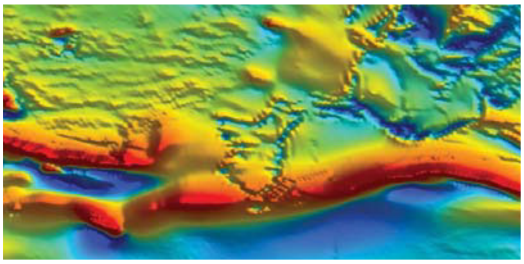
Government of **Western Australia**
Department of **Mines and Petroleum**

RECORD 2010/25

GEOTHERMAL ENERGY POTENTIAL IN SELECTED AREAS OF WESTERN AUSTRALIA (CARNARVON BASIN)

by
Hot Dry Rocks Pty Ltd



Geological Survey of Western Australia

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Hot Dry Rocks Pty Ltd[1]

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Perth 2010

Geological Survey of Western Australia

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Geothermal Energy Potential in Selected Areas of Western Australia (Carnarvon Basin)

A report prepared for the Department of Mines and Petroleum, Western Australia

Report DMP0260909

July 2010

Executive summary

Hot Dry Rocks Pty Ltd (HDR) was commissioned by the Department of Mines and Petroleum (DMP), Western Australia, to appraise the geothermal potential of four basins in Western Australia (the Browse, Bonaparte, Carnarvon and Officer basins) as part of Project DMP0260909.

A total of 74 wells were assessed; comprising 45 wells in the Carnarvon Basin, 17 wells in the Officer Basin, 10 wells in the Bonaparte Basin and two wells in the Browse Basin.

This report focuses on the Carnarvon Basin. 45 wells were assessed in detail for heat flow modelling and temperature prediction at depths to 5,000 m. Of these 45 wells, only 21 had sufficient data to enable the modelling of heat flow.

The principle findings of this report are:-

- Measured rock thermal conductivities for 61 core samples collected from the Carnarvon Basin range from 0.64–4.97 W/mK. HDR was able to incorporate a further 56 thermal conductivity values from a previous published study of the Southern Carnarvon Basin. These data were crucial for the development of 1D heat flow models to predict the depth to selected isotherms.
- Apparent surface heat flow in the Carnarvon Basin ranges from 42–95 mW/m^2 with a median value of 54 mW/m^2. This value is lower than the Australian median value of 64.5 mW/m^2 from the global heat flow database and considerably lower than the Perth and Canning basins median values of 76.5 mW/m^2 and 68 mW/m^2, respectively, recorded in previous HDR reports.
- The relatively low median heat flow value is based on just 21 data points. Furthermore, these data have limited geographical distribution, with the majority clustered on the islands off the Northern Carnarvon Basin (Saladin and Crest petroleum fields). A previous geothermal study by Chopra & Holgate (2007) reported useful temperature data from a further 93 Carnarvon Basin wells. HDR recommends expert 1D heat flow modelling of these wells and incorporating the data with the results from the current HDR study to construct a robust heat flow model of the Carnarvon Basin.

- Apparent heat flows are lowest in the Barrow and Exmouth sub-basins with values generally <60 mW/m^2. There is an increase in apparent heat flow onshore in the Peedamullah Shelf to 95 mW/m^2. However, this is based on just one well—Windoo 1A. It is quite likely the elevated apparent heat flow extending over much of the Northern Carnarvon Basin west and northwest of Pannawonica is an artefact of the gridding process.
- The Southern Carnarvon Basin shows average to moderate apparent heat flow ranging from 55 mW/m^2–70 mW/m^2.
- Based on limited well penetrations used in this study, the onshore and coastal portions of the Peedamullah Shelf and Exmouth Sub-basin have the 150°C isotherm modelled at 3,000–4,000 m, whilst northern portions of the Gascoyne Platform has the isotherm modelled at 4,000–5,000 m. In some of these areas the 150°C isotherm is coincident with Devonian–Triassic sedimentary units. Where a suitable lithology is present in this area which preserves natural permeability, it may be possible that Hot Sedimentary Aquifer (HSA) geothermal systems can be developed. Other areas may be prospective for Engineered Geothermal Systems (EGS), depending on the suitability of target lithologies for fracture stimulation.
- Borehole breakout stress indicators from petroleum wells located within the offshore North West Shelf suggest that the maximum horizontal stress direction (S_H) is approximately east-west (~101°) whilst the stress regime is inferred as either strike-slip or normal faulting regime. With respect to hydraulic stimulation and development of an EGS reservoir these two stress regimes will result in an approximately east-west trending, steeply dipping to vertical reservoir growth direction.
- HDR recommends DMP consider a field program to obtain stress field estimates via hydraulic fracturing or borehole imaging of existing onshore wells.
- HDR recommends that the heat generation potential of basement rocks be further investigated by the DMP.

Authors

Jim Driscoll compiled this report, aided by Luke Mortimer and Ben Waining. Graeme Beardsmore reviewed the report and approved its release in its final form.

Disclaimer

The information and opinions in this report have been generated to the best ability of the author, and Hot Dry Rocks Pty Ltd (HDR) hope they may be of assistance to you. However, neither the author nor any other employee of HDR guarantees that the report is without flaw or is wholly appropriate for your particular purposes, and therefore we disclaim all liability for any error, loss or other consequence that may arise from you relying on any information in this publication. Base data utilised in this report were provided by the Department of Mines and Petroleum and HDR is not responsible for the quality or accuracy of these data.

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1. Introduction

The Department of Mines and Petroleum (DMP) provided Hot Dry Rocks Pty Ltd (HDR) with basic data for 74 wells in the Bonaparte, Browse, Carnarvon and Officer basins (Figure 1). Data included scanned log headers, bottom hole temperatures (BHTs), geological and geophysical reports, and other relevant data. HDR utilised these data and collected rock samples to provide new rock thermal conductivity data to use in the determination of apparent* heat flow across the four basins as part of the overall assessment.

HDR was commissioned to utilise the supplied data to address the Scope of Services (Schedule 2; Section 1.2 of the *Request For Quote DMP0260909*) for the following topics:-

- determine depth of basement at the well locations
- verify geothermal data and extrapolate temperature to the basement
- generate isotherm maps at 100°C, 150°C and 200°C
- identify basement lithology from existing geophysical data
- relate basement lithology at depth from the existing data
- calculate the heat generating capacity of the basement rock

HDR was also requested to compile and comment on the adequacy of data on the current *in situ* stress field in areas of potential Engineered Geothermal System (EGS) interest.

This report focuses on the Carnarvon Basin. An initial 45 wells were highlighted by DMP for this study (Attachment A). Of these 45 wells, 21 had sufficient data to enable the modelling of heat flow.

* HDR uses the term "apparent heat flow" to refer to the results of heat flow modelling where the basic temperature and/or thermal conductivity data are considered poorly constrained.

Figure 1: Location of the Bonaparte, Browse, Carnarvon and Officer basins, Western Australia (individual basin polygons modified from Geoscience Australia databases).

2. Carnarvon Basin Geological Setting

The arcuate Carnarvon Basin (Figure 2) is one of a string of sedimentary basins located off northwestern Australia's margin, collectively referred to as the Westralian Superbasin or North West Shelf. The onshore basin—the main focus of this geothermal assessment—covers a total area of approximately 115,000 km^2. The basin has historically been separated into the Northern and Southern Carnarvon Basins as a result of their differing geological evolution.

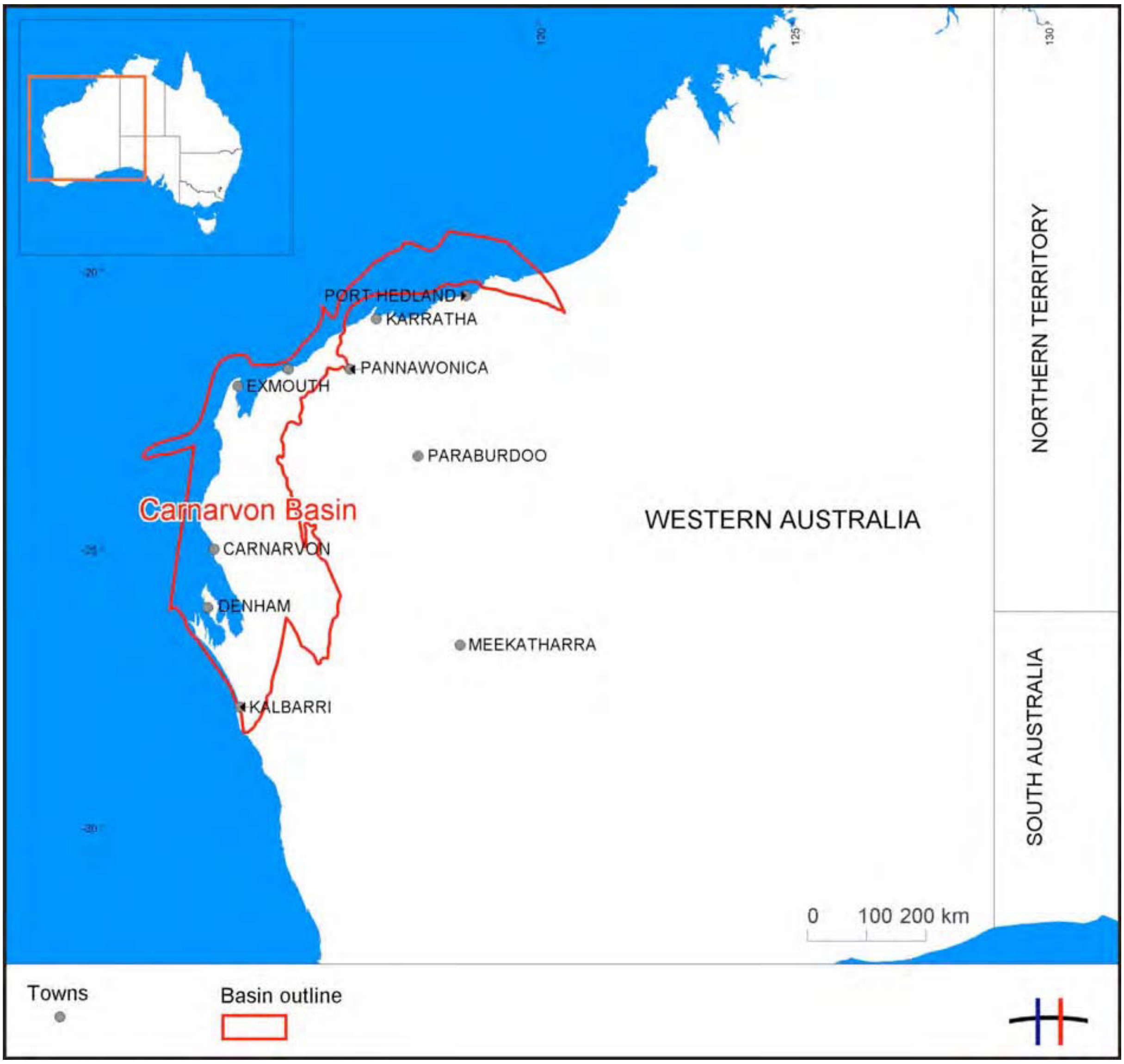

Figure 2: Location of the Carnarvon Basin (the basin polygon is taken from Geoscience Australia databases).

2.1. Tectonic Framework

The Northern Carnarvon Basin comprises a series of southwest-trending troughs, the Exmouth, Barrow, Dampier and Beagle Sub-basins (Figure 3), that contains up to 15,000 m of sedimentary fill. These troughs are flanked in the nearshore and onshore areas by the Peedamullah Shelf and Lambert Shelf that contain in excess of 6,000 m of sedimentary fill.

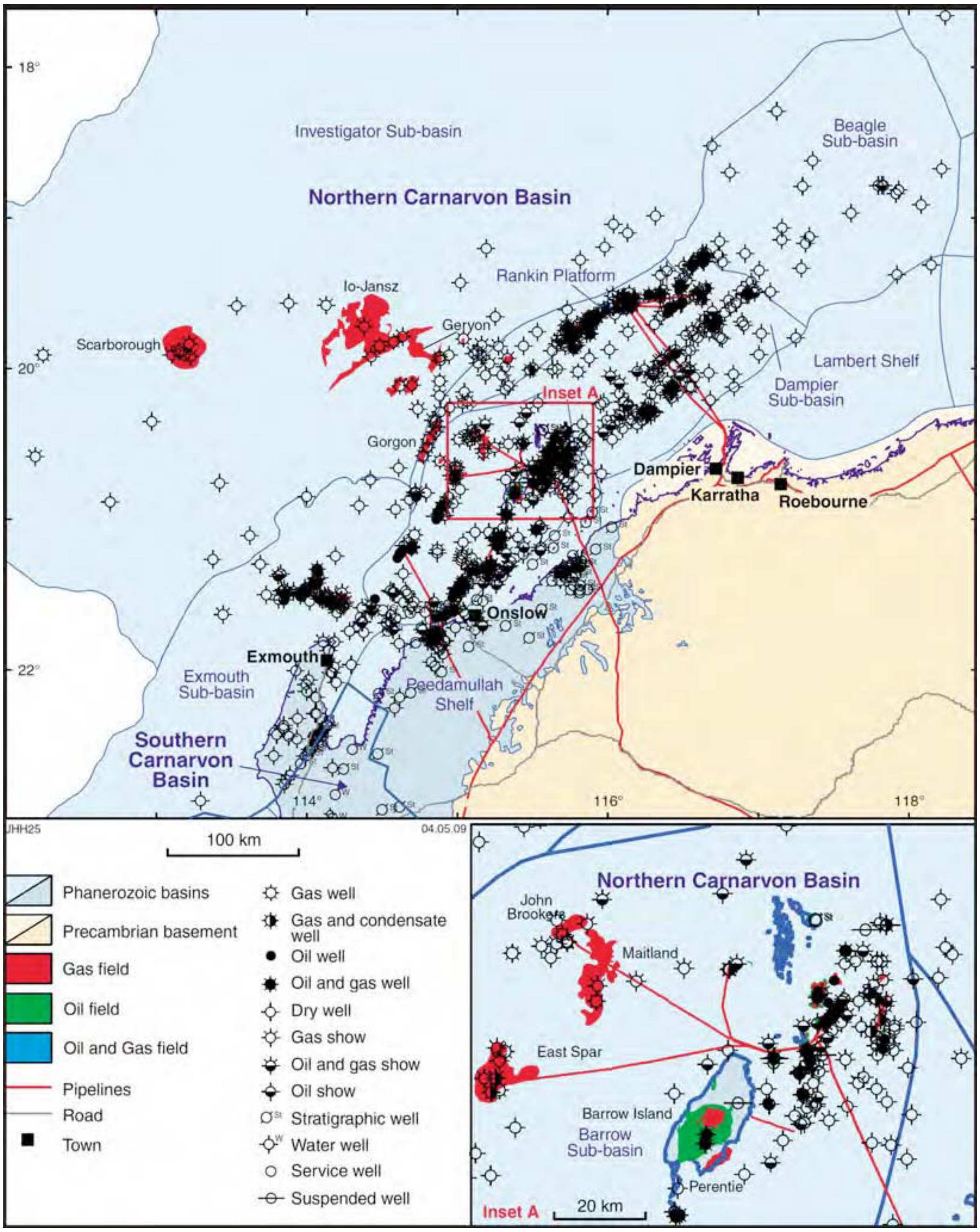

Figure 3: The Northern Carnarvon Basin showing tectonic elements, pipelines, fields and petroleum wells (from GSWA, 2009)

The Southern Carnarvon Basin comprises two principal tectonic elements; the Gascoyne Platform to the west and the Merlinleigh and Byro sub-basins to the east (Figure 4). These contain in excess of 6,000 m of sedimentary fill.

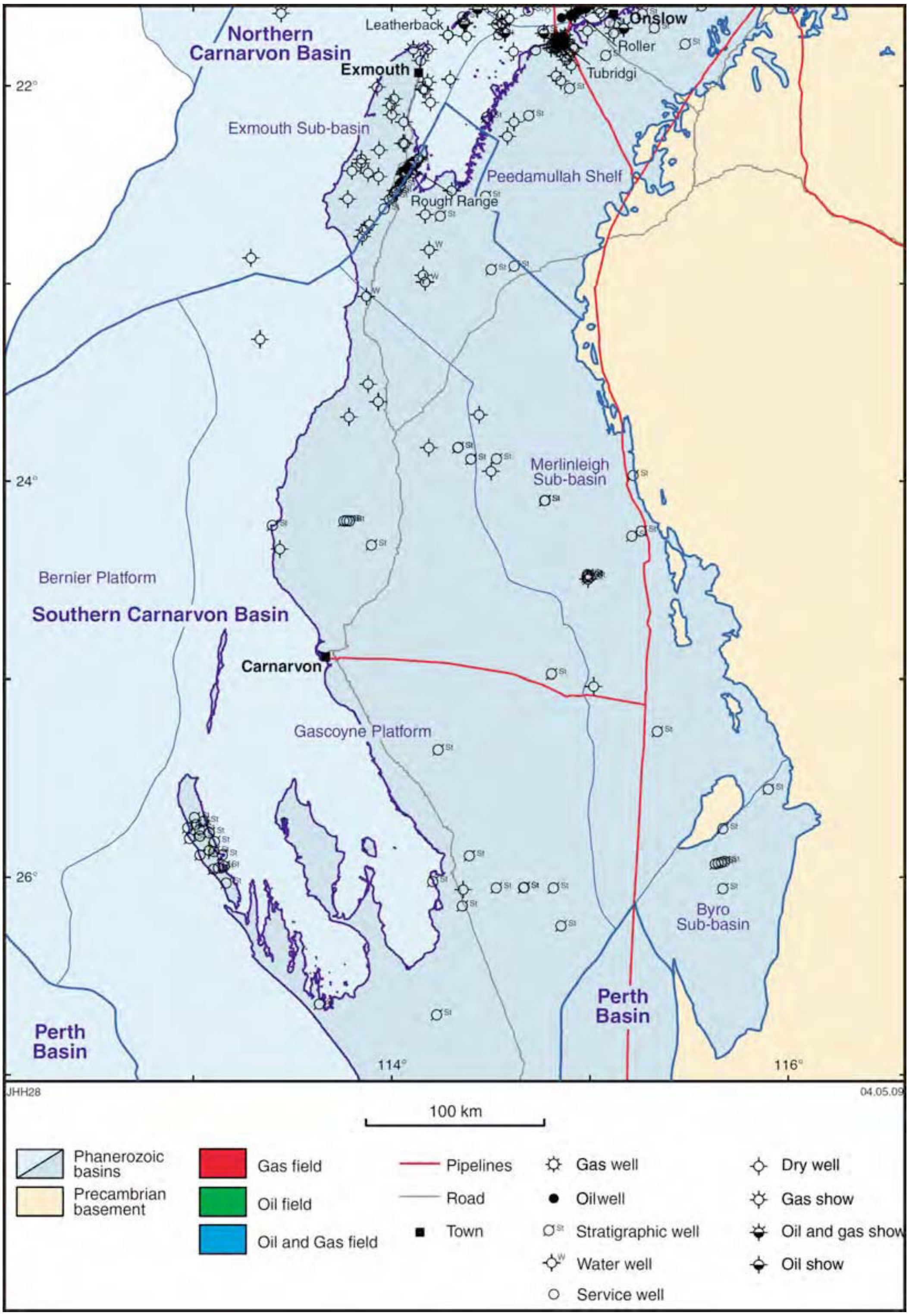

Figure 4: The Southern Carnarvon Basin showing tectonic elements, pipelines, fields and petroleum wells (from GSWA, 2009)

2.2. Stratigraphic Architecture

The stratigraphy of the Carnarvon Basin is shown in Figures 5-7. The Northern Carnarvon Basin comprises a thick Mesozoic through Cainozoic section that overlies an older, deeply buried Palaeozoic sequence.

