacement along the Pinnacles Fault, suggests that it did not control the deposition of Upper Devonian to lower Carboniferous sediment in this part of the basin. The Fairfield Group appears to conformably overlie a Devonian reef complex, on the margin of the Fitzroy Trough, that can be correlated with outcrops of mixed limestone and clastic rocks farther north on the Lennard Shelf (Playford et al., 2009).

The upper Carboniferous to Lower Triassic succession is characterized by parallel to subparallel seismic reflections and gradually thickens into the Fitzroy Trough (Figs 18a,b and 23). In addition, this succession is folded and overlain unconformably by flat-lying Jurassic strata (Fig. 18a,b). Parts of the succession are exposed along the northern part of the trough. In the subsurface to the south it is cut by a series of normal faults with small displacements. Local mapping of the Top Grant Group in this area indicates that the folds are oriented approximately east–west and these post-depositional features probably resulted from the Triassic to Jurassic Fitzroy Transpression (Zhan and Mory, 2013).

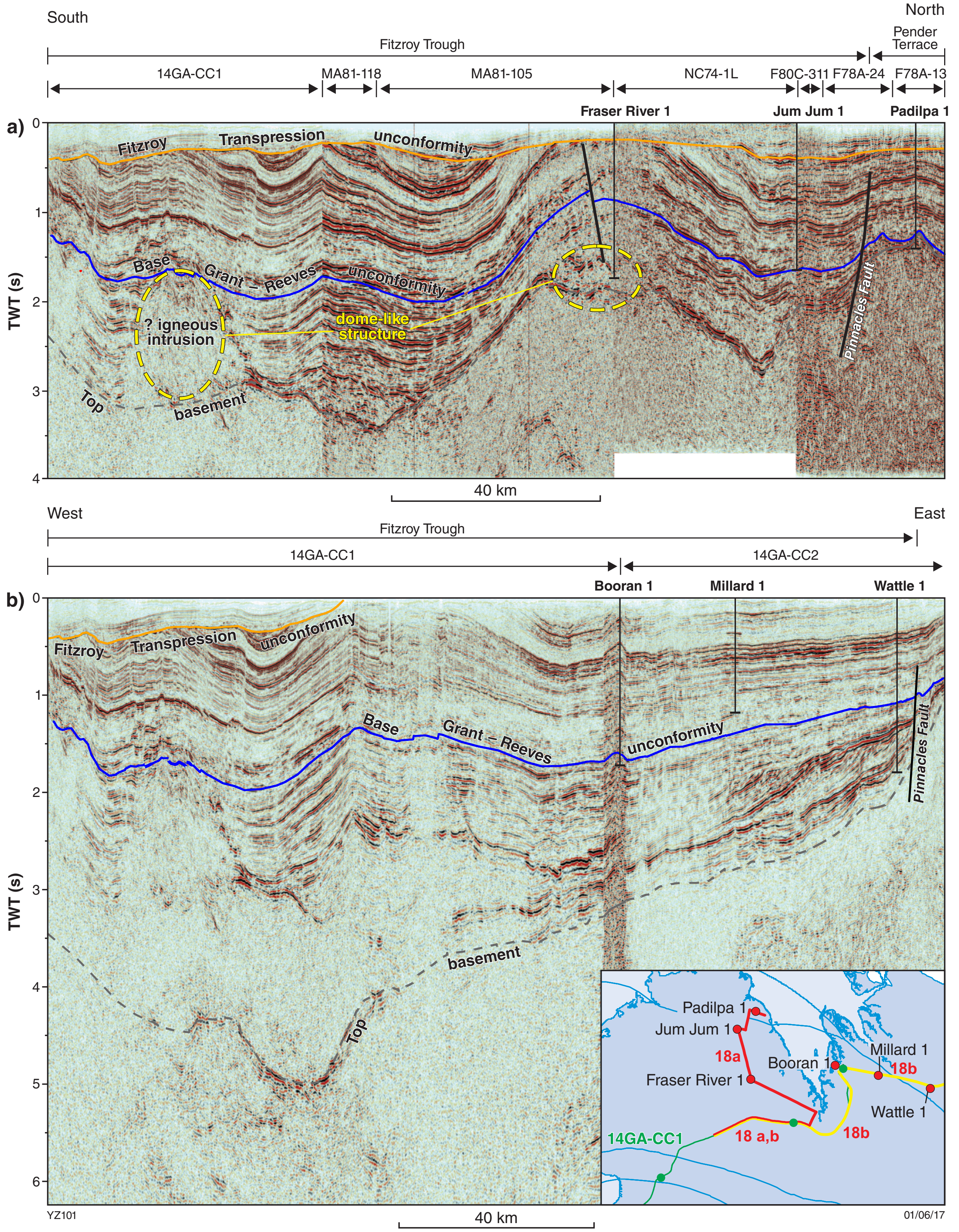


Figure 18. **Interpreted seismic sections across the Fitzroy Trough, showing the shallow (a) and deep (b) options for Top basement (see Fig. 2 for detailed stratigraphy); the dome-like structures identified on Fig. 18a correspond to the southern and northern flanks, respectively, of the same circular gravity anomaly shown in Fig. 22**

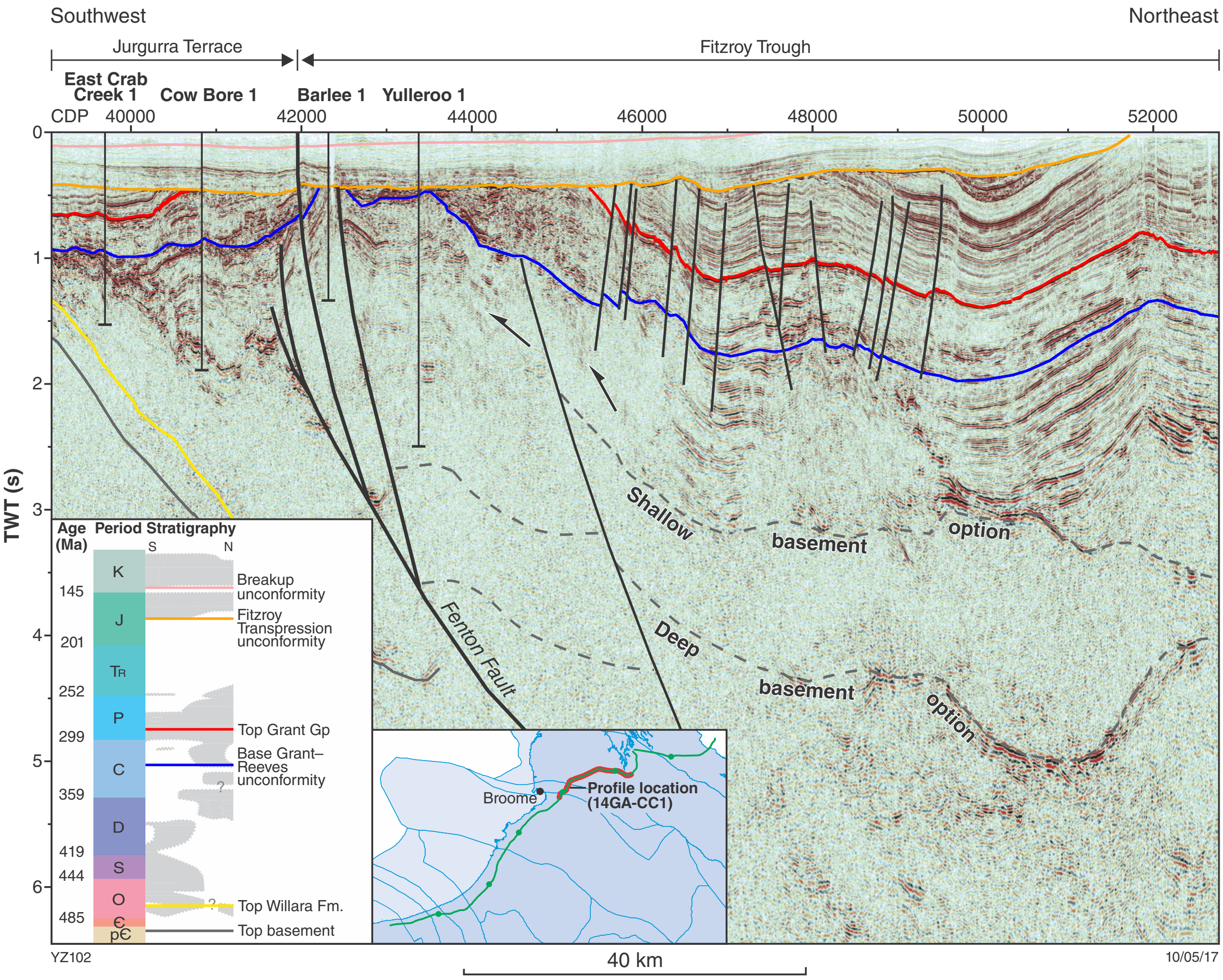


Figure 19. Interpreted seismic section along the Canning Coastal line (14GA-CC1) showing the shallow and deep options for Top basement, and the implied reverse displacement across the Fenton Fault and the inferred fault; see Fig. 2 for detailed stratigraphy