The Southern Carnarvon Basin is dominated by Palaeozoic sequences. The Gascoyne Platform is characterised by a gently folded Ordovician–Devonian section unconformably overlain by a thin veneer of Mesozoic–Cainozoic strata. The Merlinleigh and Byro sub-basins comprise a basal Devonian–Lower Carboniferous sequence overlain by a thick Upper Carboniferous–Permian package that in the south is unconformably overlain by a veneer of Cretaceous–Cainozoic sediments and to the north by Triassic strata.

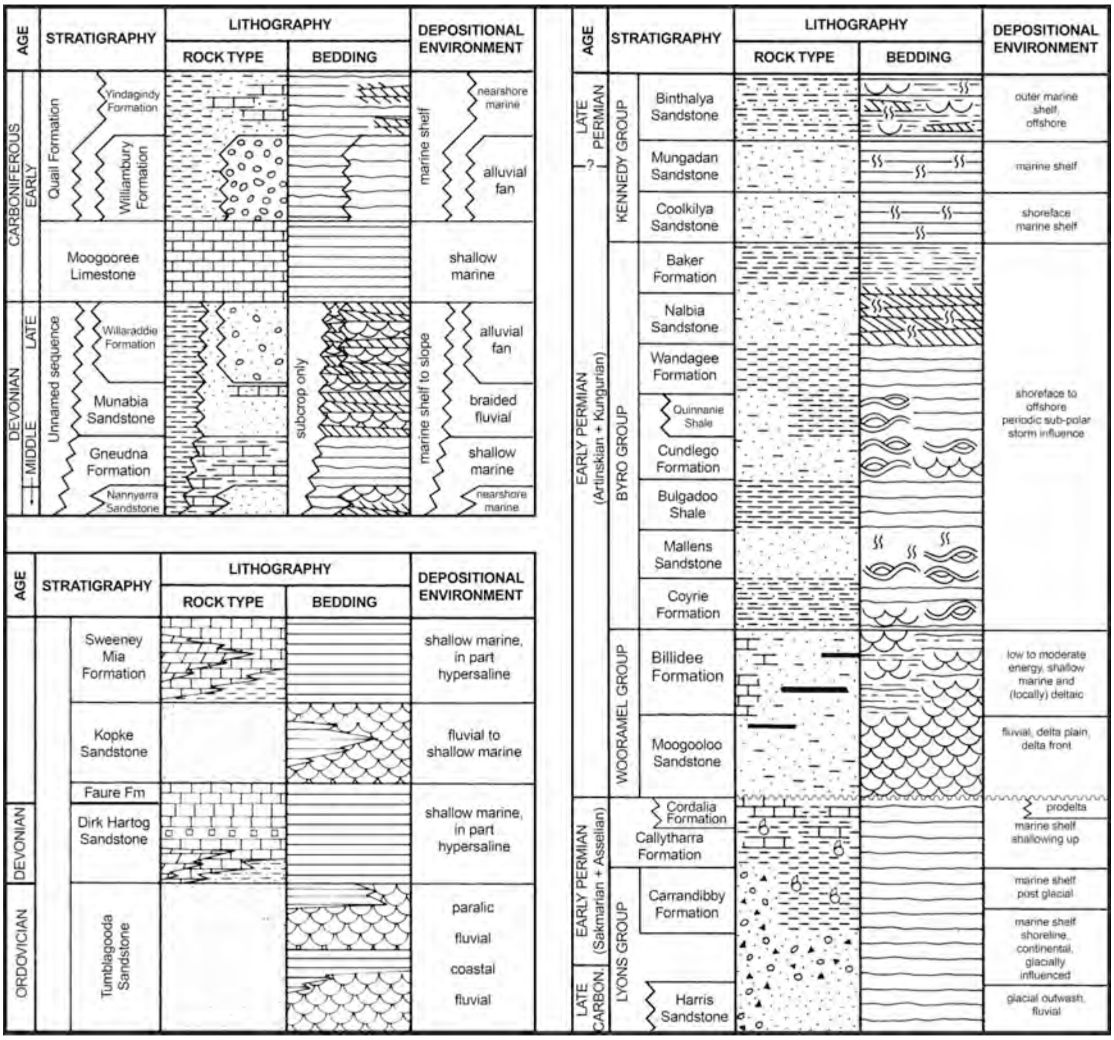

Figure 5: Stratigraphy of the Carnarvon Basin; Ordovician-Late Permian (from Hocking, 2000).

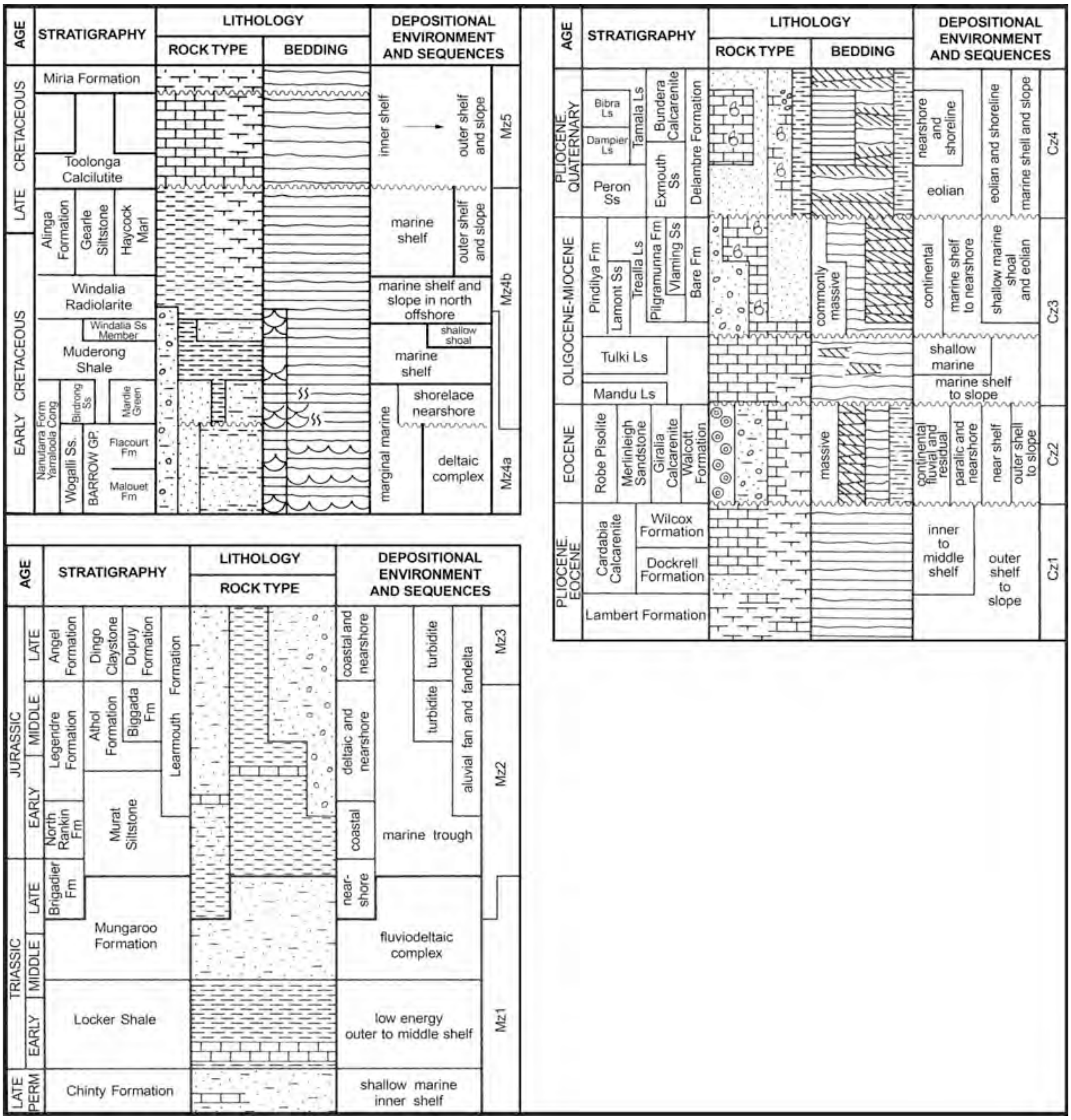

Figure 6: Stratigraphy of the Carnarvon Basin; Late Permian-Quaternary (from Hocking, 2000).

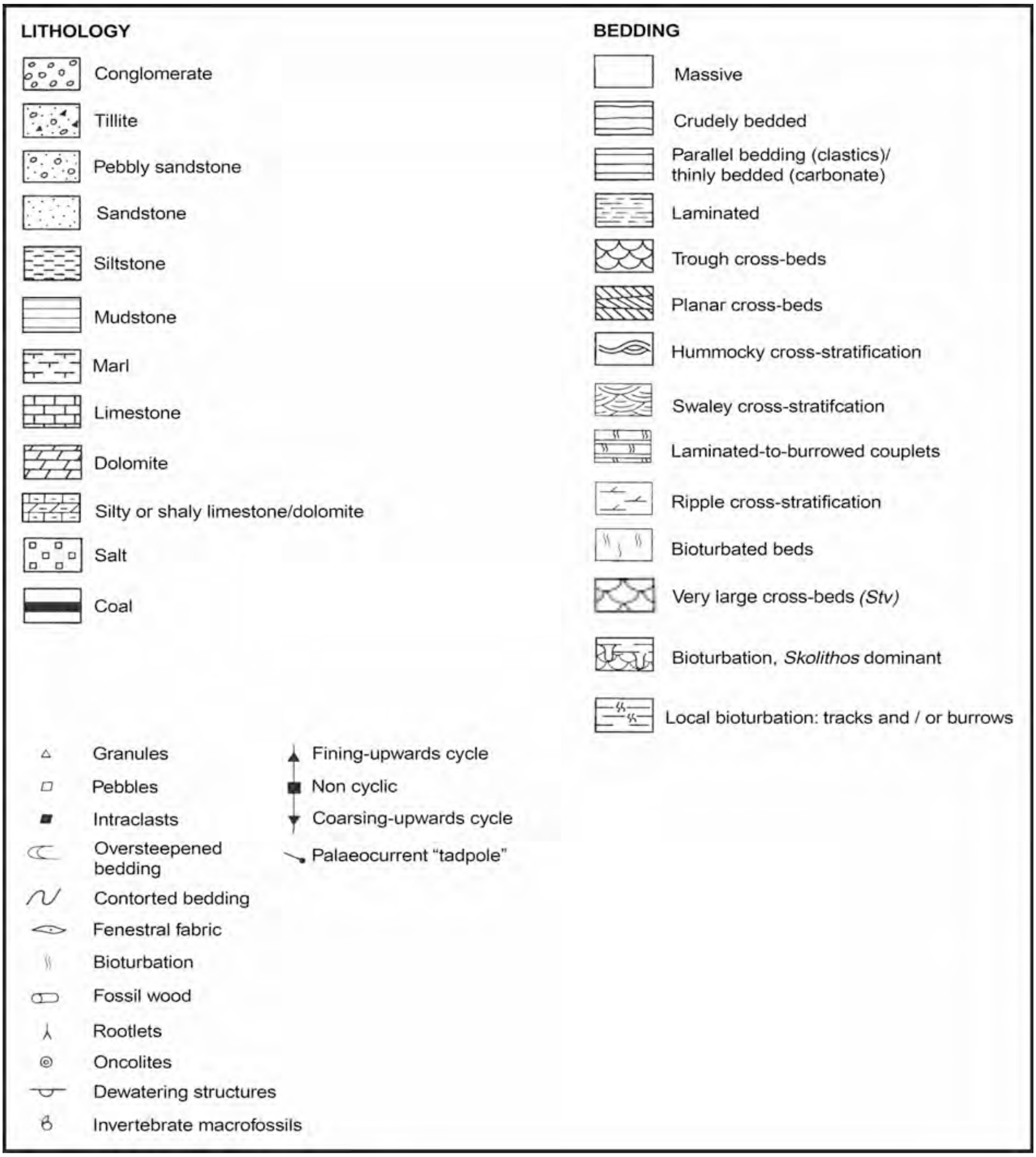

Figure 7: Stratigraphy of the Carnarvon Basin; Legend (from Hocking, 2000).

More detailed discussions of the structural evolution and stratigraphic succession can be found in Crostella (1995), Crostella & Iasky (1997), Crostella *et al*. (2000), Felton *et al*. (1992), Hocking (2000), Iasky *et al*. (1998), Iasky & Mory (1999), Lockwood & D'Ercole (2003), Mory & Backhouse (1997) and Mory *et al*. (2003).

3. Basement Investigations

This section provides information for the following topics:-

For the 45 wells to be assessed:-

- determine depth of basement at the well locations
- identify basement lithology from existing geophysical data

3.1. Basement depth

All recorded actual basement intercepts in the Carnarvon Basin (Attachment B) were assessed in conjunction with the OZ SEEBASEv2 database—shown on Figure 8—(FrOG Tech, 2007) to predict depth-to-basement[†] for the 45 wells modelled in this report. The actual basement intercepts recorded in wells were given greater weighting over the OZ SEEBASEv2 dataset. Results are presented in Attachment C.

3.2. Basement lithology

Predictions of basement lithology (Attachment C) are shown on Figure 9. Most were derived from basement lithologies intersected in nearby wells, with the assumption that a similar lithology may be intersected within a 10 km radius (being the approximate size of a small pluton). Others were derived from the continuation of geophysical signatures (gravity and magnetics) from areas of known basement composition. The exact nature of the basement of the Carnarvon Basin remains poorly constrained due to the small number of actual basement intercepts.

[†] Rounded to the nearest 250 m.

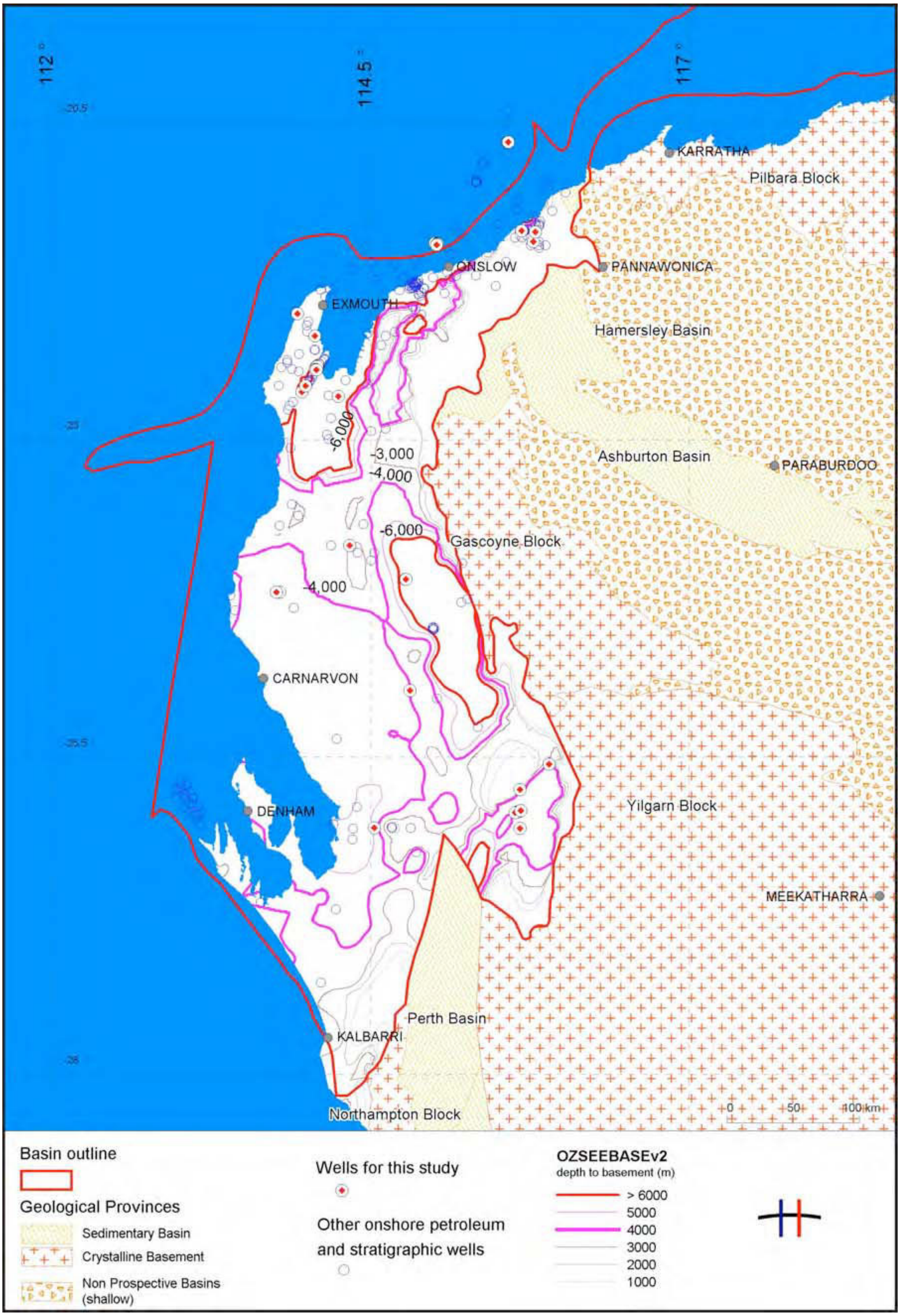

Figure 8: Depth to Basement contours for the Carnarvon Basin. Data are from OZ SEEBASEv2 (FrOG Tech, 2007). Basin thickness is estimated to exceed 6,000 m in parts of the Southern Carnarvon Basin; and 15,000 m in the coastal to offshore parts of the Northern Carnarvon Basin.

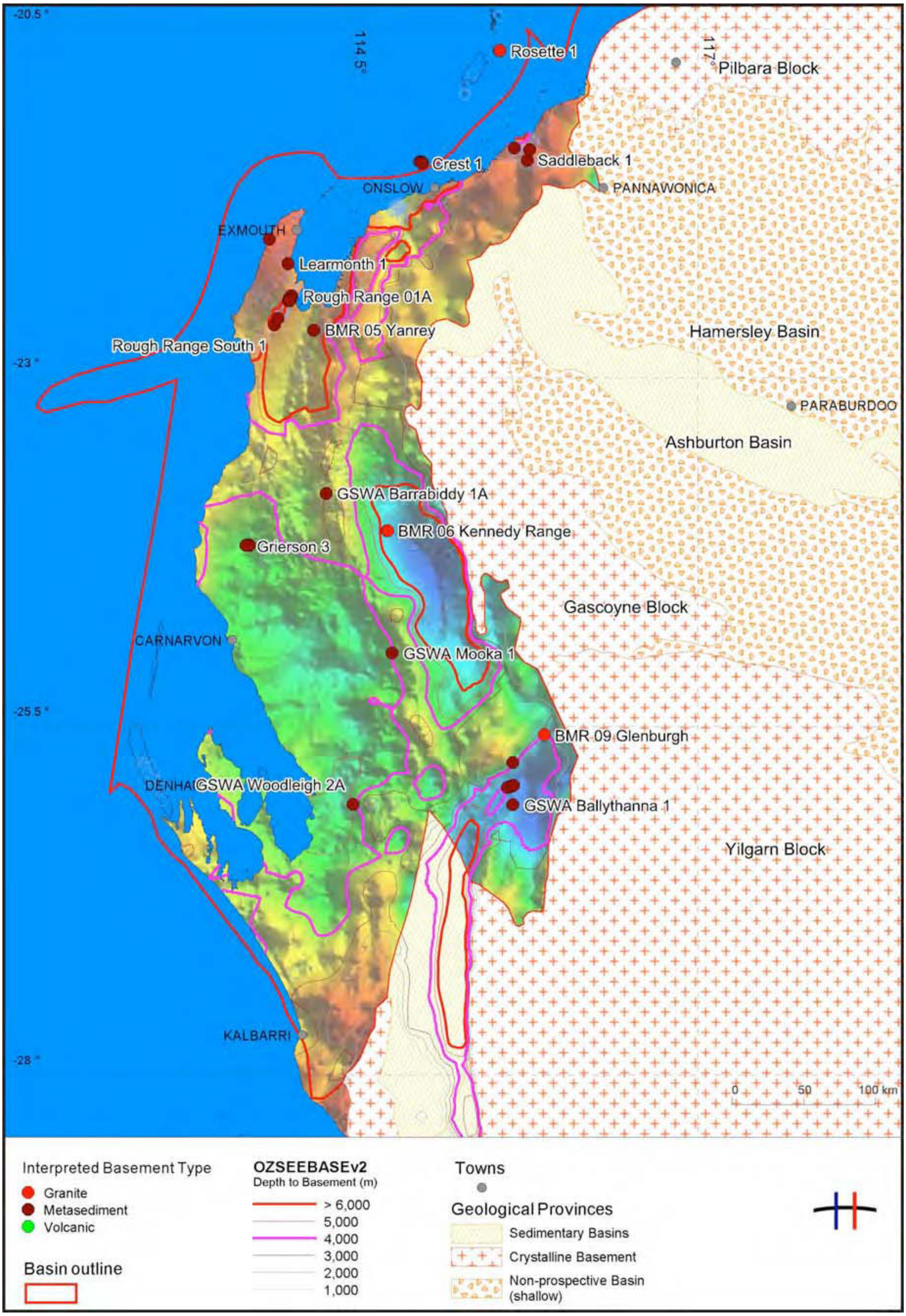

Figure 9: Predicted basement lithology in the Carnarvon Basin beneath petroleum wells listed in Attachment A. A gravity image of the basin provides the backdrop.

4. Heat flow modelling methodology

4.1. Introduction

1D conductive heat flow modelling allows for accurate extrapolation of temperature to depth as it honours the thermodynamic principles of heat transfer. The depth to which temperature can be extrapolated depends on the depth to which the assumption of purely vertical conductive heat transfer holds true. The assumption fails if a) there is a component of advective heat transfer via fluid flow, b) there is appreciable lateral conduction of heat, or c) temperatures exceed about 300°C, at which point radiation starts to play a role in heat transfer. This report assumes purely vertical conductive heat transfer with internal heat generation over the modelled depth intervals.

HDR was commissioned to investigate the thermal conditions of wells in the Carnarvon Basin based on existing temperature data. HDR used its proprietary 1D heat flow modelling software to build heat flow models for each well for which adequate data were available. Required data include downhole temperatures (corrected to approximate equilibrated conditions where sufficient information is available) and thermal conductivity data of intersected formations. Raw temperature and lithological data were provided by the DMP.

4.2. Heat flow and limitations of 1D modelling

Surface heat flow is a measure of the flux of thermal power at surface and is a function of the rate of heat generated within the crust plus heat conducted from the mantle.

The principle aim of geothermal exploration is to locate anomalously high temperatures at an economically and technically viable drilling depth. The thermal state of the crust can be expressed at the surface in the form of heat flow units (mW/m^2) and it is generally assumed that heat is transported to the surface by conductive means. In a conductive heat regime the temperature, **T**, at depth, **z**, is equal to the surface temperature, $\mathbf{T_0}$, plus the product of heat flow, **Q**, and thermal resistance, **R**, such that:

$\mathbf{T=T_0+QR}$, where **R**=**z**/(average thermal conductivity between the surface and **z**).

Consequently, the most prospective regions for geothermal exploration are those that have geological units of sufficiently low conductivity (high thermal resistance) in the cover sequence combined with high heat flow.

Heat flow is the product of temperature gradient and rock thermal conductivity. It is therefore calculated, or modelled, from these two parameters, not directly measured. Reliable modelling of heat flow is a precision skill that requires experience and a detailed understanding of physical conditions in the borehole and the physical properties of the rocks; including advective processes that may influence bore temperature (such as ground water flow or borehole convection), and the temperature dependence of conductivity.

Heat flow estimates are only as accurate as the data that have been used to generate them. It is therefore important that the temperature and conductivity data used to model heat flow represent as closely as possible the actual thermal conditions.

HDR's 1D conductive heat flow modelling software accounts for heat generation and the temperature dependence of conductivity. However, the results of 1D heat flow modelling should be treated with caution when extrapolating data spatially over considerable distance as thermal properties almost certainly change with facies variation laterally.

4.3. Verification of well temperatures

Temperature interpolations and extrapolations based solely on reported well temperatures measured during the drilling process are liable to underestimate the true virgin rock temperature of the formations at depth. To ensure the most accurate thermal modelling, corrections (such as Horner Plots) are applied to time series data recorded during logging processes.

The Horner Plot method corrects the bore hole temperature for the cooling effect of the drilling process using the parameters of recorded bore hole temperature, the time elapsed since the last fluid circulation, and the time between the end of drilling and the cessation of fluid circulation. The accuracy of the correction depends on the reliability and accuracy of the reported temperatures and times. More than one recorded temperature from the same depth, but at different times, is required for a Horner Plot.

Temperatures reported in the well completion reports of the 45 wells in the Carnarvon Basin were assessed and, where sufficient information was found, Horner corrections were applied using the methodology of Hermanrud *et al*. (1990). The corrected temperatures were used in the thermal models for these wells. Temperatures recorded during drill stem tests (DSTs) were also accepted as accurate representations of virgin rock temperature, and used in the thermal models. For other temperature data it was not possible to apply corrections. Uncertainty values were ascribed to each temperature datum, as detailed in Section 5.2.

Temperature data used for each well model, and the status of those data (corrected or uncorrected), are itemised with the individual heat flow models in Appendix 1.

4.4. Surface temperatures

Ground surface temperature is an important constraint for heat flow models defined by limited downhole temperature data. Average surface temperature for each well was estimated from mean annual air temperature data reported by the Australian Bureau of Meteorology for the Carnarvon Basin (Carnarvon Airport, Gascoyne Junction, Hamelin Pool, Learmonth, Nyang Station and Onslow weather stations).

Beardsmore (2005) undertook precision temperature logging in the Gascoyne Region of the Southern Carnarvon Basin and observed that the ground surface temperature is approximately 6°C warmer than the average air temperature, suggesting a relatively high insolation (absorption of solar radiation) or relatively low surface albedo. Ground surface temperature was therefore assumed to be 6°C hotter than mean annual air temperatures and uncertainty was assumed to be ± 1.5°C. Estimated ground surface temperatures for each well are shown within the individual heat flow models (Appendix 1).

4.5. Temperature data issues

HDR checked the well temperature compilation provided by the DMP against primary data in well completion reports and well log headers, and identified several issues with the compilation. Whilst bottom hole temperatures (BHT) were commonly recorded, there were instances where this was not the case. In addition, other sources of temperature data such as drill stem tests (DST) and formation tests were not always recorded. Furthermore, many of the wells utilised in this report were either highly deviated or horizontal production wells. The depths recorded in the DMP database were almost always recorded as 'measured depth' rather than 'true vertical depth'. HDR found it necessary to check each well and compile an internal temperature database to ensure all temperature data had been accurately extracted and recorded.

HDR recommends DMP undertake a quality control exercise of its well temperature database to ensure all relevant temperature data are captured, and to mitigate any erroneous inputs.

4.6. Rock thermal conductivity measurement

Thermal conductivity is the physical property that controls the rate at which heat energy flows through a material in a given thermal gradient. In the S.I. system of units, it is measured in watts per metre-Kelvin (W/mK). In the earth, thermal conductivity controls the rate at which temperature increases with depth for a given heat flow. The thermal conductivity distribution within a section of crust must be known in order to calculate crustal heat flow from temperature gradient data, or to predict temperature distribution from a given heat flow.

HDR undertook steady-state thermal conductivity measurements of 61 representative samples from lithologies of the Carnarvon Basin using HDR's portable electronic divided bar apparatus. Samples came from core stored at the DMP core library in Perth. The full conductivity report is provided in Appendix 2 and a summary of measurements is provided in Attachment D.

HDR was also able to draw on a further 56 thermal conductivity data collected and reported in a previous geothermal study of the Southern Carnarvon Basin by Beardsmore (2005). These data are provided in Attachment E.

The 117 measurements of thermal conductivity included a number of measurements on ‘pure’ lithological samples such as ‘shale’, ‘sandstone’, etc. Where formation descriptions in well logs indicated mixed lithologies, a conductivity value for these formations was estimated from the weighted harmonic mean of the conductivities of the ‘pure’ lithological components. This process is described in Beardsmore & Cull (2001) and a summary of the calculation inputs is provided in Attachment F.

Thermal conductivity values for each Carnarvon Basin formation, as derived using the methods described above and used in the 1D heat flow models, are shown in Table 1.

Table 1: Thermal conductivities (at 30°C for this report and 35°C for Beardsmore, 2005) by formation for the Carnarvon Basin, as used for 1D heat flow modelling in this report (see Appendix 2 and Beardsmore, 2005, for more details).

Formation	Conductivity (W/mK)	Uncertainty ±(W/mK)
Alluvium	1.42	0.14
Exmouth Sandstone	1.42	0.14
undifferentiated Tertiary carbonates	1.68	0.34
Trealla Limestone	1.68	0.34
Mandu Calcarenite	1.68	0.34
Cape Range Group	1.68	0.34
Giralia Calcarenite	1.68	0.34
Wilcox Formation	1.23	0.05
Cardabia Group	1.68	0.34
Lambert Formation	1.23	0.05
Miria Formation	1.68	0.34
Korojon Calcarenite	1.68	0.34
Toolonga Calcilutite	1.45	0.06
Gearle Siltstone - Winning Group	1.23	0.05
Alinga Fm - Winning Group	1.00	0.20
Windalia Radiolarite - Winning Group	1.45	0.10
Windalia Sandstone Member - Muderong Shale - Winning Group	2.26	0.09
Muderong Shale - Winning Group	1.69	0.13
Mardie Greensand Member - Winning Group	1.79	0.36

Birdrong Sandstone - Winning Group	2.83	0.14
Wogatti Sandstone	2.83	0.57
Yarraloola Conglomerate	2.10	0.42
Flag Sandstone - Barrow Group	2.83	0.57
Flacourt Formation - Barrow Group	2.83	0.57
Dupuy Formation	2.29	0.46
Dingo Claystone	1.15	0.18
Learmonth Formation	3.42	0.33
Woodleigh Formation	1.63	0.33
Brigadier Formation	1.56	0.22
Mungaroo Formation	2.39	0.12
Locker Shale	1.27	0.11
Coolkilya Sandstone - Kennedy Group	2.86	0.11
Byro Group (undifferentiated)	2.12	0.42
Baker Formation - Byro Group	3.51	0.05
Nalbia Sandstone - Byro Group	2.99	0.07
Wandagee Formation - Byro Group	1.77	0.14
Cundlego Formation - Byro Group	2.53	0.16
Bulgadoo Shale - Byro Group	1.27	0.13
Mallens Sandstone - Byro Group	2.69	0.14
Coyrie Formation - Byro Group	2.62	0.08
Madeline Formation - Byro Group	1.53	0.05
Billidee Formation - Wooramel Group	2.60	0.30
Keogh Formation - Wooramel Group	2.93	0.27
Moogooloo Sandstone - Wooramel Group	4.76	0.13
Cordalia Formation - Wooramel Group	1.98	0.18
Ballythanna Sandstone Member - Callytharra Formation	3.36	0.18
Callytharra Formation	1.87	0.11
Lyons Group	2.59	0.15
undifferentiated Callytharra Formation/Lyons Group	2.17	0.43
Quail Formation	3.28	0.66
Yindagindy Formation	3.80	0.76
Munabia Formation	2.55	0.15
undifferentiated Early Carboniferous-Late Devonian	3.12	0.62
Point Maud Member - Gneudna Formation	5.00	0.28
Gneudna Formation	1.91	0.11
Nannyarra Sandstone	2.50	0.16
Sweeney Mia Formation - Kalbarri Group	2.78	0.56
Kopke Sandstone - Kalbarri Group	2.99	0.17
Faure Formation	1.62	0.10
Dirk Hartog Fm	5.88	0.37
Coburn Formation - Dirk Hartog Group	2.59	0.12
Yaringa Formation - Dirk Hartog Group	4.13	0.19
Ajana Formation - Dirk Hartog Group	2.78	0.17

Marron Member - Ajana Formation - Dirk Hartog Group	2.09	0.16
Tumblagooda Sandstone	3.57	0.18
undifferentiated Early Permian-Ordovician	2.35	0.48
undifferentiated Early Carboniferous-Ordovician	2.96	0.60
undifferentiated Early Carboniferous-Ordovician	2.49	0.50
Basement - Metasedimentary	4.10	0.10
Basement - Granite (Gascoyne Complex)	4.48	0.28

4.7. Predicting lithologies at depth

1D heat flow models for temperature prediction at depth require detailed lithological data, and associated rock thermal conductivities, for all formations down to the modelled depth. HDR utilised the DMP formation top database to constrain lithologies within the drilled portion of the heat flow models. The DMP formation top database was found to contain inconsistencies when cross-referenced with the well completion reports. HDR recommends that the DMP consider a quality control exercise with regards to the Carnarvon Basin formation tops database.

The lithologies and thicknesses of deeper formations were estimated using other available data. HDR utilised existing deep wells to estimate the thickness of individual formations as a ratio of the entire stratigraphic column. OZ SEEBASEv2 depth-to-basement estimates for all wells (FrOG Tech, 2007; Attachment C) were used to constrain the overall thickness of the sedimentary section, to which the formation-specific ratios were applied.

In order to make this methodology as robust as possible, wells that reached total depth within the sedimentary sequence were tied to the nearest deep well that intersected basement. This process assumed that the units within the sedimentary pile would continue laterally between the wells in a relatively constant ratio. Whilst simplistic, this methodology provides one of the few mechanisms to estimate the likely thickness of deep units for which there is a paucity of data.

In some instances, such as the Byro Sub-basin, there are no well penetrations in the deepest sedimentary sequence through to Basement. In these instances it was necessary to utilise DMP and other reports that estimate the lithologies below the base of the deepest wells. HDR used the harmonic mean of the thermal conductivity of these undifferentiated sections to allow temperature projections.

Whilst there remains significant uncertainty in the estimated thickness and distribution of non-intersected formations within the Carnarvon Basin, HDR used all available data to make reasonable assessments on a regional scale to minimise the uncertainty.

4.8. Estimating basement heat generation

Heat generation is most effectively estimated from the analytical measurement of uranium, thorium and potassium within rock samples. As it was not possible to obtain basement samples for analytical measurement, HDR assessed the heat generation of rocks within and adjacent to the Carnarvon Basin using data from the Geoscience Australia geochemical data base (OZCHEM, 2007). Heat generation values estimated from these data have been incorporated into the 1D heat flow models for this study.

As no geochemical data were available for the Carnarvon Basin, data from the Gascoyne and Yilgarn regions were utilised as proxies, assuming that similar rocks may partly comprise the basement of the Carnarvon Basin. Heat generation ($\mu W/m^3$) was estimated using an assumed rock density and the isotopic abundance method as described in Beardsmore & Cull (2001).

Median heat generation results for granite and metasedimentary rock samples adjacent to the Carnarvon Basin are shown in Table 2. Individual results for granite and metasedimentary rocks are listed in Attachments G and H respectively.

The data suggest that a small number of granite samples exhibit good heat generation potential. However, the overall heat generating potential of granites and metasedimentary rocks around the Carnarvon Basin appears moderate.

- **HDR recommends that the heat generation potential of basement rocks (in particular granites) be further investigated by the DMP.**

Table 2: Summary of heat generation estimates for two rock types around the Carnarvon Basin.

Lithology	Number of samples	Assumed density (g/cm^3)	Heat generation ($\mu W/m^3$) Range	Heat generation ($\mu W/m^3$) Median
Granite	46	2.68	0.84-12.49	2.74
Metasedimentary	12	2.48	0.78-2.90	2.10

5. Heat flow modelling

5.1. Estimated heat flow

The possibility of heat flow modelling was assessed for all 45 wells in this study. 24 wells were found to have insufficient temperature data to allow modelling of heat flow. HDR constructed 1D conductive heat flow models (Figure 10) for the other 21 wells in the Carnarvon Basin (the individual details of these thermal models are shown in Appendix 1).

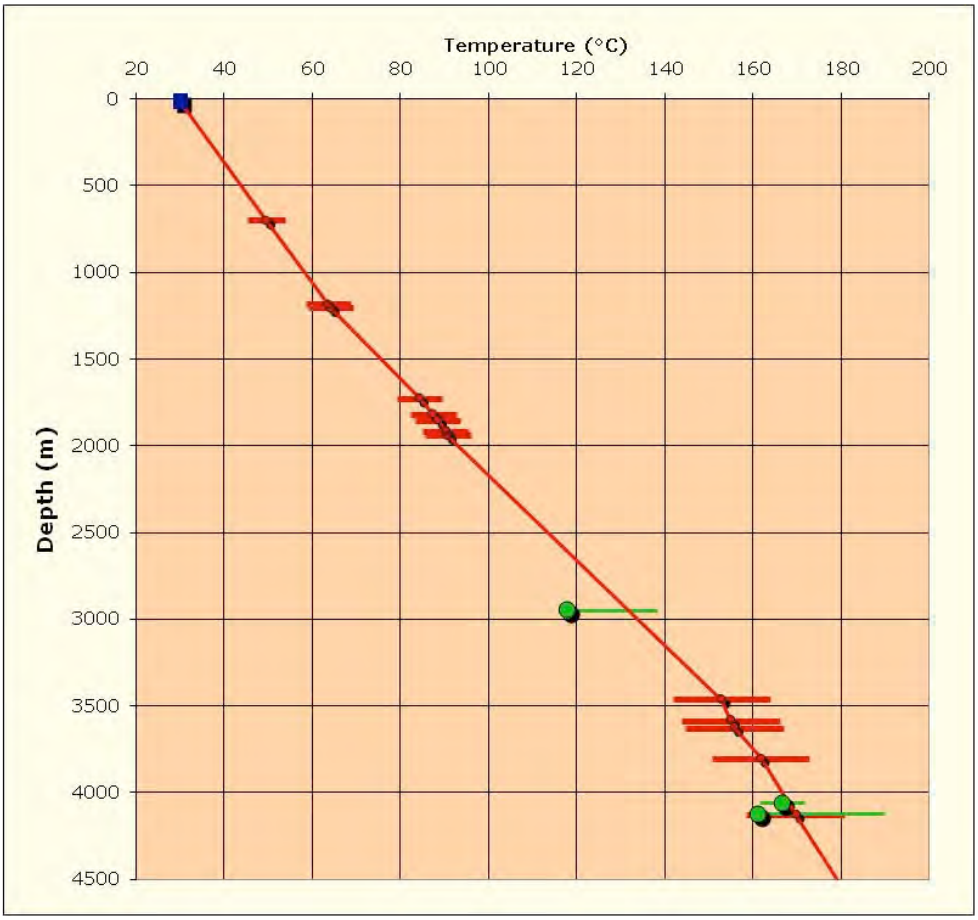

Figure 10: 1D heat flow model for the Yardie East-1 petroleum well. The green circles represent individual temperature data; the green lines represent the degree of uncertainty; the red line is the predicted temperature profile for a heat flow of 47 ± 3.5 mW/m^2

A summary of heat flow results, including the relative reliability ranking of the data, is shown in Attachment I. HDR incorporated temperature data, rock thermal conductivity data and heat generating potential estimates to model heat flow in each of the 21 wells. Heat flow was adjusted until the predicted temperature profile best fit the reported temperature datasets.

Modelled heat flow for the Carnarvon Basin ranges from 42–95 mW/m^2, with a median value of 54 mW/m^2. However, these data points have limited geographical distribution, with the majority clustered on the islands off the Northern Carnarvon Basin (the Saladin and Crest petroleum fields).

- **HDR recommends expert 1D heat flow modelling be undertaken for 93 wells identified by Chopra & Holgate (2007) as providing useful temperature data. Incorporating the data with the results from this current HDR study would result in a comprehensive heat flow model of the Carnarvon Basin.**

5.2. Reliability of heat flow data

Modelled heat flow is highly dependent upon the quality and quantity of temperature data. For each temperature datum, an uncertainty range was estimated based on the type of datum and the information known about it. For example, a well constrained Horner corrected or DST temperature was assigned a narrow uncertainty range centred on the corrected value. Uncorrected BHT values, however, were assigned a very low or zero uncertainty on the ‘negative’ side and a much larger uncertainty on the ‘positive’ side to reflect the fact that these data are very likely to understate the true temperature conditions. Heat flow models were constructed so that predicted temperature profiles passed as near as possible through the mid-point of the error bars on all temperature data.