Lennard Shelf

The Lennard Shelf is the northeastern-most tectonic unit of the Canning Basin (Fig. 1) and is separated from the Fitzroy Trough by the Pinnacles Fault (Fig. 24). Seismic horizons on the Lennard Shelf are constrained by several offset wells including Meda 1, Canegrass 1, Lloyd 1 and Lukins 1 and nearby seismic profiles, which increase the confidence in the interpretation for this area. Shallow seismic data are of poor quality due to low fold coverage and noise at this level. Therefore surface geological mapping (e.g. by Martin et al., 2015) is important for constraining interpretation of the shallow horizons and providing good correlation with formation boundaries intersected in the drillholes.

Basement below the Lennard Shelf is relatively shallow compared to beneath the Fitzroy Trough. It varies from about 3000 m deep in the south to 400 m deep in the middle of the shelf (Fig. 24). The Paleozoic succession onlaps Precambrian basement and outcrops in the north. The Ordovician to mid-Devonian succession, present extensively in the southern Canning Basin (Fig. 2), is missing in this survey area based on well-ties to Canegrass 1 and Langoora 1. Nevertheless, Ordovician strata have been recognized locally in the northeastern Canning Basin. For example, the Goldwyer Formation was intersected 20 km east of the profile in Blackstone 1 and 120 km west of the profile in Tappers Inlet 1, on the Pender Terrace (Fig. 25a,b; Haines, 2004). Lower Ordovician rocks outcrop in the northeastern part of the basin, including the Prices Creek Group on the eastern Lennard Shelf (Martin et al., 2015) and the Carranya Formation on the Billiluna Shelf and Balgo Terrace (Normore, 2017).

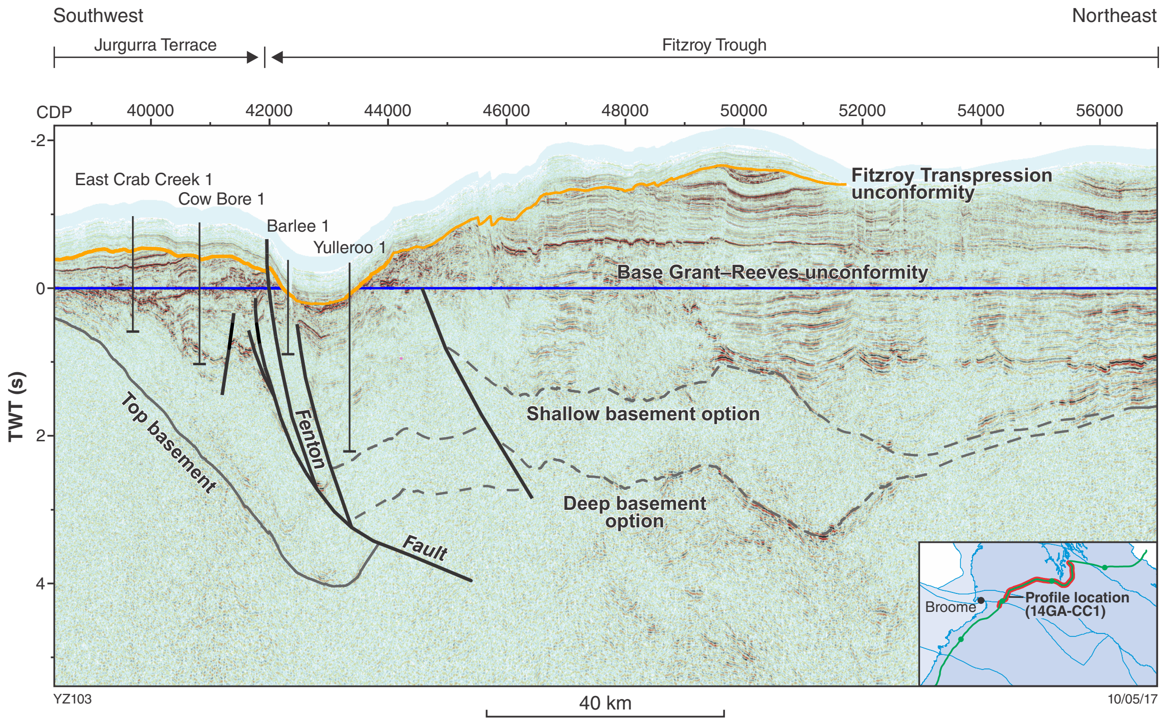


Figure 20. Interpreted seismic profile (14GA-CC1) across the Fitzroy Trough, flattened to the Base Grant–Reeves unconformity

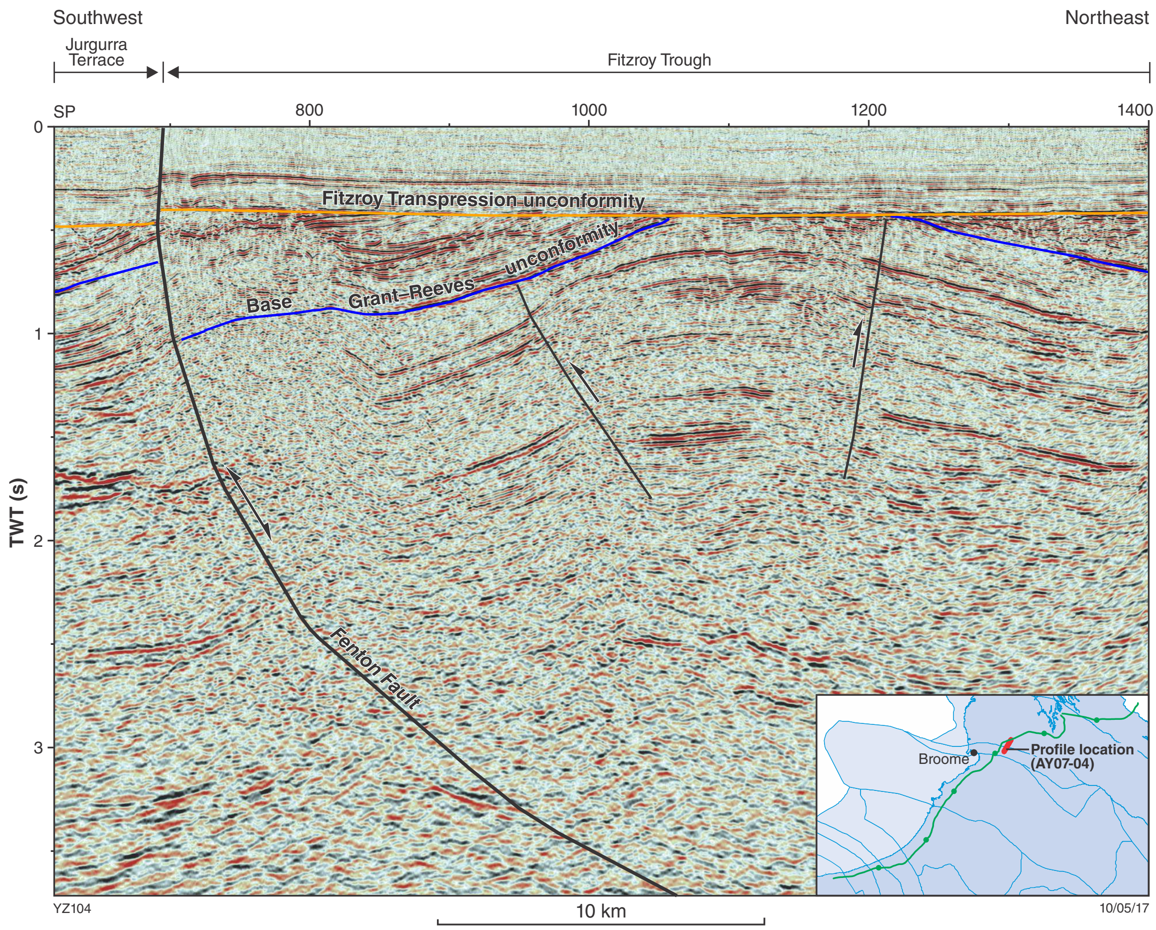


Figure 21. Interpreted seismic profile AY07-04 showing pre-Permian deformation; see Fig. 2 for detailed stratigraphy