Modelled heat flow values were ascribed a relative reliability ranking based on a qualitative assessment of the well temperature data (Table 3 and Attachment I).

Table 3: Reliability ranking scheme for the 21 wells modelled in the Carnarvon Basin.

Reliability Ranking	Most Reliable Temperature Data
1	One BHT datum
2	Several BHT data
3	One DST or Horner corrected temperature
4	Several DST or Horner corrected temperatures
5	Both DST and Horner corrected temperatures

In order to ensure robustness of ensuing modelling, HDR usually excludes wells with low reliability ranking of 1 or 2 from assessments of the spatial and magnitude distribution of heat flow (Section 5.3) and temperature projections (Section 6). However, given that 18 of the 21 wells modelled in this study have been ascribed a reliability ranking of 1 or 2, it was felt necessary in this instance to include all data.

5.3. Spatial and magnitude distribution of heat flow data

The spatial distribution of heat flow models is illustrated in Figure 11. The figure shows that the just 21 data points cover a limited geographical extent. Note that areas greater than 75 km from the nearest data point are left blank.

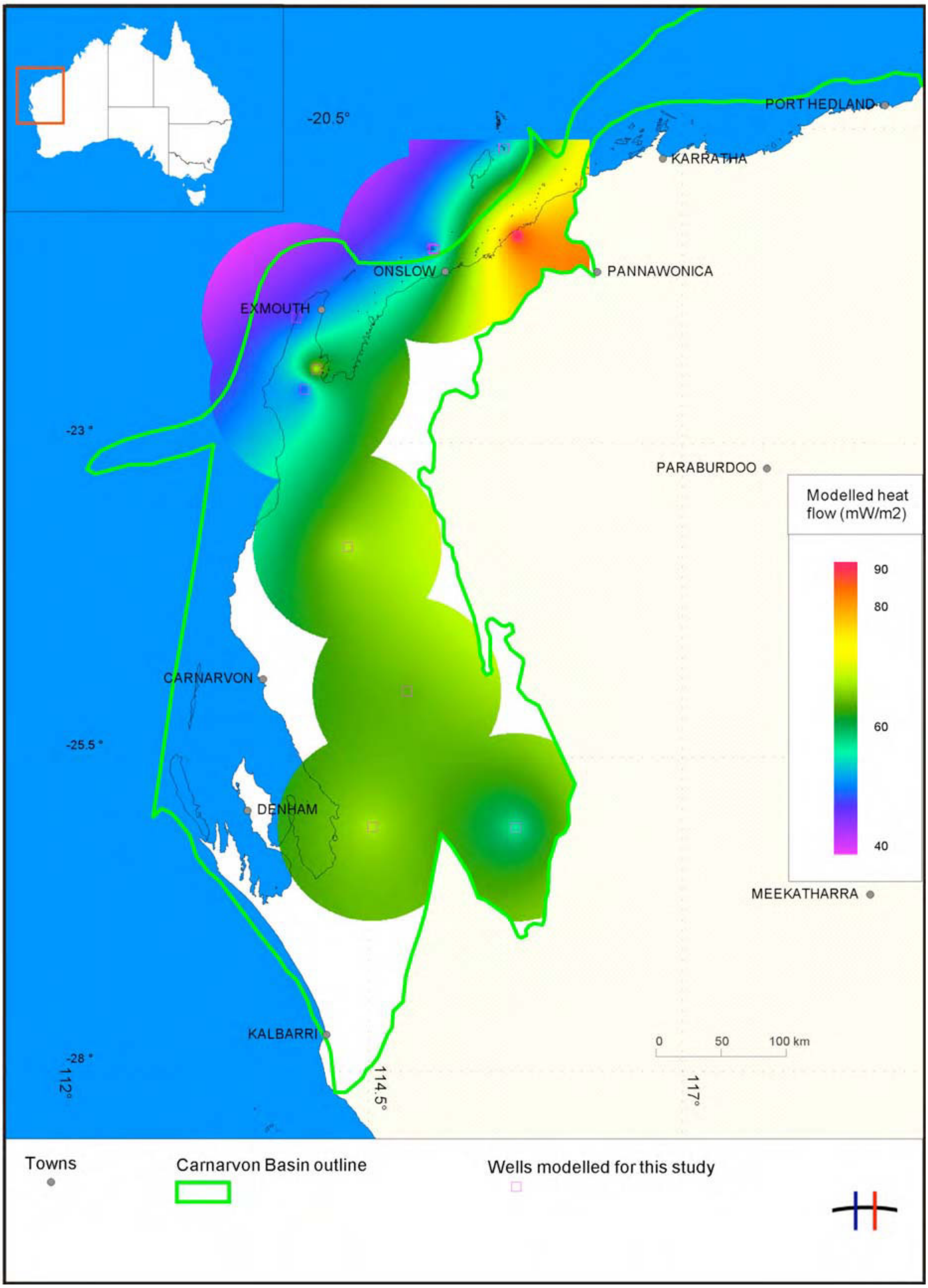

Figure 11: Gridded modelled heat flow values for the Carnarvon Basin. Each well was assumed to represent an area encompassing a radius of 75 km from the well. Parts of the basin outside those regions have been left blank. Apparent elevated heat flow extending west and northwest of Pannawonica is probably an artefact of the gridding process

6. Temperature projection

6.1. Depth to isotherms

Heat flow modelling allows the estimation of isotherm depths by applying the equation in Section 4.2. HDR was commissioned to estimate depths to the 100°C, 150°C and 200°C isotherms and a compilation of these depths beneath each well is shown in Attachment J. The predicted formation that may be intersected at the isotherm depth, as determined by the process described in Section 4.7, is also shown in Attachment J.

The gridded 100°C, 150°C and 200°C isothermal surfaces are shown in Figures 12 to 14.

6.2. Temperature at basement

HDR was commissioned to estimate the temperature at the top of the basement from 1D heat flow modelling. Following consultation with the DMP, it was agreed to amend this and extrapolate temperature to 5,000 m, an assumed economic drilling limit. Figure 15 shows the modelled temperature at 5,000 m depth for the Carnarvon Basin, and results beneath each well are tabulated in Attachment J.

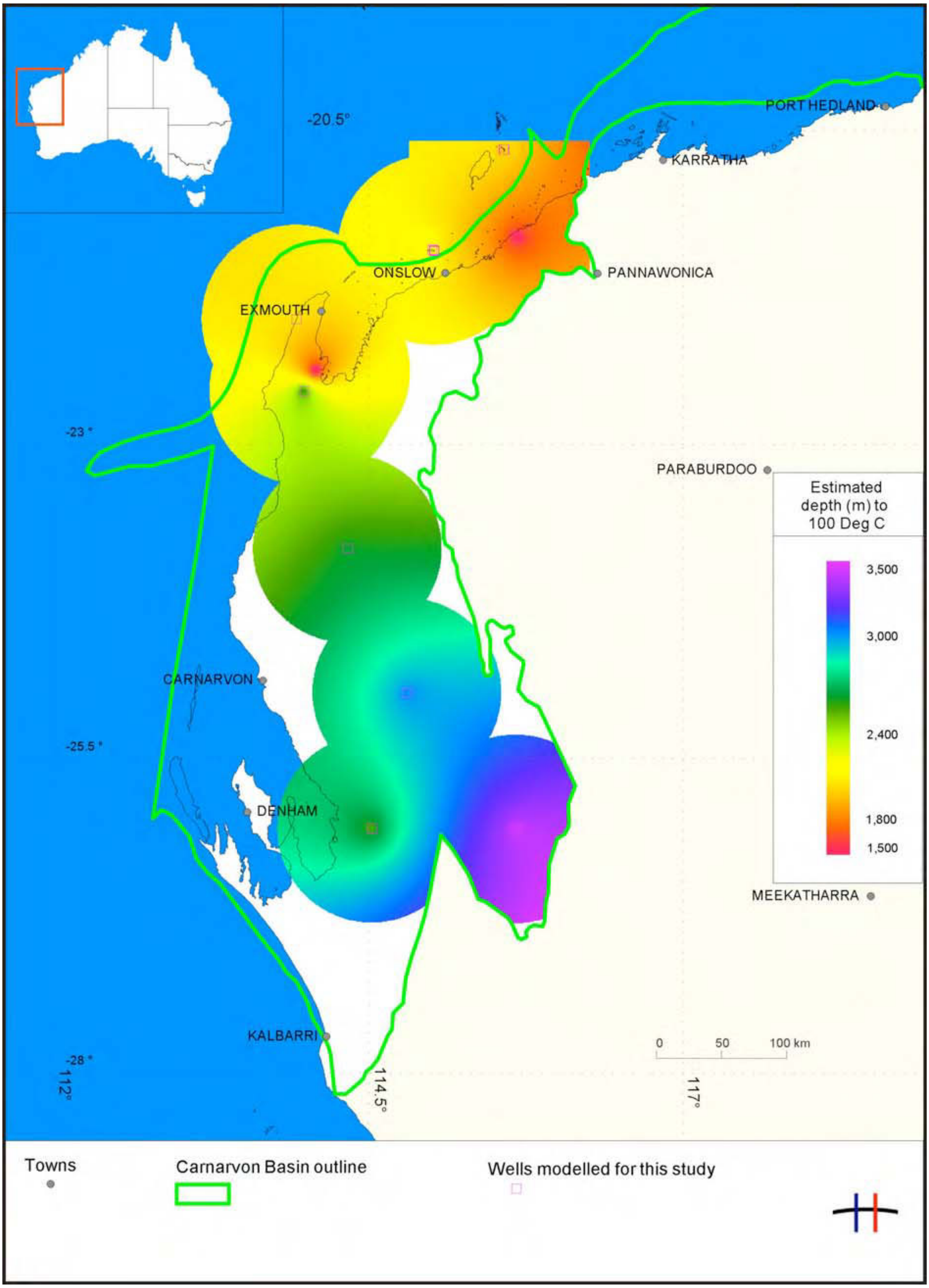

Figure 12: Estimated depth to the 100°C isotherm for the Carnarvon Basin. Each well was assumed to represent an area encompassing a radius of 75 km from the well. Parts of the basin outside these regions have been left blank.

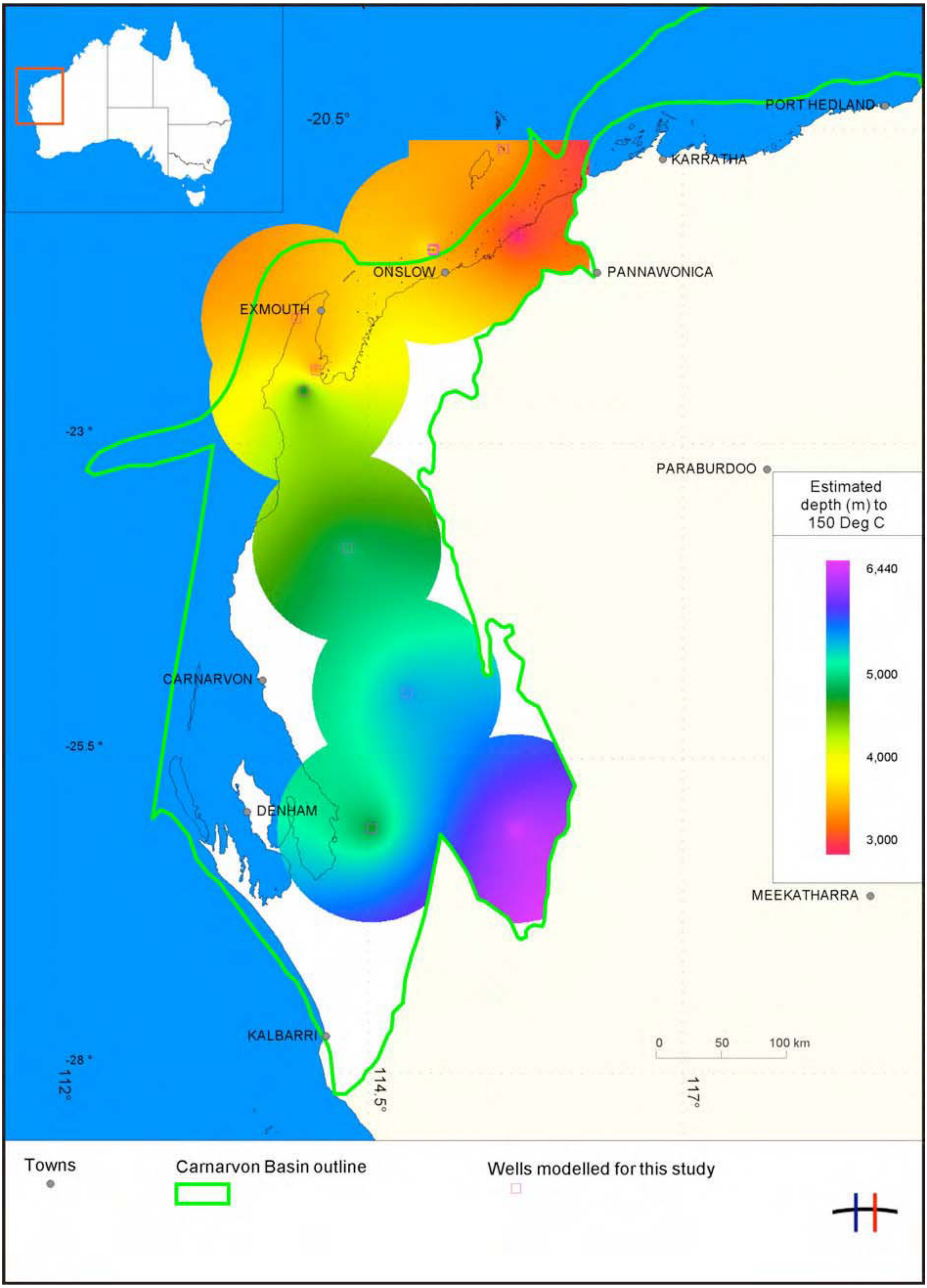

Figure 13: Estimated depth to the 150°C isotherm for the Carnarvon Basin. Each well was assumed to represent an area encompassing a radius of 75 km from the well. Parts of the basin outside these regions have been left blank.

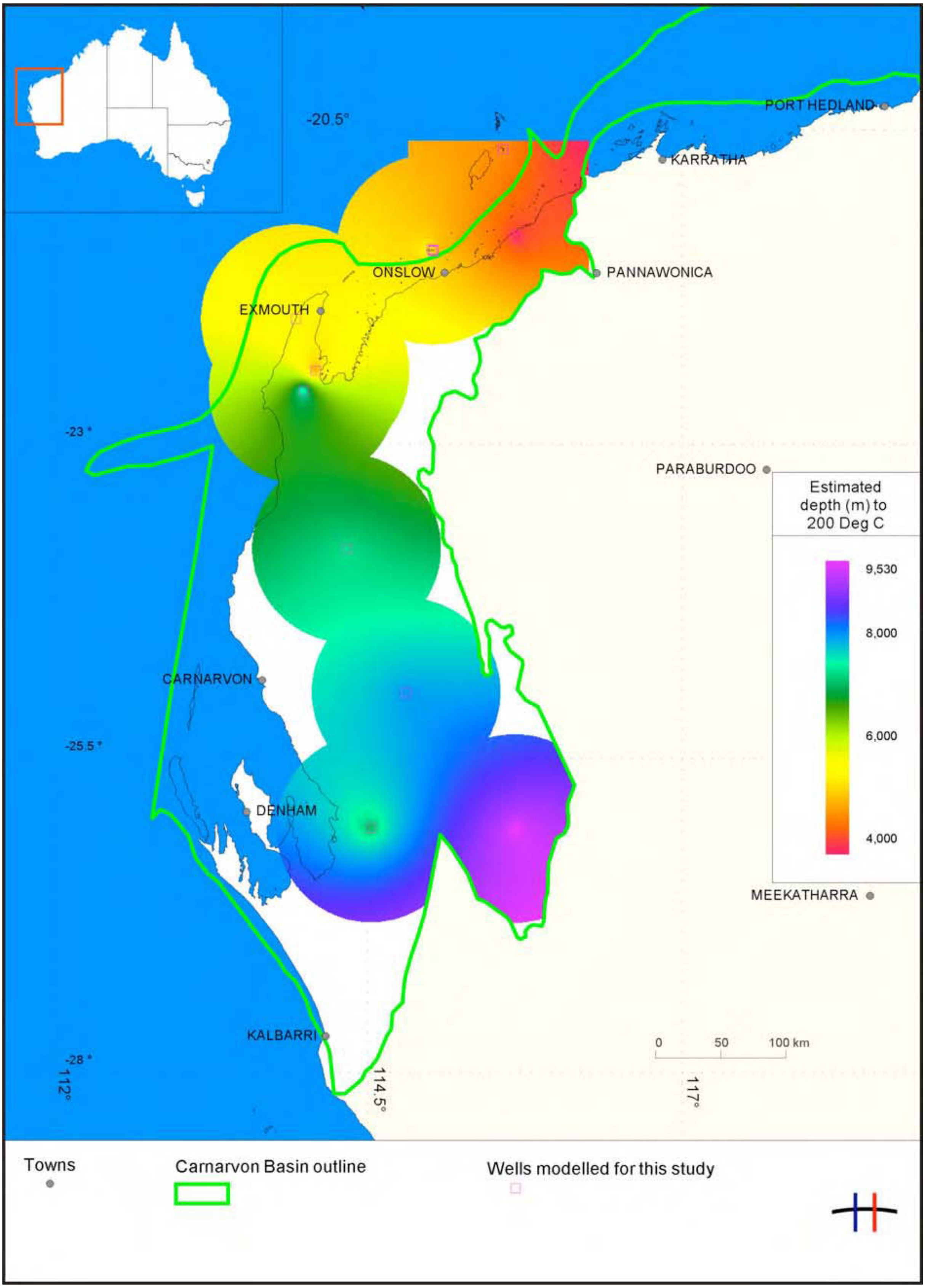

Figure 14: Estimated depth to the 200°C isotherm for the Carnarvon Basin. Each well was assumed to represent an area encompassing a radius of 75 km from the well. Parts of the basin outside these regions have been left blank.

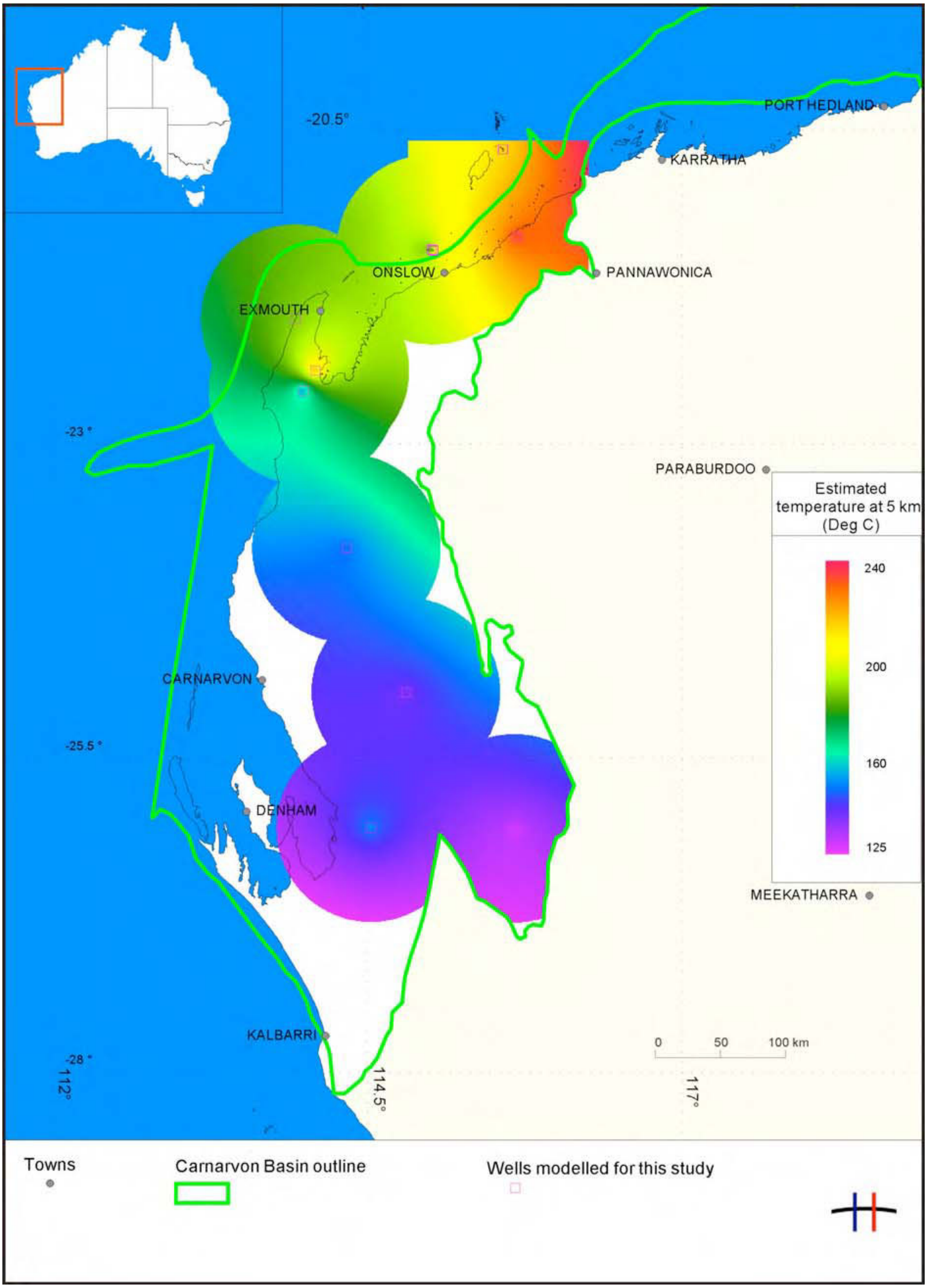

Figure 15: Estimated temperature at 5,000 m depth for the Carnarvon Basin. Each well was assumed to represent an area encompassing a radius of 75 km from the well. Parts of the basin outside these regions have been left blank.

7. Stress field in the Carnarvon Basin

7.1. Introduction

The successful development of an EGS depends upon several factors, but one of the most critical factors is the response of the fractured rock mass to the *in situ* stress field. Stress-dependant permeability of deep-seated, fractured rocks is well documented in studies relating to both hydrocarbon and geothermal reservoirs, as well as nuclear waste repositories (e.g. Gentier *et al*., 2000; Hillis *et al*., 1997; Hudson *et al*., 2005). In particular, *in situ* stress fields are known to exert a significant control on fluid flow patterns in fractured rocks with a low matrix permeability. For example, in a key study of deep (>1,700 m) boreholes, Barton *et al*. (1995) found that permeability manifests itself as fluid flow focussed along fractures favourably aligned within the *in situ* stress field, and that if fractures are critically stressed this can impart a significant anisotropy to the permeability of a fractured rock mass. Preferential flow occurs along fractures that are oriented orthogonal to the minimum principal stress direction (due to low normal stress), or inclined ~30° to the maximum principal stress direction (due to dilation).

Knowledge of both the local- and regional-scale stress regime is important in order to understand the effects of stress-dependent fracture permeability and, in EGS operations, potential reservoir growth and flooding directions under hydraulic stimulation. In general, stress fields are anisotropic and inhomogeneous. They are defined in simplified terms by three mutually orthogonal principal axes of stress, being the maximum (S_1), intermediate (S_2) and minimum (S_3) stress axes. In practice, the classification of far-field stress regimes is based upon the Andersonian scheme, which relates the three major styles of faulting in the crust to the three major arrangements of the principal axes of stress i.e. the vertical principal stress (S_V) and the maximum and minimum horizontal principal stresses (S_H and S_h, respectively) (Anderson, 1951). These three major styles of faulting are: (a) normal faulting where $S_V > S_H > S_h$; (b) strike-slip faulting where $S_H > S_V > S_h$; and (c) reverse (or thrust) faulting where $S_H > S_h > S_V$ (Figure 16).

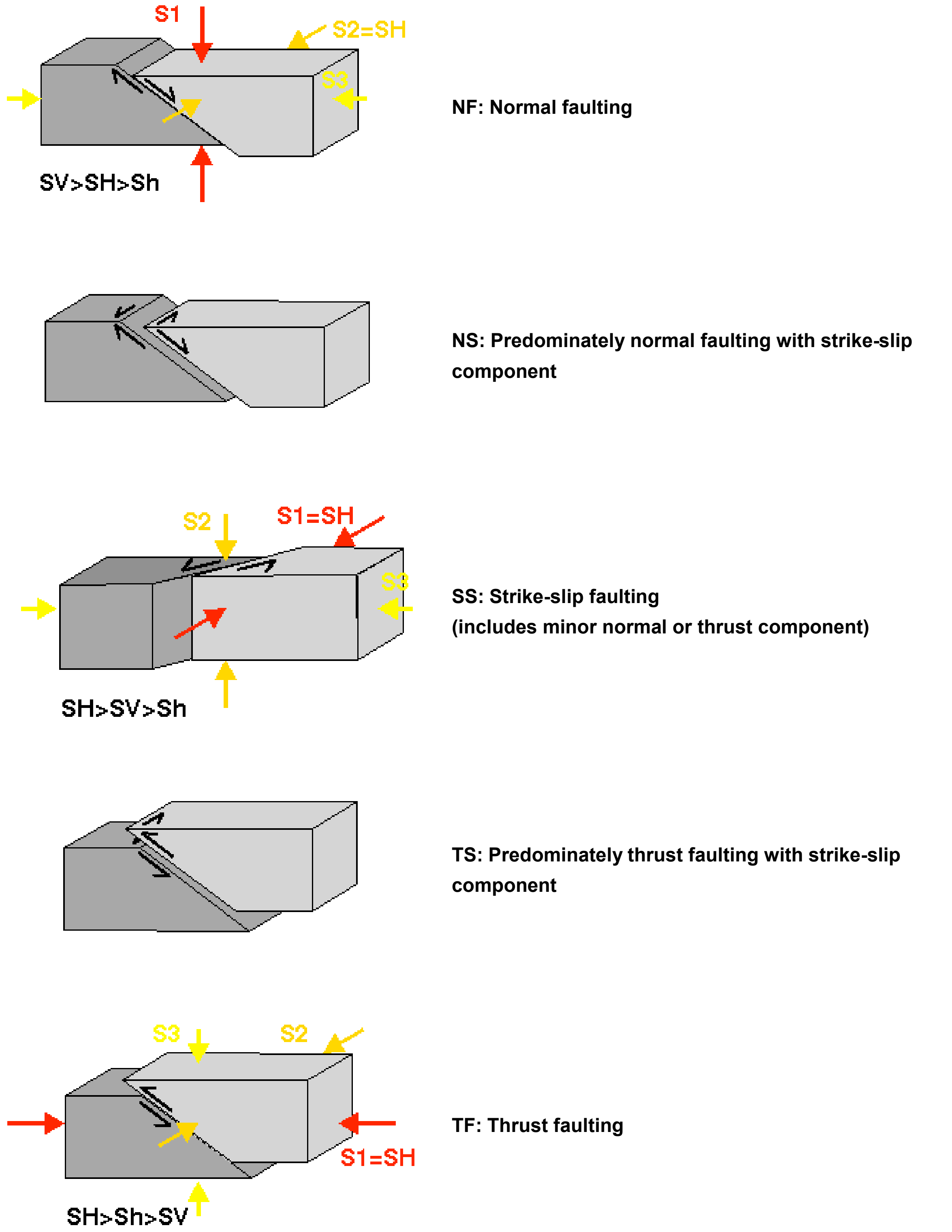

Figure 16: The World Stress Map stress regime classifications (NF, NS, SS, TS, TF) and their associated styles of faulting (from Heidbach *et al*., 2008).

The determination of the local stress field is important as theory predicts enhanced permeability associated with critically stressed faults or fractures that are either undergoing dilation (~parallel to S_1) or shear reactivation (<45° to S_1) under the influence of the contemporary stress field.

With respect to EGS developments, knowledge of the stress field and pre-existing fractured rock mass can be used to make preliminary predictions of fracture and reservoir growth directions during hydraulic stimulation. The three major fracture growth directions are:

(a) Steep to vertical dipping fractures that strike orthogonal to S_h in a normal faulting stress regime ($S_V > S_H > S_h$);

(b) Steep to vertical dipping fractures that strike <45° (commonly 30°) to the direction S_H in a strike-slip faulting stress regime ($S_H > S_V > S_h$), and;

(c) Shallow to horizontal dipping fractures (aligned in the direction of S_H) that strike ~parallel to S_h in a thrust faulting stress regime ($S_H > S_h > S_V$).

7.2. Carnarvon Basin stress measurement data

There are no World Stress Map *in situ* stress data reported for the onshore Northern or Southern Carnarvon Basin. However, borehole breakout stress indicators reported from petroleum wells located within the offshore North West Shelf (Figure 17) suggest that the maximum horizontal stress direction (S_H) in this region is approximately east-west (~101°) whilst the stress regime is inferred as either strike-slip or normal faulting regime (Hillis and Reynolds, 2000). With respect to hydraulic stimulation and development of an EGS reservoir these two stress regimes will result in an approximately east-west trending, steeply dipping to vertical reservoir growth direction.

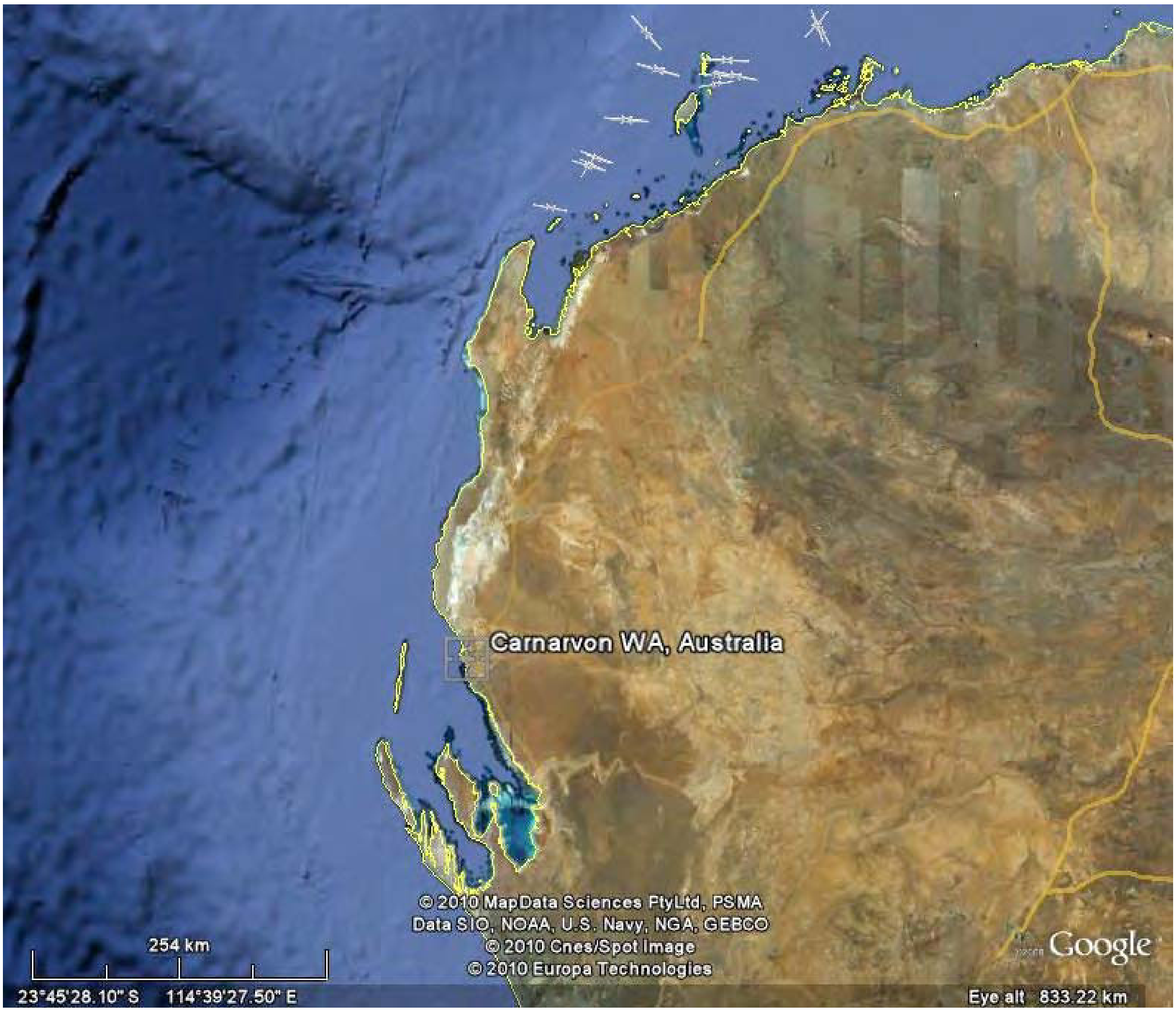

Figure 17. World Stress Map A-C quality ranked in situ stress field indicators depicting the orientation of the principle horizontal stress axis (S_{Hmax}) within the offshore North West Shelf (from Heidbach *et al*., 2008).

8. Prospectivity

Apparent surface heat flow in the Carnarvon Basin ranges from 42–95 mW/m^2 with a median value of 54 mW/m^2. This report, however, utilises data from just 21 wells with limited geographical distribution; the majority are clustered on the islands off the Northern Carnarvon Basin—the Saladin and Crest petroleum fields. A geothermal study by Chopra & Holgate (2007) confirmed useful temperature data in a further 93 Carnarvon Basin wells. Expert 1D heat flow models of these wells should be undertaken and incorporated with the results from this current study so as to build a comprehensive heat flow model of the Carnarvon Basin.

Apparent heat flows are lowest in the Barrow and Exmouth sub-basins with values generally <60 mW/m^2. There is an increase in apparent heat flow onshore in the Peedamullah Shelf to 95 mW/m^2, however, this is based on just one well (Windoo 1A) and it is quite likely the elevated apparent heat flow over much of this area (Figure 11) is an artefact of the gridding process. The Southern Carnarvon Basin shows average to moderate apparent heat flow ranging from 55 mW/m^2–70 mW/m^2.

The onshore and coastal portions of the Peedamullah Shelf and Exmouth Sub-basin have the 150°C isotherm modelled at 3,000–4,000 m, whilst northern portions of the Gascoyne Platform has the isotherm modelled at 4,000–5,000 m. In some of these areas the 150°C isotherm is coincident with Devonian–Triassic sedimentary units. If a suitable lithology which preserves natural permeability is present in this area, it may host a Hot Sedimentary Aquifer (HSA) geothermal system. Other areas may be prospective for EGS, depending on the suitability of target lithologies for fracture stimulation.

Borehole breakout stress indicators from petroleum wells located offshore suggest that the maximum horizontal stress direction (S_H) is approximately east-west (~101°) whilst the stress regime is inferred as either strike-slip or normal faulting regime. With respect to hydraulic stimulation and development of an EGS reservoir either of these two stress regimes will result in an approximately east-west trending, steeply dipping to vertical reservoir growth direction.

9. Conclusions and Recommendations

Measured rock thermal conductivities for 61 core samples collected from the Carnarvon Basin range from 0.64–4.97 W/mK. HDR was able to incorporate a further 56 thermal conductivity values utilised in a previous study of the Southern Carnarvon Basin. These data were crucial for the development of 1D heat flow models to predict the depth to selected isotherms.

Apparent surface heat flow in the Carnarvon Basin ranges from 42–95 mW/m^2 with a median value of 54 mW/m^2. This value is lower than the Australian median value of 64.5 mW/m^2 from the global heat flow database and considerably lower than the Perth and Canning basins median values of 76.5 mW/m^2 and 68 mW/m^2, respectively, recorded in previous HDR reports (HDR, 2008; Driscoll *et al.*, 2009).

The relatively low median heat flow value is based on just 21 well models. Furthermore, these wells have limited geographical distribution with the majority clustered on the islands of the Northern Carnarvon Basin (Saladin and Crest petroleum fields). A previous geothermal study by Chopra & Holgate (2007) confirmed useful temperature data for a further 93 Carnarvon Basin wells.

Apparent heat flows are lowest in the Barrow and Exmouth sub-basins with values generally <60 mW/m^2. There is an increase in apparent heat flow onshore in the Peedamullah Shelf to 95 mW/m^2. However, this is based on just one well (Windoo 1A). The Southern Carnarvon Basin shows average to moderate apparent heat flow ranging from 55 mW/m^2–70 mW/m^2.

Based on limited well penetrations assessed in this study, the onshore and coastal portions of the Peedamullah Shelf and Exmouth Sub-basin have the 150°C isotherm modelled at 3,000–4,000 m, whilst northern portions of the Gascoyne Platform has the isotherm modelled at 4,000–5,000 m. In some of these areas the 150°C isotherm is coincident with Devonian–Triassic sedimentary units. If a suitable lithology which preserves natural permeability is present in this area, it may host an HSA geothermal system. Other areas may be prospective for EGS, depending on the suitability of target lithologies for fracture stimulation.

Borehole breakout stress indicators from petroleum wells located within the offshore

North West Shelf suggest that the maximum horizontal stress direction (S_H) is approximately east-west (~101°) whilst the stress regime is inferred as either strike-slip or normal faulting regime. With respect to hydraulic stimulation and development of an EGS reservoir either of these two stress regimes will result in an approximately east-west trending, steeply dipping to vertical reservoir growth direction.

HDR makes the following specific recommendations with regards to future studies:

- HDR recommends expert 1D heat flow modelling be extended to the 93 wells with useful temperature data identified by Chopra & Holgate (2007), and incorporating the data with the results from this current HDR study to construct a comprehensive heat flow model of the Carnarvon Basin.

- HDR recommends that the heat generation potential of basement rocks be further investigated by the DMP.

- DMP should consider a field program to obtain stress field estimates via hydraulic fracturing or borehole imaging of existing onshore wells. With robust stress field data, 2D or 3D numerical hydro-mechanical modelling could be undertaken to constrain expected geothermal reservoir growth and flooding directions.

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Attachment A: Petroleum wells in the Carnarvon Basin that form this study.