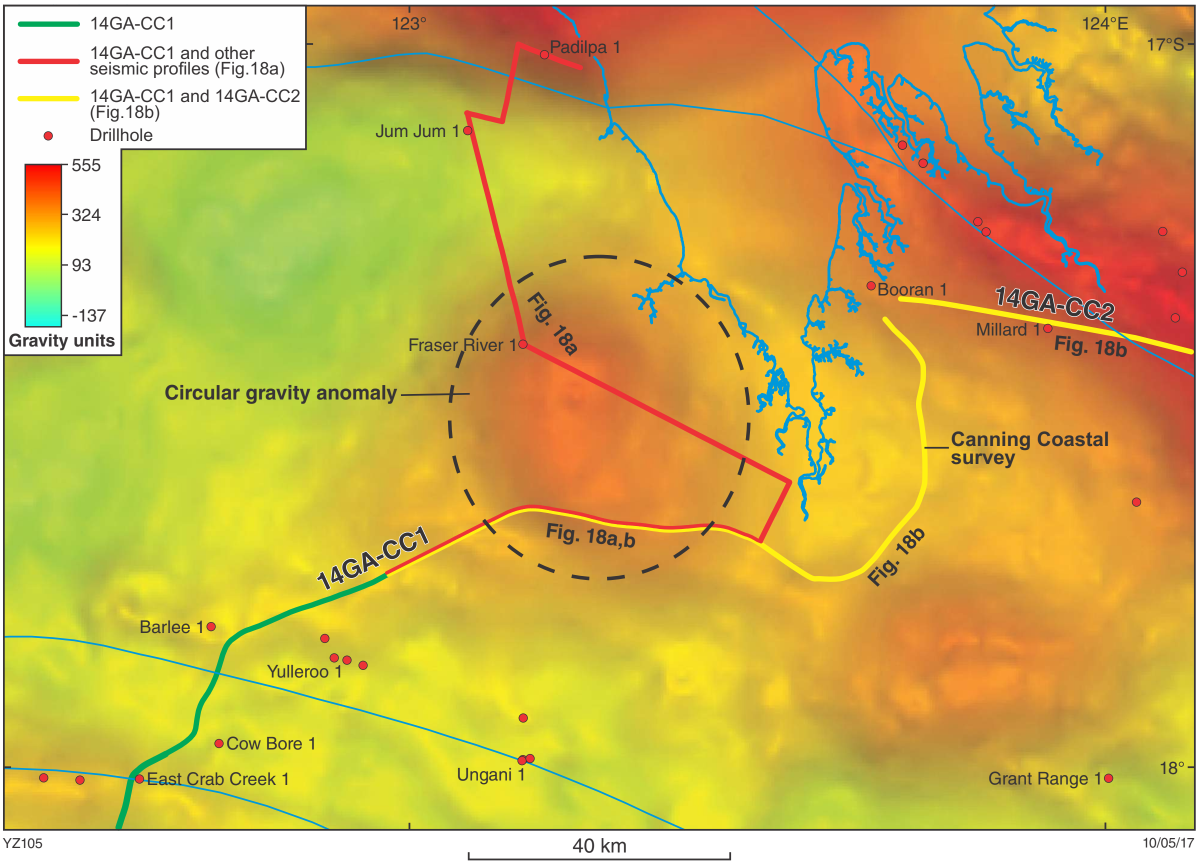


Figure 22. Gravity image showing a circular anomaly near Fraser River 1 that may correspond to the interpreted subsurface igneous intrusion shown in Fig. 18

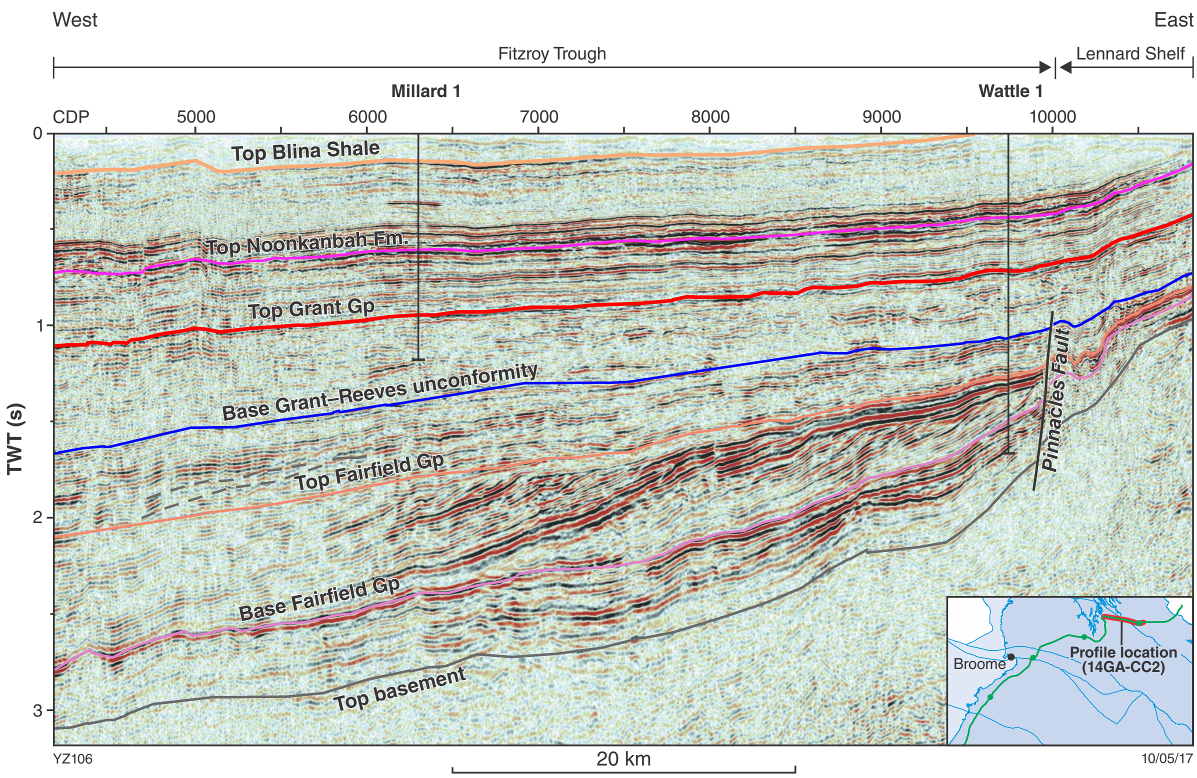


Figure 23. Interpreted seismic section (14GA-CC2) across the northern margin of the Fitzroy Trough, showing a progradational complex within the Fairfield Group; see Fig. 2 for detailed stratigraphy