Well Name	Basin	Sub-basin	Well ID	Onshore/ Island?	Deviated well?	Total Depth (mMD)	Total Depth (mTVD)	Age at Total Depth	Lithostrati-graphic Unit	Datum	Latitude (°)	Longitude (°)
BMR 05 Yanrey	Southern Carnarvon	Merlinleigh Sub-basin	W001498	Onshore	no	631.0	631.0	Early Permian	Byro Group	CLARKE	-22.658611	114.245833
BMR 06 Kennedy Range	Southern Carnarvon	Merlinleigh Sub-basin	W001499	Onshore	no	305.0	305.0	Early Permian	Cundlego Formation	CLARKE ?	-24.098611	114.772222
BMR 07 Kennedy Range	Southern Carnarvon	Merlinleigh Sub-basin	W001500	Onshore	no	609.0	609.0	Early Permian	Cundlego Formation	CLARKE ?	-24.098611	114.775000
BMR 08 Glenburgh	Southern Carnarvon	Byro Sub-basin	W001501	Onshore	no	915.6	915.6	Early Permian	Lyons Group	GDA94	-25.757058	115.670829
BMR 09 Glenburgh	Southern Carnarvon	Bidgemia Sub-basin	W001502	Onshore	no	700.7	700.7	Early Permian	Lyons Group	GDA94	-25.557053	115.899995
Crest 1 Deepening	Northern Carnarvon	Barrow Sub-basin	W002206	Island	yes	2037.0	1751.0	Late Jurassic	Dupuy Formation	GDA94	-21.456001	115.021362
Crest 2	Northern Carnarvon	Barrow Sub-basin	W001908	Island	yes	1686.5	1349.1	Early Cretaceous	Barrow Group	GDA94	-21.456126	115.021309
Crest 5	Northern Carnarvon	Barrow Sub-basin	W001995	Island	yes	1433.0	1200.0	Early Cretaceous	Barrow Group	GDA94	-21.451615	115.006626
Crest 6	Northern Carnarvon	Barrow Sub-basin	W002205	Island	yes	1954.5	1157.0	Early Cretaceous	Mardie Greensand Member	GDA94	-21.455995	115.021362
Grierson 1	Southern Carnarvon	Gascoyne Platform	W000028	Onshore	no	438.0	438.0	Late Devonian	Gneudna Formation	CLARKE	-24.201317	113.774000
Grierson 2	Southern Carnarvon	Gascoyne Platform	W000029	Onshore	no	457.5	457.5	Late Devonian	Gneudna Formation	CLARKE	-24.201944	113.786528
Grierson 3	Southern Carnarvon	Gascoyne Platform	W000030	Onshore	no	442.0	442.0	Late Devonian	Gneudna Formation	CLARKE	-24.201944	113.760139
GSWA Ballythanna 1	Southern Carnarvon	Byro Sub-basin	W001987	Onshore	no	465.2	465.2	Early Permian	Lyons Group	GDA94	-26.060395	115.671110
GSWA Barrabiddy 1A	Southern Carnarvon	Gascoyne Platform	W002081	Onshore	no	782.9	782.9	Middle Devonian	Nannyarra Sandstone	GDA94	-23.831222	114.334691
GSWA Mooka 1	Southern Carnarvon	Gascoyne Platform	W002080	Onshore	no	418.0	418.0	Silurian	Coburn Formation	GDA94	-24.975387	114.806934
GSWA Woodleigh 2A	Southern Carnarvon	Gascoyne Platform	W002317	Onshore	no	618.3	618.3	Silurian	Coburn Formation	GDA94	-26.056461	114.527581

Learmonth 1	Northern Carnarvon	Exmouth Sub-basin	W000031	Onshore	no	2327.5	2327.5	Early Permian	Early Permian	GDA94	-22.183150	114.061892
North Ballythanna Corehole 1	Southern Carnarvon	Byro Sub-basin	W000106	Onshore	no	198.1	198.1	Early Permian	Madeline Formation	CLARKE	-25.927778	115.663889
North Ballythanna Corehole 2	Southern Carnarvon	Byro Sub-basin	W000107	Onshore	no	182.9	182.9	Early Permian	Madeline Formation	CLARKE	-25.932778	115.647222
North Ballythanna Corehole 3	Southern Carnarvon	Byro Sub-basin	W000108	Onshore	no	211.8	211.8	Early Permian	Keogh Formation	CLARKE	-25.936111	115.633333
North Ballythanna Corehole 4	Southern Carnarvon	Byro Sub-basin	W000109	Onshore	no	156.9	156.9	Early Permian	Madeline Formation	CLARKE	-25.922222	115.679167
Rosette 1	Northern Carnarvon	Barrow Sub-basin	W001523	Island	yes	3279.0	2570.0	Late Jurassic	Dupuy Formation	GDA94	-20.655242	115.575266
Rough Range 01A (Re-Entry)	Southern Carnarvon	Gascoyne Platform	W002159	Onshore	no	1107.3	1107.3	Early Cretaceous	Birdrong Sandstone	GDA94	-22.417597	114.083561
Rough Range 02	Northern Carnarvon	Exmouth Sub-basin	W000034	Onshore	no	1243.3	1243.3	Late Jurassic	Learmonth Formation	CLARKE	-22.431967	114.069936
Rough Range 03	Northern Carnarvon	Exmouth Sub-basin	W000035	Onshore	no	1193.3	1193.3	Early Cretaceous	Birdrong Sandstone	CLARKE	-22.412528	114.087703
Rough Range 04	Northern Carnarvon	Exmouth Sub-basin	W000036	Onshore	no	1146.0	1146.0	Early Cretaceous	Birdrong Sandstone	CLARKE	-22.424525	114.083386
Rough Range 05	Northern Carnarvon	Exmouth Sub-basin	W000037	Onshore	no	1149.7	1149.7	Early Cretaceous	Birdrong Sandstone	CLARKE	-22.420086	114.077756
Rough Range 06	Northern Carnarvon	Exmouth Sub-basin	W000038	Onshore	no	1126.8	1126.8	Early Cretaceous	Birdrong Sandstone	CLARKE	-22.421606	114.082047
Rough Range 07	Northern Carnarvon	Exmouth Sub-basin	W000039	Onshore	no	1304.8	1304.8	Early Cretaceous	Wogatti Sandstone	CLARKE	-22.445867	114.070222
Rough Range 08	Northern Carnarvon	Exmouth Sub-basin	W000040	Onshore	no	1194.5	1194.5	Early Cretaceous	Birdrong Sandstone	CLARKE	-22.447522	114.064111
Rough Range 09	Northern Carnarvon	Exmouth Sub-basin	W000041	Onshore	no	1171.7	1171.7	Early Cretaceous	Wogatti Sandstone	CLARKE	-22.448639	114.074661
Rough Range South 1	Northern Carnarvon	Exmouth Sub-basin	W000043	Onshore	no	873.9	873.9	Late Cretaceous	Gearle Siltstone	CLARKE	-22.622383	113.962044
Rough Range South 5	Northern Carnarvon	Exmouth/ Merlinleigh sub-basins	W000047	Onshore	no	1450.8	1450.8	Early Permian	Lyons Group	CLARKE	-22.574908	113.989519
Saddleback 1	Northern Carnarvon	Peedamullah Shelf	W001108	Onshore	no	148.0	148.0	Early Cretaceous	Yarraloola Conglomerate	GDA94	-21.440350	115.776340

Saladin 13H	Northern Carnarvon	Barrow Sub-basin	W001993	Island	yes	2240.0	1103.7	Early Cretaceous	Mardie Greensand Member	GDA94	-21.463009	115.019037
Saladin 13H ST1	Northern Carnarvon	Barrow Sub-basin	W001993	Island	yes	2252.0	1110.6	Early Cretaceous	Mardie Greensand Member	GDA94	-21.463009	115.019037
Saladin 14	Northern Carnarvon	Barrow Sub-basin	W002064	Island	yes	2571.0	1083.0	Early Cretaceous	Mardie Greensand Member	GDA94	-21.459043	115.024481
Saladin 18M	Northern Carnarvon	Barrow Sub-basin	W002343	Island	yes	2229.0	1102.8	Early Cretaceous	Mardie Greensand Member	GDA94	-21.462848	115.019042
Saladin 19M ST1	Northern Carnarvon	Barrow Sub-basin	W002339	Island	yes	2650.0	1100.0	Early Cretaceous	Mardie Greensand Member	GDA94	-21.462848	115.019034
Saladin 24	Northern Carnarvon	Barrow Sub-basin	W002335	Island	yes	2145.0	1130.5	Early Cretaceous	Barrow Group	GDA94	-21.463098	115.018909
Tanami 3 ST1	Northern Carnarvon	Barrow Sub-basin	W001912	Island	yes	3080.0	1867.2	Early Cretaceous	Flag Sandstone	GDA94	-20.653557	115.579662
Tanami 3 ST2	Northern Carnarvon	Barrow Sub-basin	W001912	Island	yes	2815.0	1901.5	Early Cretaceous	Flag Sandstone	GDA94	-20.653557	115.579662
Windoo 1A	Northern Carnarvon	Peedamullah Shelf	W000904	Onshore	no	218.5	218.5	Early Cretaceous	Yarraloola Conglomerate	GDA94	-21.353684	115.683281
Woorawa 1	Northern Carnarvon	Peedamullah Shelf	W000848	Onshore	no	202.4	202.4	Early Permian	Lyons Group	GDA94	-21.364043	115.793893
Yardie East 1	Northern Carnarvon	Exmouth Sub-basin	W001101	Onshore	yes	5594.0	4127.0	Late Triassic	Mungaroo Formation	GDA94	-22.006484	113.927321

Attachment B: Basement lithology and depths for all wells in the Carnarvon Basin that intersected basement.

Well Name	Datum	Latitude (°)	Longitude (°)	TD (m)	Basement type	Depth to Basement (m)	Notes
Candace 1	GDA94	-20.825732	115.919949	2063.0	pyroclastic breccia	2017.5	see robe river corehole 3 report W6137R2A16 p.45
Cane River 3	GDA94	-21.706470	115.325782	254.8	quartzite	240.8	
Cane River 4	GDA94	-21.597020	115.563840	172.8	quartz-chlorite-calcite rock [chlorite gneiss/quartzite?]	158.5	
Cane River 5	GDA94	-21.788136	115.481339	200.9	marble	256	
Coonga 1	GDA94	-21.050873	116.031221	176.5	phyllite	157	
Enderby 1	?GA website	-20.155780	116.408089	2149.0	rhyolite	2081	G2850A5 p.293
Garden Mill 1	GDA94	-22.559441	114.473594	555.0	phyllic schist	544.4	
GSWA Gneudna 1	GDA94	-23.971492	115.218025	492.1	granite	488.3	
Hampton 1	?GA website	-20.116601	116.547835	2584.0	silicified sst, slt and chert	2477	
Hauy 1	GDA94	-19.792894	117.255619	825.4	dolerite	805.3	
Kanji 1	GDA94	-20.035948	116.841540	1288.0	dolerite	1282	
Lawley 1	GDA94	-19.904447	117.010242	1120.0	altered granitic gneiss	1091	
Mardie West 1	GDA94	-21.197710	115.924640	135.3	indurated mudstone; quartz veins	124.1	
Mermaid 1	GDA94	-20.697285	115.962303	1271.0	granitic gneiss	1259	
Poissonnier 1	GDA94	-19.307984	118.156615	1962.0	fine-grained plagioclase-rich basic to intermediate igneous	1947	
Robe River Corehole 3	GDA94	-21.466006	115.871015	121.9	Proterozoic ?metasedimentary	50	No WCR in WAPIMS. Fm tops database has the lithology as slt/sst/cst.
Tent Hill 1	GDA94	-22.182768	114.618456	580.0	metasediments [slt/sst]	572	
Woodleigh 1981/2	GDA94	-26.054848	114.668608	965.0	granite gneiss, impact shocked	171	also known as GSWA Woodleigh 1
Yanrey 1	CLARKE	-22.255769	114.584308	430.7	schist	421.5	

Attachment C: Predicted basement lithology and depths for all wells in this study.

Well Name	Well ID	Total Depth (mMD)	Total Depth (mTVD)	Probable Basement Lithology	Basement Depth (m)	Depth to Basement Beneath Total Depth (m)	Datum	Latitude (°)	Longitude (°)
BMR 05 Yanrey	W001498	631.0	631.0	Metasediment	8000	7369.0	CLARKE	-22.658611	114.245833
BMR 06 Kennedy Range	W001499	305.0	305.0	Granite	6000	5695	CLARKE?	-24.098611	114.772222
BMR 07 Kennedy Range	W001500	609.0	609.0	Granite	6000	5391	CLARKE?	-24.098611	114.775000
BMR 08 Glenburgh	W001501	915.6	915.6	Metasediment	3250	2334.4	GDA94	-25.757058	115.670829
BMR 09 Glenburgh	W001502	700.7	700.7	Granite	4000	3299.3	GDA94	-25.557053	115.899995
Crest 1 Deepening	W002206	2037.0	1751.0	Metasediment	12000	10249	GDA94	-21.456001	115.021362
Crest 2	W001908	1686.5	1349.1	Metasediment	12000	10650.9	GDA94	-21.456126	115.021309
Crest 5	W001995	1433.0	1200.0	Metasediment	12000	10800	GDA94	-21.451615	115.006626
Crest 6	W002205	1954.5	1157.0	Metasediment	12000	10843	GDA94	-21.455995	115.021362
Grierson 1	W000028	438.0	438.0	Metasediment	4500	4062	CLARKE	-24.201317	113.774000
Grierson 2	W000029	457.5	457.5	Metasediment	4500	4042.5	CLARKE	-24.201944	113.786528
Grierson 3	W000030	442.0	442.0	Metasediment	4500	4058	CLARKE	-24.201944	113.760139
GSWA Ballythanna 1	W001987	465.2	465.2	Metasediment	4000	3534.8	GDA94	-26.060395	115.671110
GSWA Barrabiddy 1A	W002081	782.9	782.9	Metasediment	3200	2417.1	GDA94	-23.831222	114.334691
GSWA Mooka 1	W002080	418.0	418.0	Metasediment	4000	3582	GDA94	-24.975387	114.806934
GSWA Woodleigh 2A	W002317	618.3	618.3	Metasediment	4500	3881.7	GDA94	-26.056461	114.527581
Learmonth 1	W000031	2327.5	2327.5	Metasediment	15000	12672.5	GDA94	-22.183150	114.061892
North Ballythanna Corehole 1	W000106	198.1	198.1	Metasediment	4000	3801.9	CLARKE	-25.927778	115.663889
North Ballythanna Corehole 2	W000107	182.9	182.9	Metasediment	4000	3817.1	CLARKE	-25.932778	115.647222
North Ballythanna Corehole 3	W000108	211.8	211.8	Metasediment	4000	3788.2	CLARKE	-25.936111	115.633333
North Ballythanna Corehole 4	W000109	156.9	156.9	Metasediment	4000	3843.1	CLARKE	-25.922222	115.679167
Rosette 1	W001523	3279.0	2570.0	Granite	15000	12430	GDA94	-20.655242	115.575266
Rough Range 01A (Re-Entry)	W002159	1107.3	1107.3	Metasediment	5000	3892.7	GDA94	-22.417597	114.083561
Rough Range 02	W000034	1243.3	1243.3	Metasediment	5000	3756.7	CLARKE	-22.431967	114.069936
Rough Range 03	W000035	1193.3	1193.3	Metasediment	5000	3806.7	CLARKE	-22.412528	114.087703

Rough Range 04	W000036	1146.0	1146.0	Metasediment	5500	4354	CLARKE	-22.424525	114.083386
Rough Range 05	W000037	1149.7	1149.7	Metasediment	5000	3850.3	CLARKE	-22.420086	114.077756
Rough Range 06	W000038	1126.8	1126.8	Metasediment	5000	3873.2	CLARKE	-22.421606	114.082047
Rough Range 07	W000039	1304.8	1304.8	Metasediment	5000	3695.2	CLARKE	-22.445867	114.070222
Rough Range 08	W000040	1194.5	1194.5	Metasediment	5000	3805.5	CLARKE	-22.447522	114.064111
Rough Range 09	W000041	1171.7	1171.7	Metasediment	6000	4828.3	CLARKE	-22.448639	114.074661
Rough Range South 1	W000043	873.9	873.9	Metasediment	5500	4626.1	CLARKE	-22.622383	113.962044
Rough Range South 5	W000047	1450.8	1450.8	Metasediment	6000	4549.2	CLARKE	-22.574908	113.989519
Saddleback 1	W001108	148.0	148.0	Metasediment	1000	852	GDA94	-21.440350	115.776340
Saladin 13H	W001993	2240.0	1103.7	Metasediment	12000	10896.3	GDA94	-21.463009	115.019037
Saladin 13H ST1	W001993	2252.0	1110.6	Metasediment	12000	10889.4	GDA94	-21.463009	115.019037
Saladin 14	W002064	2571.0	1083.0	Metasediment	12000	10917	GDA94	-21.459043	115.024481
Saladin 18M	W002343	2229.0	1102.8	Metasediment	12000	10897.2	GDA94	-21.462848	115.019042
Saladin 19M ST1	W002339	2650.0	1100.0	Metasediment	12000	10900	GDA94	-21.462848	115.019034
Saladin 24	W002335	2145.0	1130.5	Granite	15000	13869.5	GDA94	-21.463098	115.018909
Tanami 3 ST1	W001912	3080.0	1867.2	Granite	15000	13132.8	GDA94	-20.653557	115.579662
Tanami 3 ST2	W001912	2815.0	1901.5	Granite	15000	13098.5	GDA94	-20.653557	115.579662
Windoo 1A	W000904	218.5	218.5	Metasediment	4000	3781.5	GDA94	-21.353684	115.683281
Woorawa 1	W000848	202.4	202.4	Metasediment	2000	1797.6	GDA94	-21.364043	115.793893
Yardie East 1	W001101	5594.0	4127.0	Metasediment	16000	11873	GDA94	-22.006484	113.927321

Attachment D: Summary of measured rock thermal conductivity data (measured at 30°C) for the Carnarvon Basin (Appendix 2 of this report).

Sample	Well	Depth from (m)	Depth to (m)	Depth from (')	Depth to (')	Conductivity (W/mK)	Uncertainty (W/mK)	Formation	Lithology
DIR089	Coburn 1	73.70	73.92			1.48	0.03	Toolonga Calcilutite	light grey marl
DIR090	Coburn 1	172.70	172.85			2.47	0.06	Birdrong Sandstone – Winning Group	light brown carbonaceous fine-grained sst
DIR091	Coburn 1	212.70	212.85			3.12	0.19	Kopke Sandstone – Kalbarri Group	grey light brown sst with finely laminated
DIR092	Coburn 1	404.40	404.55			3.64	0.07	Kopke Sandstone – Kalbarri Group	red bed sst finely laminated, similar to DIR091 but red
DIR093	Coburn 1	475.40	475.50			1.61	0.06	Kopke Sandstone – Kalbarri Group	red/green/grey mottled slt/cst - differing oxidising regimes
DIR094	Coburn 1	564.60	564.80			2.14	0.08	Faure Formation	bioturbated grey/red/brown cst
DIR095	Coburn 1	616.70	616.85			3.50	0.17	Coburn Formation – Dirk Hartog Group	blue/grey (light and dark laminations) dolomitic cst
DIR096	Coburn 1	685.50	685.65			2.53	0.04	Coburn Formation – Dirk Hartog Group	blue/grey (light and dark laminations) dolomitic cst
DIR097	Coburn 1	794.40	794.65			3.16	0.08	Yaringa Formation – Dirk Hartog Group	blue/grey (light and dark banding) dolomitic cst/slt
DIR098	Coburn 1	893.75	893.90			2.48	0.15	Ajana Formation – Dirk Hartog Group	blue/grey (light and dark laminations) dolomitic cst
DIR099	Coburn 1	920.30	920.45			2.00	0.12	Marron Member – Ajana Formation – Dirk Hartog Group	dark blue/grey cst
DIR100	Coburn 1	951.70	951.90			3.93	0.57	Marron Member – Ajana Formation – Dirk Hartog Group	pale tan cst with numerous grey salt patches
DIR101	Coburn 1	1011.40	1011.65			2.65	0.10	Tumblagooda Sandstone	dark brown/red slt beds [10% of cored interval]
DIR102	Coburn 1	1030.00	1030.20			2.90	0.14	Tumblagooda Sandstone	pale pink to pink-red medium-grained to granule sst [90% of cored interval]; predom quartz and orthoclase grains
DIR103	Coburn 1	150.80	151.00			2.56	0.04	Windalia Sandstone Member – Muderong Shale – Winning Group	sst [friable]
DIR104	Coburn 1	166.30	166.50			1.75	0.15	Muderong Shale – Winning Group	mst
DIR105	GSWA Ballythanna 1	35.90	36.10			3.24	0.50	Keogh Formation – Wooramel Group	medium-grained to granule sst common cross beds