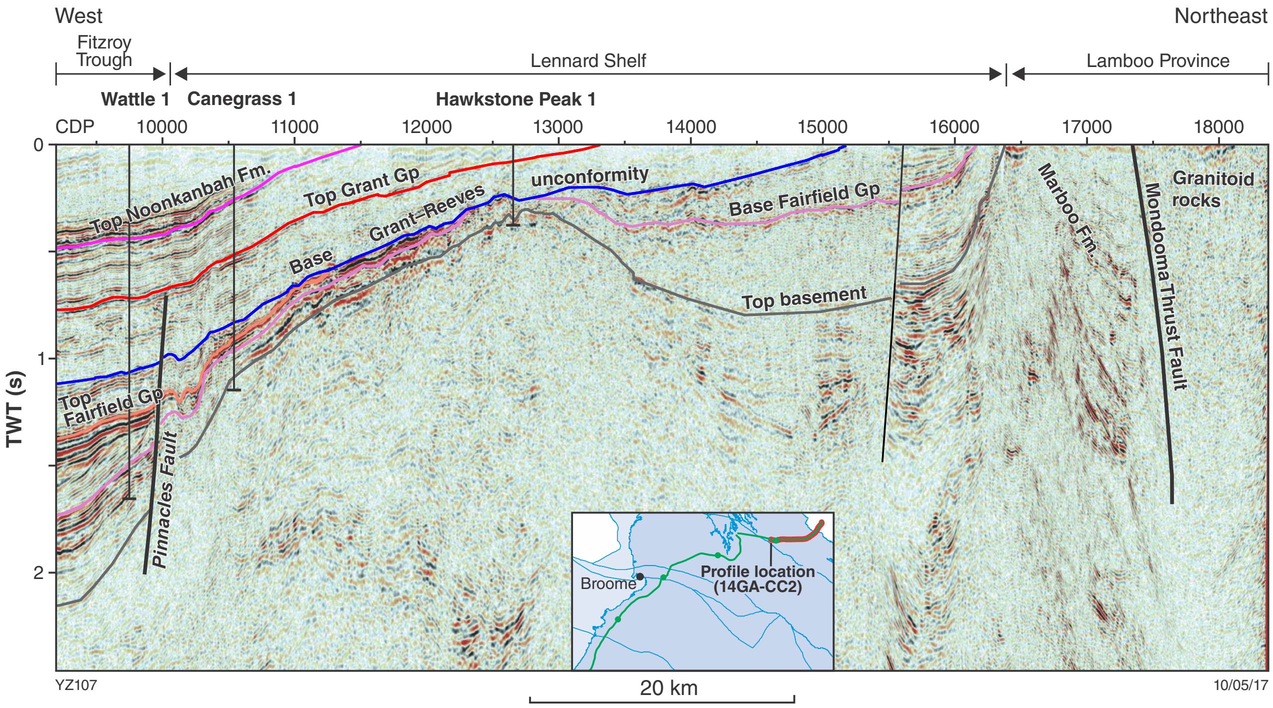


Figure 24. Interpreted seismic profile of the northern end of the Canning Coastal survey (14GA-CC2), showing the geometry of the Lennard Shelf and southern part of the Lamboo Province; see Fig. 2 for detailed stratigraphy

A 25 km wide, sag-like depression is interpreted on 14GA-CC2 between CDP 13000 and 16400, in the northern Lennard Shelf (Fig. 24). Rocks deposited in this depression were intersected in Napier 1 (Newstead, 1969) and Hawkstone Peak 1 (Gardner, 1963), both located about 30 km northwest of the Canning Coastal seismic line (Fig. 1b). Drillhole data indicate that the depression is about 1800 m deep and mainly filled by a Middle–Upper Devonian reef complex and the Upper Devonian to lower Carboniferous Fairfield Group, both of which shallow and outcrop at the northeastern margin of this depression (Playford et al., 2009). These two units probably correspond to zones of low-amplitude and relatively strong reflection, respectively (Fig. 24). The uppermost basement, characterized by a series of continuous high-amplitude reflectors beneath the depression, from CDP 14000 to 16000, thins and pinches out near the northern margin of the basin. These basement reflections have a sharp contact against the Lamboo Province (Griffin et al., 1993) to the north, indicating different basement rocks beneath the depression. Here, the basement is interpreted to be Neoproterozoic sedimentary rock equivalent to the Oscar Range Inlier, which is surrounded by the Paleozoic succession of the Lennard Shelf (Hocking, 1994a,b).

Lamboo Province

The Lamboo Province in the King Leopold Orogen of the North Australian Craton consists of the Paleoproterozoic metasedimentary Marboo Formation, metamorphosed Ruins Dolerite, Whitewater Volcanics, and a number of granitic rock units (Griffin et al., 1993; Tyler et al., 1995, 2012). The Canning Coastal survey extends across approximately 20 km of the southernmost Lamboo Province, although data quality is only adequate for the very southern part between CDP 16400 and 17500. Seismic data show that the southwest boundary of the Lamboo Province is marked by a sharp juxtaposition of apparently southwest-dipping Paleozoic strata against northeast-dipping Proterozoic metasedimentary rocks (Fig. 24). The Marboo Formation in the south thickens to the northeast and is characterized by steeply dipping, high-amplitude and high-frequency reflections. The chaotic and low-amplitude reflections north of the Marboo Formation are interpreted to correspond to grantitoid rocks (Fig. 24). The poor quality of the seismic data is related both to the scattering of seismic reflections by igneous rocks and reduced fold coverage towards the northern end of the survey. The granitic rocks abut the Marboo Formation along the Mondooma Thrust Fault (Griffin et al., 1993), which dips steeply to the northeast.

Conclusions

The Canning Coastal seismic data are of generally good quality across much of the basin, and provide a high degree of confidence in interpreting the structure and stratigraphy in the Willara Sub-basin, Broome Platform and the northern part of the Fitzroy Trough. However, in the central part of the line, the data quality deteriorates with depth as a result of both acquisition difficulties and local geological complications. As a result, the ambiguous and subtle reflections allow a diverse range of interpretations.

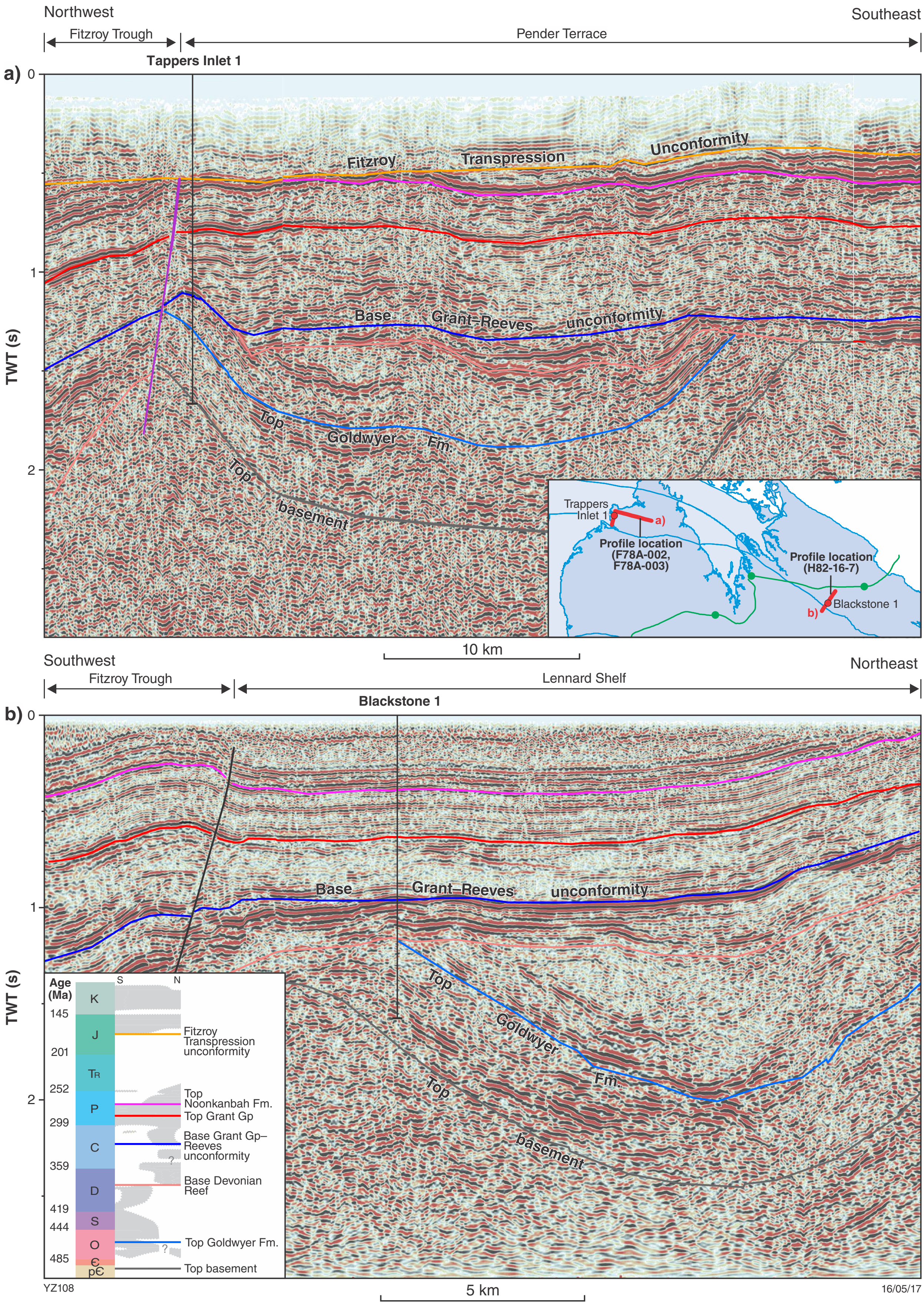


Figure 25. Interpreted seismic profiles showing the local occurrence of Lower Ordovician strata: a) composite profile across Tappers Inlet 1 on the Pender Terrace with location of profiles; b) line H82-16-7 across Blackstone 1 on the Lennard Shelf; see Fig. 2 for detailed stratigraphy

Data from 28 drillholes and a number of nearby seismic profiles adjacent to the Canning Coastal survey were used to constrain the seismic interpretation of Canning Basin stratigraphy. The wells are tied to the seismic profiles using sonic logs and velocity surveys. Based on these interpretations, the Phanerozoic succession in the Canning Basin has been divided into four megasequences, separated by major angular unconformities (Fig. 2):

1. Ordovician to Middle Devonian: this megasequence generally extends throughout the southern Canning Basin but is only locally preserved in the north. The Upper Ordovician – Middle Devonian part of this megasequence has been removed by erosion in the coastal area.

2. Middle Devonian to mid-Carboniferous: this megasequence is only present in the northern Canning Basin, and varies significantly in thickness, reaching its maximum in the Fitzroy Trough and thinning towards the Jurgurra Terrace in the southwest and Lennard Shelf in the northeast.

3. Mid-Carboniferous to Triassic: this megasequence is laterally extensive and unconformably overlies Lower Ordovician to Middle Devonian rocks in the south, and Middle Devonian to mid-Carboniferous rocks in the north. It was truncated by erosion during the Late Triassic to Jurassic Fitzroy Transpression movement.

4. Jurassic to Cretaceous: this megasequence is characterized by a package of flat-lying seismic reflections across the coastal seismic survey. It has a relatively uniform thickness in the south but pinches out northwards in the Fitzroy Trough.

Interpretation of basin architecture from the Canning Coastal seismic profiles suggests that the Wallal Embayment, in the southwestern Canning Basin, is one of the basin outliers, isolated from the major depocentre as a result of tectonics and extensive erosion across the basin's southwestern margin. The Samphire Graben is mostly filled with Permian to Mesozoic sedimentary rocks and lacks an Ordovician to Devonian succession. The Willara Sub-basin and Broome Platform are both interpreted to have been uplifted after the deposition of the Nita Formation, leading to increased erosion of the Mid-Ordovician to Mid-Devonian succession towards the northern margin of the Broome Platform in the coastal area. The Paleozoic succession in the Jurgurra Terrace thickens to the northeast, towards the Fenton Fault, and incorporates two megasequences: the Lower Ordovician to Middle Devonian, and the Middle Devonian to lower Carboniferous, mainly present in the south and north of the Canning Basin, respectively. Interpretation of the depth of the Fitzroy Trough is difficult due to ambiguous seismic reflections and lack of well penetration. There are two alternative interpretations for the depth to Top basement in the trough: the deep option is characterized by a strong acoustic response below a thick interval of no reflection; and the shallow option is correlated using offset seismic profiles and the intersection of metasedimentary rocks in Padilpa 1. Either interpretation implies a considerable amount of reverse movement along the Fenton Fault and a complex history of fault movement. The basement generally shallows from the Fitzroy Trough to the Lennard Shelf, although there is a small-scale Upper Devonian to Carboniferous depression near the northern margin of the basin. The Upper Devonian to Carboniferous succession shallows and outcrops along the northern margin of the basin as the northwesterly trending Devonian reef complex.

References

Alavi, N 2013, Structure, stratigraphy and petroleum prospectivity of the Waukarlycarly Embayment, Canning Basin, Western Australia: Geological Survey of Western Australia, Record 2013/10, 36p.

Bagas, L 2004, Proterozoic evolution and tectonic setting of the northwest Paterson Orogen, Western Australia: Precambrian Research, v. 128, p. 475–496.

Bastian, LV 1963, Bores BMR 4 and 4A Wallal, *in* Stratigraphic Drilling, Canning Basin, Western Australia *edited by* SD Henderson and MA Condon: Bureau of Mineral Resources, Report 60, p. 56–75.

Bischoff, G 1968, Yulleroo 1 Western Australian well completion report; Gewerkschaft Elwerath Inc.: Geological Survey of Western Australia, Statutory petroleum exploration report, W348 A1 (unpublished).

Boog, R 1994, Well completion report Corbett-1 onshore Canning Basin; Stirling Resources N.L.: Geological Survey of Western Australia, Statutory petroleum exploration report, W20212A2.

Buru Energy 2009, Yulleroo 2007 seismic survey interpretation report EP 391R1, EP428 and EP436; Buru Energy: Geological Survey of Western Australia, Statutory petroleum exploration report, S10643A4.

Campbell, W and Coleshill, L 2014, Canning Coastal 2D seismic survey field operations report: Geological Survey of Western Australia: Statutory petroleum exploration report, S10808A1b.

Cawood, PA and Korsch, RJ 2008, Assembling Australia: Proterozoic building of a continent: Precambrian Research, v. 166, no. 1–4, p. 1–38.

Douglas McKenna & Partners 1992, Report on diamond drilling SD1 at Sandfire WA, E45/1169 and EA45/1247 for Pittston Australasian Mineral Exploration Pty Ltd: Geological Survey of Western Australia, Statutory mineral exploration report, A38450.

DownUnder Geosolutions 2015, 2D land seismic data processing, Canning Basin — processing report: Geological Survey of Western Australia: Statutory petroleum exploration report, S10808A2.

Drummond, BJ, Sexton, MJ, Barton, TJ and Shaw, RD 1991, The nature of faulting along the margins of the Fitzroy Trough, Canning Basin, and implications for the tectonic development of the trough: Exploration Geophysics, v. 22, p. 111–116.

Edwards, PB and Streitberg, E 2013, Have we deciphered the Canning?, *in* The sedimentary basins of Western Australia *edited by* M Keep and SJ Moss: Petroleum Exploration Society of Australia; West Australian Basins Symposium, Perth, 18 August 2013, 13p.

Forman, DJ and Wales, DW 1981, Geological evolution of the Canning Basin, Western Australia: Bureau of Mineral Resources, Geology and Geophysics, Bulletin 210, 91p.

Gardner, WE 1963, Hawkstone Peak No.1 well completion report: Geological Survey of Western Australia, Statutory petroleum exploration report, W47A1.

Geological Survey of Western Australia 2013, Magnetic anomaly grid (80 m) of Western Australia (2013 – version 2): Geological Survey of Western Australia, digital data layer.

Geophysical Service International Party 852 1967, Wallal marine seismic survey: Geological Survey of Western Australia, Statutory petroleum exploration report, S408A1.

Geotrack International Pty Ltd 1999, Apatite fission track analysis and vitrinite reflectance in samples from the offshore Canning Basin; Geotrack International Pty Ltd: Geological Survey of Western Australia, Statutory petroleum exploration report, G31324A1.

Griffin, TJ, Tyler, IM and Playford, PE 1993, Explanatory notes on the Lennard River 1:250 000 geological sheet SE/51-8, Western Australia (3rd edition): Geological Survey of Western Australia, Record 1992/5, 85p.

Haines, PW 2004, Depositional facies and regional correlations of the Ordovician Goldwyer and Nita Formations, Canning Basin, Western Australia, with implications for petroleum exploration: Geological Survey of Western Australia, Record 2004/7, 45p.