DIR106	GSWA Ballythanna 1	131.90	132.05			3.18	0.05	Ballythanna Sandstone Member –Callytharra Formation	light tan fine-grained to medium-grained sst [50% of cored interval]
DIR107	GSWA Ballythanna 1	292.30	292.43			3.21	0.19	Ballythanna Sandstone Member – Callytharra Formation	fine-grained sst with common carbonaceous flaser interbeds, whisps and slumped layers; pyritic; bioturbated [50% of cored interval]
DIR108	GSWA Ballythanna 1	358.75	358.90			1.70	0.08	Callytharra Formation	dark grey very fossiliferous shale
DIR109	GSWA Ballythanna 1	397.55	397.70			3.08	0.07	Lyons Group	fine-grained sst cream coloured
DIR110	GSWA Ballythanna 1	453.40	453.55			2.67	0.17	Lyons Group	light grey fine-grained sst with common flaser beds of dark grey slt
DIR111	GSWA Ballythanna 1	461.70	461.85			2.56	0.16	Lyons Group	dark grey interbedded slt/fine-grained sst
DIR112	Giralia 1	682.10	682.22			2.60	0.30	Billidee Formation – Wooramel Group	dark grey slt, fine-grained sst heterolithic
DIR113	Giralia 1	919.00	919.10			1.98	0.18	Cordalia Formation	dark grey cst?
DIR114	Kennedy Range 1			1530'	1530' 9"	2.86	0.11	Coolkilya Sandstone – Kennedy Group	tan grey medium-grained sst
DIR115	Kennedy Range 1			2005'	2005' 9"	3.51	0.05	Baker Formation – Byro Group	reddish brown medium-grained sst
DIR116	Kennedy Range 1			2015' 6"	2016' 3"	2.99	0.07	Nalbia Sandstone – Byro Group	brown medium-grained sst, occasional bioturbation
DIR117	Kennedy Range 1			2210'	2210' 6"	1.77	0.14	Wandagee Formation – Byro Group	dark brown slt/sst, heavily bioturbated
DIR118	Kennedy Range 1			2817'	2817' 9"	2.93	0.17	Cundlego Formation – Byro Group	dark grey/light grey sst, finely laminated, pin stripe laminations [50% of cored interval]
DIR119	Kennedy Range 1			2819' 6"	2820' 3"	2.23	0.15	Cundlego Formation – Byro Group	dark brown slt/sst, heavily bioturbated [50% of cored interval]
DIR120	Kennedy Range 1			4163' 6"	4164' 3"	1.27	0.13	Bulgadoo Shale – Byro Group	brown slt
DIR121	Kennedy Range 1			4711'	4711' 6"	2.75	0.14	Mallens Sandstone – Byro Group	dark grey/light grey sst, finely laminated, pin stripe laminations [25% of cored interval]
DIR122	Kennedy Range 1			5104'	5104' 9"	2.64	0.15	Mallens Sandstone – Byro Group	dark brown slt/sst, heavily bioturbated [75% of cored interval]
DIR123	Kennedy Range 1			5484' 3"	5484' 10"	2.29	0.07	Coyrie Formation – Byro Group	brown sst, minor bioturbation
DIR124	Kennedy Range 1			5537' 3"	5538'	3.04	0.09	Coyrie Formation – Byro Group	pale pink/tan sst, no bioturbation

DIR125	Linda 2	2814.80	2815.05			1.15	0.18	Dingo Claystone	dark grey cst/slt with thin stringers of light grey slt/sst - lenticular bedding
DIR126	Kennedy Range 1			6606'	6606' 9"	4.76	0.13	Moogooloo Sandstone – Wooramel Group	light tan grey coarse-grained sst with minor carbonaceous flecks
DIR127	GSWA Barrabiddy 1A	781.70	781.95			2.50	0.14	Nannyarra Sandstone	green grey mottled sst/slt
DIR128	GSWA Barrabiddy 1A	773.90	774.10			3.37	0.13	Gneudna Formation	light grey fine-grained sst with rare slt flasers, some slumping in adjacent core
DIR129	GSWA Barrabiddy 1A	759.55	759.70			1.80	0.30	Gneudna Formation	green-grey to light grey calcareous? Sst; highly fossiliferous
DIR130	GSWA Barrabiddy 1A	669.35	669.55			2.49	0.05	Gneudna Formation	light blue/grey lst with common stylolites
DIR131	GSWA Barrabiddy 1A	616.90	617.10			1.93	0.25	Gneudna Formation	dark green/grey slt/cst
DIR132	GSWA Barrabiddy 1A	617.65	617.90			0.64	0.00	Gneudna Formation	dark green/grey slt/cst; highly fossiliferous
DIR133	GSWA Barrabiddy 1A	551.75	551.95			3.93	0.08	Point Maud Member – Gneudna Formation	tan coloured lst; vugs/borings rare [10% of cored interval]
DIR134	GSWA Barrabiddy 1A	467.00	467.20			3.80	0.29	Point Maud Member – Gneudna Formation	tan coloured lst; ubiquitous vugs/borings [90% of cored interval]
DIR135	GSWA Barrabiddy 1A	213.20	213.45			2.55	0.18	Munabia Formation	light grey fine- to medium-grained sst with common flaser slt beds [~29 m = 34% of cored interval]
DIR136	GSWA Barrabiddy 1A	246.25	246.40			1.42	0.04	Munabia Formation	dark green/grey mst, mottled [~56 m = 66% of cored interval]
DIR137	Quail 1			8649'	8649' 9"	2.45	0.03	Yindagindy Formation	dark blue/grey calcareous mst
DIR138	Quail 1			7319'	7319' 9"	4.97	0.24	Quail Formation	reddish brown medium-grained sst
DIR139	Onslow 1			3781' 3"	3782'	2.02	0.09	Mungaroo Formation	grey mottled slt
DIR140	Onslow 1			4279' 9"	4280' 6"	2.91	0.17	Mungaroo Formation	pale grey/buff sst
DIR141	Onslow 1			5706'	5706' 9"	3.08	0.09	Locker Shale	light brown sst
DIR142	Onslow 1			6631'	6631' 9"	1.19	0.08	Locker Shale	dark grey shale
DIR143	Learmonth 2			5375'	5375' 9"	3.42	0.33	Learmonth Formation	cream medium-grained sst
DIR144	Pluto 3	3056.70	3057.00			1.35	0.09	Brigadier Formation	dark grey sly, highly bioturbated, thin whisps of fine-grained sst

DIR145	Pluto 3	3067.20	3067.50			1.84	0.45	Brigadier Formation	heterolithic fine-grained yellow/buff sst and dark grey slt; occasional bioturbation
DIR158	GSWA Barrabiddy 1A	66.00	66.30			1.19	0.03	Gearle Siltstone – Winning Group	dark grey friable mst
DIR159	GSWA Barrabiddy 1A	127.75	127.95			1.31	0.10	Windalia Radiolarite – Winning Group	grey mst, not dense
DIR160	GSWA Barrabiddy 1A	157.30	157.45			1.79	0.05	Windalia Sandstone Member – Muderong Shale – Winning Group	green slt to fine-grained sst; glauconitic
DIR207	BMR Glenburgh 9			192'	192' 6"	1.53	0.05	Madeline Formation – Byro Group	dark grey slt, cst; rare fossiliferous [graptolite?]

Attachment E: Summary of measured rock thermal conductivity data (measured at 35°C) for the Carnarvon Basin from Beardsmore (2005).

Sample	Well	Depth from (m)	Depth to (m)	Conductivity (W/mK)	Uncertainty (W/mK)	Formation	Lithology
GRB01	Coburn 1	48.73	48.77	1.42	0.09	Toolonga Calcilutite	Calcilutite
GRB02	GSWA Barrabiddy 1A	94.40	94.43	1.27	0.08	Gearle Siltstone – Winning Group	Green, grey siltstone
GRB03	Coburn 1	114.89	114.94	0.70	0.04	Alinga Fm – Winning Group	Dark grey siltstone
GRB04	GSWA Barrabiddy 1A	107.70	107.75	1.63	0.10	Windalia Radiolarite – Winning Group	Radiolarite
GRB05	Coburn 1	133.80	133.85	3.11	0.20	Windalia Sandstone Member – Muderong Shale – Winning Group	Poorly consolidated sand
GRB06	GSWA Barrabiddy 1A	160.62	160.65	2.00	0.13	Windalia Sandstone Member – Muderong Shale – Winning Group	Fine sandstone
GRB07	GSWA Barrabiddy 1A	180.35	180.38	1.63	0.10	Muderong Shale – Winning Group	Light grey shale
GRB08	Coburn 1	169.65	169.70	2.98	0.19	Birdrong Sandstone – Winning Group	Light grey, fine sandstone
GRB09	GSWA Mooka 1	92.50	92.53	3.12	0.20	Birdrong Sandstone – Winning Group	Medium quartz sandstone
GRB10	GSWA Ballythanna 1	26.00	26.03	3.23	0.21	Keogh Formation – Wooramel Group	Medium quartz sandstone
GRB11	GSWA Ballythanna 1	20.90	20.94	2.47	0.16	Keogh Formation – Wooramel Group	Fine to medium quartz sandstone
GRB12	GSWA Ballythanna 1	54.45	54.48	2.83	0.18	Callytharra Formation	Grey calcareous siltstone
GRB13	GSWA Ballythanna 1	135.00	135.04	3.26	0.21	Ballythanna Sandstone Member – Callytharra Formation	Medium quartz sandstone
GRB14	GSWA Ballythanna 1	157.50	157.53	3.30	0.21	Ballythanna Sandstone Member – Callytharra Formation	Shaly sandstone
GRB15	GSWA Ballythanna 1	215.90	215.93	3.93	0.25	Ballythanna Sandstone Member – Callytharra Formation	Carbonaceous sandstone
GRB16	GSWA Ballythanna 1	332.10	332.12	1.51	0.10	Callytharra Formation	Carbonaceous/fossiliferous siltstone
GRB17	GSWA Ballythanna 1	390.04	390.07	1.75	0.11	Lyons Group	Pebbly grey sandstone
GRB18	GSWA Ballythanna 1	410.14	410.17	3.75	0.24	Lyons Group	Fine quartz sandstone
GRB19	GSWA Barrabiddy 1A	193.67	193.71	4.42	0.28	Munabia Formation	Grey micaceous siltstone
GRB20	GSWA Barrabiddy 1A	205.17	205.22	4.03	0.26	Munabia Formation	Dolostone
GRB21	GSWA Gneudna 1A	15.72	15.74	2.54	0.16	Munabia Formation	Fine sandstone

GRB22	GSWA Barrabiddy 1A	378.77	378.80	5.73	0.36	Point Maud Member – Gneudna Formation	Vuggy dolostone
GRB23	GSWA Barrabiddy 1A	477.50	477.53	5.49	0.35	Point Maud Member – Gneudna Formation	Porous dolostone
GRB24	GSWA Barrabiddy 1A	489.15	489.20	6.21	0.39	Point Maud Member – Gneudna Formation	Dolostone
GRB25	GSWA Barrabiddy 1A	602.85	602.90	6.11	0.39	Point Maud Member – Gneudna Formation	Vuggy dolostone
GRB26	GSWA Barrabiddy 1A	628.67	628.70	2.30	0.15	Gneudna Formation	Dark grey fossiliferous limestone
GRB27	GSWA Barrabiddy 1A	768.58	768.60	1.27	0.08	Gneudna Formation	Dark grey limestone
GRB28	GSWA Gneudna 1A	57.25	57.27	3.17	0.20	Gneudna Formation	Pale siltstone
GRB29	GSWA Gneudna 1A	163.23	163.25	3.14	0.20	Gneudna Formation	Fossiliferous limestone
GRB30	GSWA Gneudna 1A	304.00	304.02	2.16	0.14	Gneudna Formation	Silty limestone
GRB31	GSWA Barrabiddy 1A	779.80	779.83	1.92	0.12	Nannyarra Sandstone	Laminated grey sandstone/siltstone
GRB32	GSWA Gneudna 1A	405.20	405.22	1.64	0.10	Nannyarra Sandstone	Dark grey siltstone w/ veins
GRB33	GSWA Gneudna 1A	474.08	474.10	3.23	0.21	Nannyarra Sandstone	Fine red sandstone
GRB34	Coburn 1	190.82	190.85	3.12	0.20	Kopke Sandstone – Kalbarri Group	Medium quartz sandstone
GRB35	Coburn 1	219.96	220.00	3.38	0.21	Kopke Sandstone – Kalbarri Group	Medium quartz sandstone
GRB36	Coburn 1	305.18	305.22	4.64	0.30	Kopke Sandstone – Kalbarri Group	Medium quartz sandstone
GRB37	Coburn 1	480.96	481.00	1.42	0.09	Kopke Sandstone – Kalbarri Group	Chloritised siltstone
GRB38	GSWA Mooka 1	111.37	111.40	2.74	0.17	Kopke Sandstone – Kalbarri Group	Chloritic, medium sandstone
GRB39	GSWA Mooka 1	112.97	113.00	3.07	0.20	Kopke Sandstone – Kalbarri Group	Clean, coarse sandstone
GRB40	Coburn 1	508.70	508.73	1.25	0.08	Faure Formation	Dolomudstone
GRB41	Coburn 1	508.70	508.73	1.77	0.11	Faure Formation	Dolomudstone
GRB42	GSWA Mooka 1	187.94	187.96	1.79	0.11	Faure Formation	Fine sandstone
GRB43	GSWA Mooka 1	220.77	220.80	1.88	0.12	Faure Formation	Fine red sandstone (Matrix material, hosts gypsum veins)
GRB44	GSWA Mooka 1	224.62	224.65	1.12	0.07	Faure Formation	Gypsum vein (makes up 10-15% of rock)
GRB45	GSWA Mooka 1	258.30	258.33	2.24	0.14	Faure Formation	Interbedded red/grey sandstone
GRB46	GSWA Mooka 1	312.05	312.09	5.88	0.37	Dirk Hartog Fm – Kalbarri Group	Dolostone
GRB47	GSWA Mooka 1	334.75	334.78	7.38	0.47	Dirk Hartog Fm – Kalbarri Group	Vuggy dolostone

GRB48	Coburn 1	611.60	611.65	1.47	0.09	Coburn Formation – Dirk Hartog Group	Dolomudstone
GRB49	Coburn 1	706.28	706.35	5.56	0.35	Coburn Formation – Dirk Hartog Group	Dolomite?
GRB50	Coburn 1	784.35	784.38	5.97	0.38	Yaringa Formation – Dirk Hartog Group	Dolomite?
GRB51	Coburn 1	814.60	814.64	4.11	0.26	Yaringa Formation – Dirk Hartog Group	Dolomudstone
GRB52	Coburn 1	909.50	909.55	3.16	0.20	Ajana Formation – Dirk Hartog Group	Dolomudstone
GRB53	Coburn 1	917.60	917.65	1.98	0.13	Marron Member – Ajana Formation – Dirk Hartog Group	Brown mudstone
GRB54	Coburn 1	917.60	917.65	1.53	0.10	Marron Member – Ajana Formation – Dirk Hartog Group	Brown mudstone
GRB55	Coburn 1	1090.98	1091.02	5.15	0.33	Tumblagooda Sandstone	Medium quartz sandstone
GRB56	GSWA Gneudna 1A	492.07	492.10	4.48	0.28	Basement (Gascoyne Complex)	Undeformed granite

Attachment F: Formation conductivities for the Carnarvon Basin based on lithology mixing methods. Notes refer to lithology mixing proportions and other reports generated by HDR for this same project.

Formation	Formation Conductivity (W/mK)	Uncer-tainty (W/mK)	Notes
Alluvium	1.42	0.14	Formation not tested; use Beardsmore (2005) value
Exmouth Sandstone	1.42	0.14	Formation not tested; Quaternary sands; use Alluvium value
undifferentiated Tertiary carbonates	1.68	0.34	Formation not tested; use Gippsland Limestone value (HDR, 2010)
Trealla Limestone	1.68	0.34	Formation not tested; use Gippsland Limestone value (HDR, 2010)
Mandu Calcarenite	1.68	0.34	Formation not tested; use Gippsland Limestone value (HDR, 2010)
Cape Range Group	1.68	0.34	Formation not tested; use Gippsland Limestone value (HDR, 2010)
Giralia Calcarenite	1.68	0.34	Formation not tested; use Gippsland Limestone value (HDR, 2010)
Wilcox Formation	1.23	0.05	Formation not tested; use Gearle Siltstone value
Cardabia Group	1.68	0.34	Formation not tested; use Gippsland Limestone value (HDR, 2010)
Lambert Formation	1.23	0.05	Formation not tested; use Gearle Siltstone value
Miria Formation	1.68	0.34	Formation not tested; use Gippsland Limestone value (HDR, 2010)
Korojon Calcarenite	1.68	0.34	Formation not tested; use Gippsland Limestone value (HDR, 2010)
Toolonga Calcilutite	1.45	0.06	Value calculated from DIR089 [50% of the representative lithology] and GRB01 [50% of the representative lithology]
Gearle Siltstone – Winning Group	1.23	0.05	Value calculated from DIR158 [50% of the representative lithology] and GRB02 [50% of the representative lithology]
Alinga Fm – Winning Group	1.00	0.20	Value from GRB03 is low and questionable as to whether this one sample is representative of the entire formation. Thus a value of 1.0 ± 0.2 is assigned to more accurately reflect the lithology
Windalia Radiolarite – Winning Group	1.45	0.10	Value calculated from DIR159 [50% of the representative lithology] and GRB04 [50% of the representative lithology]
Windalia Sandstone Member – Muderong Shale – Winning Group	2.26	0.09	Value calculated from DIR103 [25% of the representative lithology], DIR160 [25% of the representative lithology], GRB05 [25% of the representative lithology] and GRB06 [25% of the representative lithology]
Muderong Shale – Winning Group	1.69	0.13	Value calculated from DIR104 [50% of the representative lithology] and GRB07 [50% of the representative lithology]
Mardie Greensand Member – Winning Group	1.79	0.36	Formation not tested; use DIR160 value
Birdrong Sandstone – Winning Group	2.83	0.14	Value calculated from DIR090 [33.3% of the representative lithology], GRB08 [33.3% of the representative lithology] and GRB09 [33.3% of the representative lithology]

Wogatti Sandstone	2.83	0.57	Formation not tested; use Birdrong Sandstone value
Yarraloola Conglomerate	2.10	0.42	Formation not tested; use Beardsmore (1996) value
Flag Sandstone – Barrow Group	2.83	0.57	Formation not tested; use Birdrong Sandstone value
Flacourt Formation – Barrow Group	2.83	0.57	Formation not tested; use Birdrong Sandstone value
Dupuy Formation	2.29	0.46	Formation not tested; use 50% Learmonth Fm & 50% Dingo Claystone
Dingo Claystone	1.15	0.18	Value based on DIR125
Learmonth Formation	3.42	0.33	Value based on DIR143
Woodleigh Formation	1.63	0.33	Formation not tested; described as lacustrine shaly succession; use GRB07 value
Brigadier Formation	1.56	0.22	Value calculated from DIR144 [50% of the representative lithology] and DIR145 [50% of the representative lithology]
Mungaroo Formation	2.39	0.12	Value calculated from DIR139 [50% of the representative lithology] and DIR140 [50% of the representative lithology]
Locker Shale	1.27	0.11	Value calculated from DIR141 [10% of the representative lithology] and DIR142 [90% of the representative lithology]
Coolkilya Sandstone – Kennedy Group	2.86	0.11	Value based on DIR114
Byro Group (undifferentiated)	2.12	0.42	Value based on harmonic mean of Baker Formation, Nalbia Sandstone, Wandagee Formation, Cundlego Formation, Bulgadoo Shale, Mallens Sandstone, Coyrie Formation, and Madeline Formation; 20% uncertainty
Baker Formation – Byro Group	3.51	0.05	Value based on DIR115
Nalbia Sandstone – Byro Group	2.99	0.07	Value based on DIR116
Wandagee Formation – Byro Group	1.77	0.14	Value based on DIR117
Cundlego Formation – Byro Group	2.53	0.16	Value calculated from DIR118 [50% of the representative lithology] and DIR119 [50% of the representative lithology]
Bulgadoo Shale – Byro Group	1.27	0.13	Value based on DIR120
Mallens Sandstone – Byro Group	2.69	0.14	Value calculated from DIR121 [50% of the representative lithology] and DIR122 [50% of the representative lithology]
Coyrie Formation – Byro Group	2.62	0.08	Value calculated from DIR123 [50% of the representative lithology] and DIR124 [50% of the representative lithology]
Madeline Formation – Byro Group	1.53	0.05	Value based on DIR207
Billidee Formation – Wooramel Group	2.60	0.30	Value based on DIR112
Keogh Formation – Wooramel Group	2.93	0.27	Value calculated from DIR105 [33.3% of the representative lithology], GRB10 [33.3% of the representative lithology] and GRB11 [33.3% of the representative lithology]