Haines, PW 2009, The Carribuddy Group and Worral Formation, Canning Basin, Western Australia: stratigraphy, sedimentology, and petroleum potential: Geological Survey of Western Australia, Report 105, 60p.

Haines, PW and Allen, HJ 2016, The Murraba Basin: another piece of the Centralian Superbasin jigsaw puzzle falls into place, *in* GSWA 2016 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2016/2, p. 31–35.

Haines, PW, Wingate, MTD and Kirkland, CL 2013, Detrital zircon U–Pb ages from the Paleozoic of the Canning and Officer Basins, Western Australia: implications for provenance and interbasin connections, *in* The Sedimentary Basins of Western Australia IV *edited by* M Keep and SJ Moss: Petroleum Exploration Society of Australia; West Australian Basins Symposium, Perth, 18 August 2013, 19p.

Haines, PW, Wingate, MTD, Kirkland, CL and Allen, HJ 2015, Detrital zircon geochronology of upper Ediacaran to lower Cambrian deposits (Supersequence 4), western Amadeus Basin: testing revised stratigraphic correlations: Geological Survey of Western Australia, Record 2015/8, 35p.

Hocking, RM 1994a, Basin subdivisions of Western Australia *in* Subdivisions of Western Australian Neoproterozoic and Phanerozoic sedimetary basins: Geological Survey of Western Australia, Record 1994/4, Plate 1.

Hocking, RM 1994b, Subdivisions of Western Australian Neoproterozoic and Phanerozoic sedimentary basins: Geological Survey of Western Australia, Record 1994/4, 85p.

Hocking, RM, Mory, AJ and Williams, IR 1994, An atlas of Neoproterozoic and Phanerozoic basins of Western Australia, *in* The sedimentary basins of Western Australia *edited by* PG Purcell and RR Purcell: Petroleum Exploration Society of Australia, Western Australian Basins Symposium, Perth, p. 21–43.

Howard, HM, Smithies, RH, Kirkland, CL, Kelsey, DE, Aitken, A, Wingate, MTD, Quentin de Gromard, R, Spaggiari, CV and Maier, WD 2015, The burning heart — the Proterozoic geology and geological evolution of the west Musgrave Region, central Australia: Gondwana Research, v. 27, no. 1, p. 64–94.

Hunt, PM 1956, Canning Basin Fraser River No.1 well completion report; West Australian Petroleum Pty Ltd: Geological Survey of Western Australia, Statutory petroleum exploration report, W95A5.

Johnstone, MH 1961, Samphire Marsh No. 1 Well Western Australia: Bureau of Mineral Resources, Geology and Geophysics, 43p.

Kennard, JM, Jackson, MJ, Romine, KK, Shaw, RD and Southgate, PN 1994, Depositional sequences and associated petroleum systems of the Canning Basin, WA, *in* The sedimentary basins of Western Australia *edited by* PG Purcell and RR Purcell: Petroleum Exploration Society of Australia, West Australian Basins Symposium, Perth, p. 657–676.

Maidment, DW, Hand, M and Williams, IS 2005, Tectonic cycles in the Strangways Metamorphic Complex, Arunta Inlier, central Australia: geochronological evidence for exhumation and basin formation between two high-grade metamorphic events: Australian Journal of Earth Sciences, v. 52, no. 2, p. 205–215.

Martin, DM, Hocking, RM, Riganti, A and Tyler, IM 2015, 1:500 000 tectonic units of Western Australia, 2015: Geological Survey of Western Australia, <www.dmp.wa.gov.au/geoview>.

McCracken, SR 1994, Timing of hydrocarbon migration into the Admiral Bay Fault Zone, Canning Basin, *in* The sedimentary basins of Western Australia *edited by* PG Purcell and RR Purcell: Petroleum Exploration Society of Australia; West Australian Basins Symposium, Perth, p. 739–751.

McCracken, SR 1997, Stratigraphic, diagenetic, and structural controls of the Admiral Bay carbonate-hosted Zn–Pb–Ag deposits, Canning Basin, Western Australia: The University of Western Australia, Perth, PhD thesis (unpublished), 340p.

McDougall, I and Harrison, TM 1999, Geochronology and thermochronology by the $^{40}Ar/^{39}Ar$ method (2nd edition): Oxford University Press, UK, 269p.

Mory, AJ 2010, A review of mid-Carboniferous to Triassic stratigraphy, Canning Basin, Western Australia: Geological Survey of Western Australia, Report 107, 130p.

Mory, AJ and Haines, PW 2013, A Paleozoic perspective of Western Australia, *in* The Sedimentary Basins of Western Australia IV *edited by* M Keep and SJ Moss: Petroleum Exploration Society of Australia; West Australian Basins Symposium, Perth, 18 August 2013, 25p.

Newstead, PG 1969, Napier No. 1 well completion report: Geological Survey of Western Australia, Statutory petroleum exploration report, W482A3.

Normore, LS 2017, Provenance, depositional setting, and regional correlations of the Ordovician Carranya Formation, Canning Basin: Geological Survey of Western Australia, Record 2017/3, 22p.

O'Reilly, S 1987, Regional geochemical review of the Canning Basin, Western Australia: Geological Survey of Western Australia, Statutory petroleum exploration report, G3429A1.

Owad-Jones, S, Lehmann, P and Dorsch, C 1988, EP104 Padilpa-1 final well report: Geological Survey of Western Australia, Statutory petroleum exploration report, W3205A2.

Playford, PE, Hocking, RM and Cockbain, AE 2009, Devonian reef complexes of the Canning Basin, Western Australia: Geological Survey of Western Australia, Bulletin 145, 443p.

Playford, PE and Johnstone, MH 1959, Oil exploration in Australia: Bulletin of the American Association of Petroleum Geologists, v. 43, p. 397–433.

Santos, 1986, EP-315 1985 Radi Hills seismic survey final report: Geological Survey of Western Australia, Statutory petroleum exploration report, S2915A3.

Smithies, RH 2004, Geology of the De Grey and Pardoo 1:100 000 sheets: Geological Survey of Western Australia, 1:100 000 Geological Series Explanatory Notes, 23p.

Smithies, RH, Howard, HM, Evins, PM, Kirkland, CL, Bodorkos, S and Wingate, MTD 2009, West Musgrave Complex — new geological insights from recent mapping, geochronology, and geochemical studies: Geological Survey of Western Australia, Record 2008/19, 20p.

Taylor, DD, Middleton, MF and Luck, GR (compilers) 1991, Onshore Canning Basin — base-Grant Group: Geological Survey of Western Australia, 1:1 000 000 seismic subsurface time structure map.

Taylor, FJ 1990, Latitudes and longitudes of shots and stations, water occurrences and drilling conditions: Canning Basin seismic survey, 1988: Bureau of Mineral Resources, Geology and Geophysics, Record 1990/33, 255p.

Towner, RR and Gibson, DL 1983, Geology of the onshore Canning Basin, Western Australia: Bureau of Mineral Resources, Geology and Geophysics, Bulletin 215, 51p.

Tyler, IM, Griffin, TJ, Page, RW and Shaw, RD 1995, Are there terranes within the Lamboo Complex of the Halls Creek Orogen?, *in* Geological Survey of Western Australia Annual Review 1993–94: Geological Survey of Western Australia, p. 37–46.

Tyler, IM, Hocking, RM and Haines, PW 2012, Geological evolution of the Kimberley region of Western Australia: Episodes, v. 35, p. 298–306.

Veevers, JJ and Wells, AT 1961, The geology of the Canning Basin: Bureau of Mineral Resources, Geology and Geophysics, Bulletin 60, 323p.

Williams, IR 1990, Paterson Orogen — Yeneena Basin, *in* Geology and mineral resources of Western Australia: Geological Survey of Western Australia, Memoir 3, p. 277–282.

Williams, IR, Brakel, AT, Chin, RJ and Williams, SJ 1976, The stratigraphy of the eastern Bangemall Basin and the Paterson Province, *in* Annual report for the year 1975: Geological Survey of Western Australia, p. 79–83.

Williams, IR and Trendall, AF 1998, Geology of the Isabella 1:100 000 sheet: Geological Survey of Western Australia, 1:100 000 Geological Series Explanatory Notes, 24p.

Zhan, Y and Mory, AJ 2013, Structural interpretation of the northern Canning Basin, Western Australia, *in* The Sedimentary Basins of Western Australia IV *edited by* M Keep and SJ Moss: Petroleum Exploration Society of Australia; West Australian Basins Symposium, Perth, 18 August 2013, 18p.

Table 1. Summary of formation tops (metre, measured depth) in selected drillholes adjacent to the Canning Coastal seismic survey; vertical lines indicate significant stratigraphic contacts (refer to Fig. 2)

Drillhole	*Base Broome Ss. (Cretaceous)*	*Base Wallal–Barbwire Ss. (Jurassic)*	*Top Erskine–Blina–Liveringa (Late Permian – Early Triassic)*	*Top Noonkanbah Fm. (Permian)*	*Top Poole Ss. (Permian)*	*Top Grant Gp (Lower Permian)*	*Top Reeves Fm. (Upper Carboniferous)*	*Base Grant Gp – Reeves Fm. (Upper Carboniferous – lower Permian)*	*Top Anderson Fm. (Middle Carboniferous)*	*Top Fairfield Gp (Lower Carboniferous)*	*Base Fairfield Gp (Upper Devonian)*	*Base Devonian Reef*	*Top Carribuddy Gp (Lower Silurian)*	*Top Nita Fm. (Upper Ordovician)*	*Top Goldwyer Fm. (Middle Ordovician)*	*Top Willara Fm. (Middle Ordovician)*	*Top Nambeet Fm. (Lower Ordovician)*	*Top basement*	*Total depth (m)*
Chirup 1	139	499	499			630													762.6
Corbett 1		324	324			435													800
BMR 04A Mandora	114	587						677										677	679
Pittston SD 1	42	386																	760
Samphire Marsh 1	170	688				688		1240									1240	2015	2031.2
Anna Plains 1	144.5	653				653		1023						1023	1111				1161
Calamia 1	125	477				477		888						888	938	1272.5	1461.4	1671.4	1700
Woods Hills 1	157	448				448		1081					1081	1334	1419	1831			1978
Parda 1	209	612				612		980					980	1148	1266.5	1493		1777	1908.8
Sharon Ann 1	184.5	586				586		890						890	942	1361	1768		1830
Hilltop 1	156.5	491.5				491.5		954							954	1180	1418	1756	1770
Hedonia 1	116	488.5				488.5	805	916							916	1050	1290	1531	1543
East Crab Creek 1	158	477		477	676	758.5		1252		1252	1457		2663	2741					2813
Cow Bore 1	114.5	517				517	?1060	1106	1106	1297	2401								2940
Barlee 1	44	679							679	?2350									2469.2
Yulleroo 1	66	442.5					442.5	858	858	?1871									4572.3
Fraser River 1		219				219	866	1174	1174	2438									3091.9
Jum Jum 1	254	577	577	1110	1545	1604	?2139	2273											2600
Padilpa 1	128	428	428	688	1041	1080.5	?1556	1791											2184.3
Tappers Inlet 1		641		641	930	971		1532			1532	1963			2016		2202.5	2834.6	2856.3
Millard 1			4	790	1177.6	1235													1680
Meda 1			18	388	678	726	?1185	1281	1281	1505	2019	2640						2640	2685
Wattle 1			0	575	900	953	?1441	1590	1590	1710	2942								3056
Canegrass 1			0	264	555	601		1175	1175	1290	1584	1866						1866	2006.5
Langoora 1			32	311	540	594	?1112	1274	1274	1308	1484	1597						1597	1617
Blackstone 1			5	500	780	846	1402	1486		1486	1812	2220		2220	2311				3050
Hawkstone Peak 1						15		186		186	462	1175						1175	1187.8
Napier 1									4	202	833	1773						1773	1801.4

NOTE: Question mark indicates uncertain depth of the boundary between formations

RECORD 2017/5

This Record is published in digital format (PDF) and is available as a free download from the DMP website at <www.dmp.wa.gov.au/GSWApublications>.

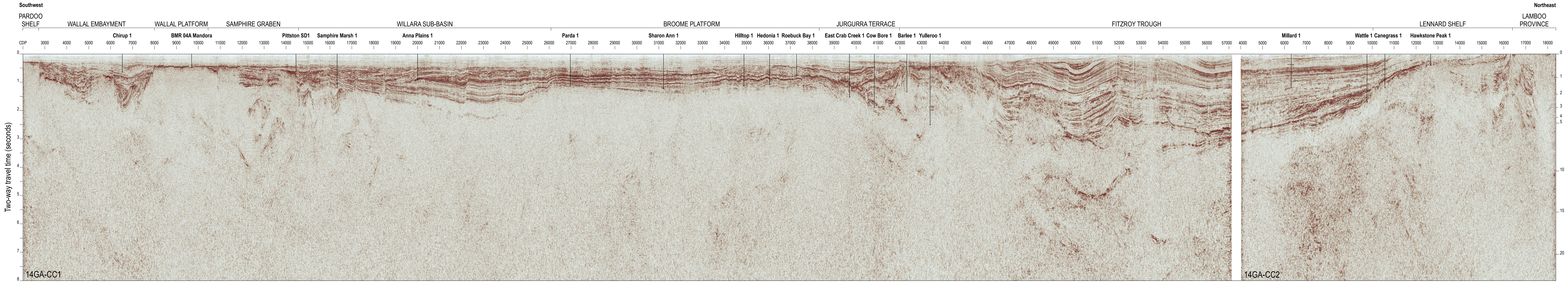
Further details of geological products produced by the Geological Survey of Western Australia can be obtained by contacting:

Information Centre
Department of Mines and Petroleum
100 Plain Street
EAST PERTH WESTERN AUSTRALIA 6004
Phone: +61 8 9222 3459 Fax: +61 8 9222 3444
www.dmp.wa.gov.au/GSWApublications

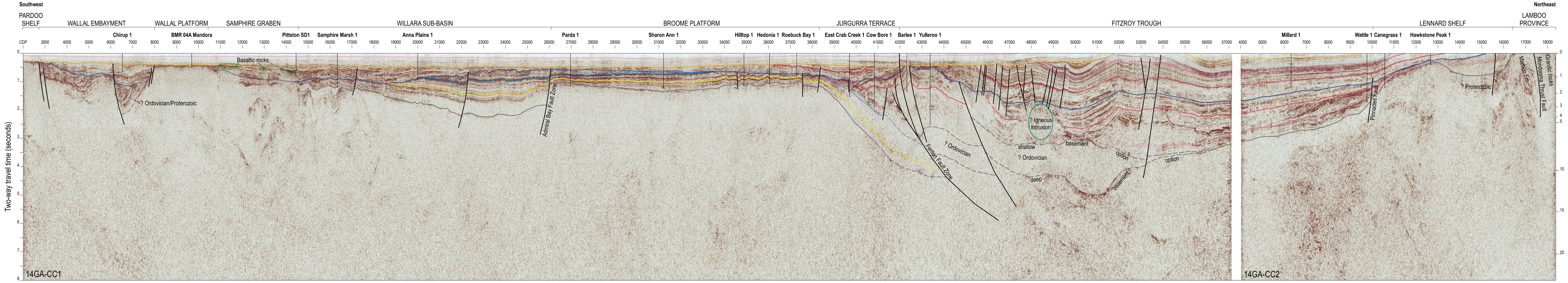
CANNING COASTAL SEISMIC SURVEY — AN OVERVIEW OF THE CANNING BASIN

Zhan

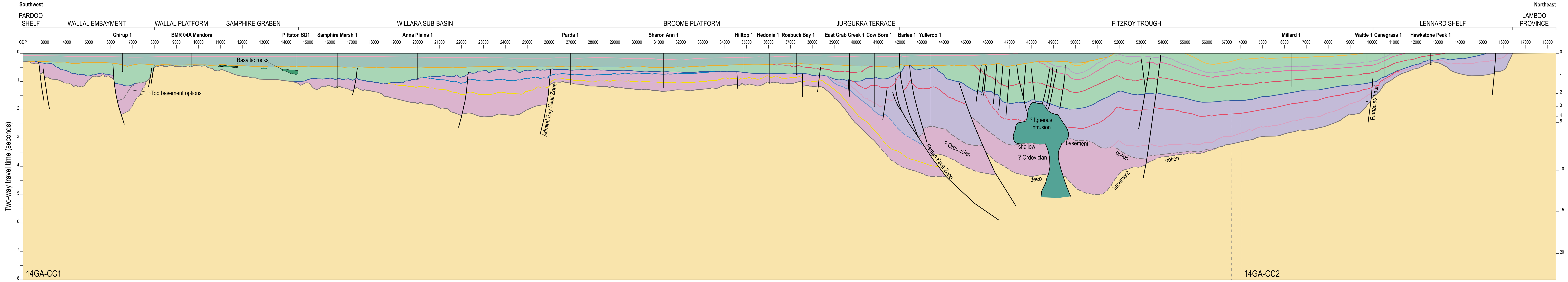
MIGRATED SEISMIC SECTION

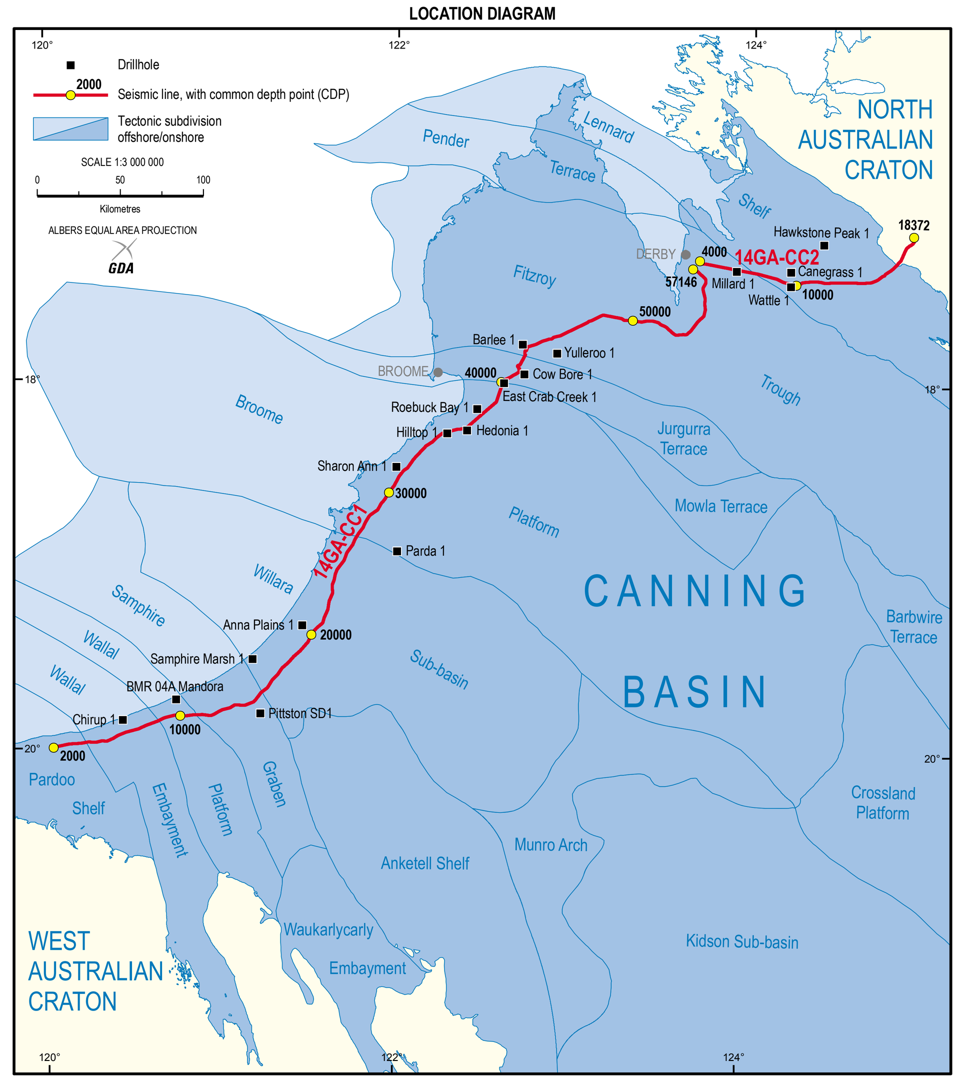


INTERPRETED MIGRATED SEISMIC SECTION

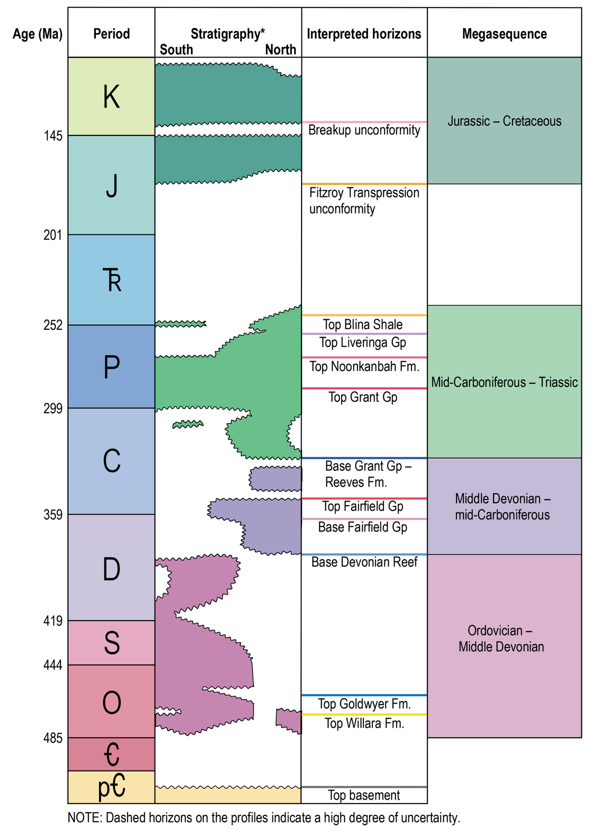


INTERPRETED GEOLOGICAL SECTION





NOTES: Drillholes adjacent to the Canning Coastal seismic lines are structurally projected onto the profile.
Tectonic subdivision boundaries shown on the map do not coincide exactly with structural features labelled on the profiles.



NOTE: Dashed horizons on the profiles indicate a high degree of uncertainty.

Compiled by Y Zhan

Interpretation by Y Zhan

*Stratigraphy modified from:

Haines, PW 2009, Geological Survey of Western Australia, Report 105, 60p.

Haines, PW, Wingate, MTD and Kirkland, CL 2013, *in* The Sedimentary Basins of Western Australia IV: PESA, West Australian Basins Symposium, August 2013, 19p.

Mory, AJ 2010, Geological Survey of Western Australia, Report 107, 130p.

Mory, AJ and Haines, PW 2013, *in* The Sedimentary Basins of Western Australia IV: PESA, West Australian Basins Symposium, August 2013, 25p.

Cartography by PJ Backhouse

Edited by MA Ferland

Published by Geological Survey of Western Australia

This map is published in digital format (PDF) and is available online at <www.dmp.wa.gov.au/GSWApublications>.
Copies are available from:
Information Centre
Department of Mines and Petroleum
100 Plain Street
East Perth, Western Australia 6004
Phone: +61 8 9222 3459 Fax: +61 8 9222 3444
Website: www.dmp.wa.gov.au/gswa Email: geological.survey@dmp.wa.gov.au

The recommended reference for this map is
Zhan, Y 2017 Canning Coastal seismic survey — an overview of the Canning Basin: Geological Survey of Western Australia, Record 2017/5, Plate 1.

EXPLORATION INCENTIVE SCHEME

Australian Government
Geoscience Australia

Government of Western Australia
Department of Mines and Petroleum

Geological Survey of Western Australia

HON BILL JOHNSTON MLA
MINISTER FOR MINES AND PETROLEUM

RICK ROGERSON
EXECUTIVE DIRECTOR

SCALE 1:750 000

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

RECORD 2017/5 PLATE 1

GEOLOGICAL INTERPRETATION OF THE CANNING BASIN ALONG CANNING COASTAL SEISMIC LINES 14GA-CC1 AND 14GA-CC2

June 2017