Moogooloo Sandstone – Wooramel Group	4.76	0.13	Value based on DIR126
Cordalia Formation – Wooramel Group	1.98	0.18	Value based on DIR113
Ballythanna Sandstone Member – Callytharra Formation	3.36	0.18	Value calculated from DIR106 [20% of the representative lithology], DIR107 [20% of the representative lithology], GRB13 [20% of the representative lithology], GRB14 [20% of the representative lithology] and GRB15 [20% of the representative lithology]
Callytharra Formation	1.87	0.11	Value calculated from DIR108 [33.3% of the representative lithology], GRB12 [33.3% of the representative lithology] and GRB16 [33.3% of the representative lithology]
Lyons Group	2.59	0.15	Value calculated from DIR109 [20% of the representative lithology], DIR110 [20% of the representative lithology], DIR111 [20% of the representative lithology], GRB17 [20% of the representative lithology] and GRB18 [20% of the representative lithology]
undifferentiated Callytharra Formation/Lyons Group	2.17	0.43	Value based on harmonic mean of Callytharra Formation and Lyons Group (for use in the offshore northern Carnarvon Basin); 20% uncertainty
Quail Formation	3.28	0.66	Formation not tested; use 50% DIR137 & 50% DIR138
Yindagindy Formation	3.80	0.76	Formation not tested; use 70% DIR138 & 30% DIR137
Munabia Formation	2.55	0.15	Value calculated from DIR135 [35% of the representative lithology], DIR136 [10% of the representative lithology], GRB19 [10% of the representative lithology], GRB20 [10% of the representative lithology] and GRB21 [35% of the representative lithology]
undifferentiated Early Carboniferous-Late Devonian	3.12	0.62	Value based on harmonic mean of Quail Formation, Yindagindy Formation and Munabia Formation (for use in the onshore northern Carnarvon Basin); 20% uncertainty
Point Maud Member – Gneudna Formation	5.00	0.28	Value calculated from DIR133 [16.7% of the representative lithology], DIR134 [16.7% of the representative lithology], GRB22 [16.7% of the representative lithology], GRB23 [16.7% of the representative lithology], GRB24 [16.7% of the representative lithology] and GRB25 [16.7% of the representative lithology]
Gneudna Formation	1.91	0.11	Value calculated from DIR128 [5% of the representative lithology], DIR129 [5% of the representative lithology], DIR130 [15% of the representative lithology], DIR131 [5% of the representative lithology], DIR132 [5% of the representative lithology], GRB26 [15% of the representative lithology], GRB27 [15% of the representative lithology], GRB28 [5% of the representative lithology], GRB29 [15% of the representative lithology] and GRB30 [15% of the representative lithology]
Nannyarra Sandstone	2.50	0.16	Value calculated from DIR127 [15% of the representative lithology], GRB31 [15% of the representative lithology], GRB32 [15% of the representative lithology] and GRB33 [55% of the representative lithology]
Sweeney Mia Formation – Kalbarri Group	2.78	0.56	Formation not tested; use Ajana Formation – Dirk Hartog Group value

Kopke Sandstone – Kalbarri Group	2.99	0.17	Value calculated from DIR091 [13% of the representative lithology], DIR092 [13% of the representative lithology], DIR093 [4.5% of the representative lithology], GRB34 [13% of the representative lithology], GRB35 [13% of the representative lithology], GRB36 [13% of the representative lithology], GRB37 [4.5% of the representative lithology], GRB38 [13% of the representative lithology] and GRB39 [13% of the representative lithology]
Faure Formation	1.62	0.10	Value calculated from DIR094 [15% of the representative lithology], GRB40 [15% of the representative lithology], GRB41 [15% of the representative lithology], GRB42 [15% of the representative lithology], GRB43 [15% of the representative lithology], GRB44 [15% of the representative lithology] and GRB45 [10% of the representative lithology]
Dirk Hartog Fm	5.88	0.37	Value based on GRB46 [GRB47 not used as possible calibration issue]
Coburn Formation – Dirk Hartog Group	2.59	0.12	Value calculated from DIR095 [25% of the representative lithology], DIR096 [25% of the representative lithology], GRB48 [25% of the representative lithology] and GRB49 [25% of the representative lithology]
Yaringa Formation – Dirk Hartog Group	4.13	0.19	Value calculated from DIR097 [33.3% of the representative lithology], GRB50 [33.3% of the representative lithology] and GRB51 [33.3% of the representative lithology]
Ajana Formation – Dirk Hartog Group	2.78	0.17	Value calculated from DIR098 [50% of the representative lithology] and GRB52 [50% of the representative lithology]
Marron Member – Ajana Formation – Dirk Hartog Group	2.09	0.16	Value calculated from DIR099 [25% of the representative lithology], DIR100 [25% of the representative lithology], GRB53 [25% of the representative lithology] and GRB54 [25% of the representative lithology]
Tumblagooda Sandstone	3.57	0.18	Value calculated from DIR101 [10% of the representative lithology], DIR102 [45% of the representative lithology] and GRB55 [45% of the representative lithology]
undifferentiated Early Permian-Ordovician	2.35	0.48	Value based on harmonic mean of Lyons Group, Callytharra Formation, Gneudna Formation, Nannyarra Sandstone and Tumblagooda Sandstone (for use in the offshore northern Carnarvon Basin); 20% uncertainty
undifferentiated Early Carboniferous-Ordovician	2.96	0.60	Value based on harmonic mean of Quail Formation, Yindagindy Formation, Munabia Sandstone, Point Maud Member, Gneudna Formation, Nannyarra Sandstone and Tumblagooda Sandstone (for use in the onshore Byron Sub-basin); 20% uncertainty
undifferentiated Early Carboniferous-Ordovician	2.49	0.50	Value based on harmonic mean of Gneudna Formation, Nannyarra Sandstone and Tumblagooda Sandstone (for use in the offshore northern Carnarvon Basin); 20% uncertainty
Basement – Metasedimentary	4.10	0.10	Formation not tested; use Driscoll *et al* (2009) value
Basement – Granite (Gascoyne Complex)	4.48	0.28	Value based on GRB56

Attachment G: Estimated heat generation for granite samples adjacent to the Carnarvon Basin. K_2O, U and Th data from OZCHEM (2007).

Region	Province	Latitude (°)	Longitude (°)	Datum	Lithname	Description	K_2O by weight %	K (ppm)	U (ppm)	Th (ppm)	Average assumed density (g/cm^3)	Heat generation from isotopic abundance ratios ($\mu W/m^3$)
Gascoyne Region	-	-25.069936	116.598265	GDA94	granite	biotite monzogranite	5.86	48600	2.19	67.1	2.68	5.75
Gascoyne Region	-	-25.609110	116.338535	GDA94	granite	biotite tonalite dyke	1.6	13300	2.42	39.1	2.68	3.51
Gascoyne Region	Gascoyne Block	-24.133633	115.729084	GDA94	granite	medium to coarse grained biotite granodiorite [informal name: Minnie Creek granodiorite]	2.81	23300	2	17	2.68	1.94
Yilgarn Region	Gascoyne Block	-24.786967	115.893590	GDA94	granite	felsic intrusive [informal name: Yinnetharra gneissic granodiorite]	5.1	42300	4	55	2.68	5.31
Gascoyne Region	Gascoyne Block	-23.558642	115.347179	GDA94	granite	felsic intrusive	3.7	30700	2	20	2.68	2.22
Gascoyne Region	Gascoyne Block	-23.196140	115.255575	GDA94	granite	pegmatite	5.6	46500	4	10	2.68	2.18
Gascoyne Region	Gascoyne Block	-23.500312	115.338878	GDA94	granite	felsic intrusive [informal name: Black Hill granodiorite]	3.5	29100	3	30	2.68	3.16
Gascoyne Region	Gascoyne Block	-23.662813	115.351380	GDA94	granite	felsic intrusive [informal name: Black Hill granodiorite]	2.7	22400	1	20	2.68	1.88
Gascoyne Region	Gascoyne Block	-23.612813	115.318879	GDA94	granite	felsic intrusive [informal name: Black Hill granodiorite]	2.8	23200	4	20	2.68	2.66
Gascoyne Region	Gascoyne Block	-23.591972	115.368079	GDA94	granite	felsic intrusive	3.2	26600	2	10	2.68	1.47
Gascoyne Region	Gascoyne Block	-23.958644	115.447183	GDA94	granite	felsic intrusive	7.45	61800	2	15	2.68	2.16
Gascoyne Region	Gascoyne Block	-24.062839	115.235584	GDA94	granite	felsic intrusive	3.26	27100	4	15	2.68	2.35
Gascoyne Region	Gascoyne Block	-24.179499	115.385585	GDA94	granite	felsic intrusive	3.82	31700	6	15	2.68	2.91
Gascoyne Region	Gascoyne Block	-23.833645	115.318882	GDA94	granite	felsic intrusive [informal name: Minnie Creek granodiorite]	5.47	45400	3	45	2.68	4.38
Gascoyne Region	Gascoyne Block	-23.800314	115.305581	GDA94	granite	felsic intrusive	5.39	44700	6	40	2.68	4.79
Gascoyne Region	Gascoyne Block	-23.921144	115.497182	GDA94	granite	felsic intrusive [informal name: Minnie Creek granodiorite]	3.32	27600	1	10	2.68	1.22

Gascoyne Region	Gascoyne Block	-23.825314	115.318081	GDA94	granite	pegmatite	8.85	73500	2	5	2.68	1.56
Gascoyne Region	Gascoyne Block	-23.866974	115.380582	GDA94	granite	felsic intrusive [informal name: Minnie Creek granodiorite]	3.29	27300	1	15	2.68	1.57
Gascoyne Region	Gascoyne Block	-23.858643	115.468081	GDA94	granite	felsic intrusive [informal name: Minnie Creek granodiorite]	5.52	45800	4	40	2.68	4.29
Gascoyne Region	Gascoyne Block	-24.000669	115.232884	GDA94	granite	felsic intrusive [informal name: Minnie Creek granodiorite]	3.43	28500	2	15	2.68	1.84
Gascoyne Region	Gascoyne Block	-24.019169	115.245884	GDA94	granite	felsic intrusive	2.88	23900	1	5	2.68	0.84
Gascoyne Region	Gascoyne Block	-23.700314	115.285580	GDA94	granite	felsic intrusive	4.65	38600	1	15	2.68	1.68
Gascoyne Region	Gascoyne Block	-23.079470	115.234674	GDA94	granite	felsic intrusive	5.86	48600	2	10	2.68	1.68
Gascoyne Region	Gascoyne Block	-23.954475	115.335583	GDA94	granite	felsic intrusive	5.56	46200	2	10	2.68	1.66
Gascoyne Region	Gascoyne Block	-23.971145	115.401383	GDA94	granite	felsic intrusive	1.73	14400	11	30	2.68	5.10
Gascoyne Region	Gascoyne Block	-23.750313	115.455580	GDA94	granite	felsic intrusive	6.75	56000	5	25	2.68	3.58
Gascoyne Region	Gascoyne Block	-23.996157	115.297191	GDA94	granite	felsic intrusive [informal name: Minnie Creek granodiorite]	5.51	45700	6	30	2.68	4.10
Gascoyne Region	Gascoyne Block	-24.265573	115.802485	GDA94	granite	felsic intrusive	3.1	25700	2	5	2.68	1.11
Gascoyne Region	Gascoyne Block	-24.141667	115.486884	GDA94	granite	felsic intrusive [informal name: Minnie Creek granodiorite]|	2.62	21800	6	15	2.68	2.82
Gascoyne Region	Gascoyne Block	-24.021134	115.561883	GDA94	granite	felsic intrusive [informal name: Minnie Creek granodiorite]	5.1	42300	2	30	2.68	3.03
Gascoyne Region	Gascoyne Block	-23.275311	115.199976	GDA94	granite	felsic intrusive	5.83	48400	8	65	2.68	7.11
Gascoyne Region	Gascoyne Block	-23.305863	115.102477	GDA94	granite	felsic intrusive [informal name: Black Hill granodiorite]	6.12	50800	6	60	2.68	6.26
Gascoyne Region	Gascoyne Block	-23.069748	115.449973	GDA94	granite	felsic intrusive	4.6	38200	2	10	2.68	1.58
Yilgarn Region	Gascoyne Block	-25.119757	116.134994	GDA94	granite	felsic intrusive [informal name: Dunnawah granite]	5.62	46700	2	130	2.68	10.12
Yilgarn Region	Gascoyne Block	-25.450348	116.268097	GDA94	granite	felsic intrusive [informal name: Dalgety gneissic granodiorite]	2.27	18800	1.5	22	2.68	2.12
Yilgarn Region	Gascoyne Block	-24.742808	115.748090	GDA94	granite	felsic intrusive [informal name: Yinnetharra gneissic granodiorite]	4.6	38200	4	25	2.68	3.16
Gascoyne Region	Gascoyne Block	-23.708644	115.280580	GDA94	granite	felsic intrusive	5.33	44200	10	70	2.68	7.94

Gascoyne Region	Gascoyne Block	-23.485031	115.477777	GDA94	granite	felsic intrusive	5.05	41900	2	50	2.68	4.44
Gascoyne Region	Gascoyne Block	-23.380861	115.284977	GDA94	granite	felsic intrusive	5.82	48300	6	55	2.68	5.88
Gascoyne Region	Gascoyne Block	-24.589196	115.734689	GDA94	granite	felsic intrusive [informal name: Dunnawah granite]	6.68	55500	1	75	2.68	6.07
Gascoyne Region	Gascoyne Block	-24.181668	115.463985	GDA94	granite	felsic intrusive	3.7	30700	1	30	2.68	2.66
Gascoyne Region	Gascoyne Block	-23.621142	115.402179	GDA94	granite	felsic intrusive [informal name: Black Hill granodiorite]	3	24900	2	10	2.68	1.46
Gascoyne Region	Gascoyne Block	-23.766975	115.263881	GDA94	granite	felsic intrusive	4.66	38700	3	15	2.68	2.20
Gascoyne Region	Gascoyne Block	-23.875316	115.238882	GDA94	granite	biotite granodiorite dyke	2.45	20300	10	25	2.68	4.54
Yilgarn Region	Gascoyne Block	-25.073949	115.877754	GDA94	granite	gneissic biotite granite	6.15	51100	11	130	2.68	12.49
Gascoyne Region	Gascoyne Block	-23.933644	115.488882	GDA94	granite	granite dyke [informal name: Minnie Creek granodiorite]	2.98	24700	4	10	2.68	1.97

Median	**2.74**

Attachment H: Estimated heat generation for metasedimentary rock samples adjacent to the Carnarvon Basin. K_2O, U and Th data from OZCHEM (2007).

Region	Province	Latitude (°)	Longitude (°)	Datum	Lithname	Description	K_2O by weight %	K (ppm)	U (ppm)	Th (ppm)	Average assumed density (g/cm^3)	Heat generation from isotopic abundance ratios ($\mu W/m^3$)
Gascoyne Region	-	-25.265412	116.316973	GDA94	sandstone	metasandstone	0.3	2500	0.57	9.5	2.48	0.78
Gascoyne Region	Gascoyne Block	-23.041938	115.401373	GDA94	schist	metasediment	3.9	32400	3	20	2.48	2.31
Gascoyne Region	Gascoyne Block	-23.000308	115.322173	GDA94	schist	metasediment	4.5	37400	1	20	2.48	1.87
Gascoyne Region	Gascoyne Block	-23.004468	115.322173	GDA94	schist	metasediment	2.2	18300	5	10	2.48	2.01
Gascoyne Region	Ashburton Basin	-23.058639	115.313874	GDA94	phyllite	metasediment	3.5	29100	1	20	2.48	1.80
Gascoyne Region	Gascoyne Block	-23.108639	115.301374	GDA94	schist	metasediment	5.5	45700	2	20	2.48	2.18
Gascoyne Region	Gascoyne Block	-23.525311	115.430578	GDA94	schist	metasediment	4.2	34900	2	30	2.48	2.74
Gascoyne Region	Gascoyne Block	-23.537812	115.351378	GDA94	arkose	metamorphic arkose?	5.9	49000	2	20	2.48	2.21
Gascoyne Region	Gascoyne Block	-23.587812	115.441379	GDA94	arkose	metamorphic arkose	5.7	47300	2	30	2.48	2.85
Gascoyne Region	Gascoyne Block	-23.583641	115.451379	GDA94	arkose	metamorphic arkose	3.7	30700	2	10	2.48	1.40
Gascoyne Region	Gascoyne Block	-23.246139	115.485275	GDA94	schist	metasediment	4.6	38200	8	10	2.48	2.90
Gascoyne Region	Gascoyne Block	-23.525311	115.418078	GDA94	arkose	metamorphic arkose	4	33200	1	10	2.48	1.18

Median	**2.10**

Attachment I: Modelled heat flow values and estimates of reliability for wells in the Carnarvon Basin.

Well Name	Total Depth (mMD)	Total Depth (mTVD)	Probable basement lithology	Depth to Basement (m)	Depth from Total Depth to Basement (m)	Datum	Latitude (°)	Longitude (°)	DST Temp Data (y/n)	Horner Temp Data (y/n)	Overall Reliability (1 lowest to 5 highest)	Heat Flow (mW/m^2)	Uncer-tainty ± (mW/m^2)
BMR 05 Yanrey	631.0	631.0	Meta-sediment	8000	7369.0	CLARKE	-22.658611	114.245833	No Temperature Data				
BMR 06 Kennedy Range	305.0	305.0	Granite	6000	5695	CLARKE ?	-24.098611	114.772222	No Temperature Data				
BMR 07 Kennedy Range	609.0	609.0	Granite	6000	5391	CLARKE ?	-24.098611	114.775000	No Temperature Data				
BMR 08 Glenburgh	915.6	915.6	Meta-sediment	3250	2334.4	GDA94	-25.757058	115.670829	No Temperature Data				
BMR 09 Glenburgh	700.7	700.7	Granite	4000	3299.3	GDA94	-25.557053	115.899995	No Temperature Data				
Crest 1 Deepening	2037.0	1751.0	Meta-sediment	12000	10249	GDA94	-21.456001	115.021362	n	n	2	50	4.1
Crest 2	1686.5	1349.1	Meta-sediment	12000	10650.9	GDA94	-21.456126	115.021309	n	n	2	55	4.8
Crest 5	1433.0	1200.0	Meta-sediment	12000	10800	GDA94	-21.451615	115.006626	n	n	2	42	3.4
Crest 6	1954.5	1157.0	Meta-sediment	12000	10843	GDA94	-21.455995	115.021362	n	n	2	52	4.6
Grierson 1	438.0	438.0	Meta-sediment	4500	4062	CLARKE	-24.201317	113.774000	No Temperature Data				
Grierson 2	457.5	457.5	Meta-sediment	4500	4042.5	CLARKE	-24.201944	113.786528	No Temperature Data				
Grierson 3	442.0	442.0	Meta-sediment	4500	4058	CLARKE	-24.201944	113.760139	No Temperature Data				
GSWA Ballythanna 1	465.2	465.2	Meta-sediment	4000	3534.8	GDA94	-26.060395	115.671110	n	n	2	55	11.4
GSWA Barrabiddy 1A	782.9	782.9	Meta-sediment	3200	2417.1	GDA94	-23.831222	114.334691	n	n	2	70	5.2
GSWA Mooka 1	418.0	418.0	Meta-sediment	4000	3582	GDA94	-24.975387	114.806934	n	n	2	65	7.1
GSWA Woodleigh 2A	618.3	618.3	Meta-sediment	4500	3881.7	GDA94	-26.056461	114.527581	n	n	1	70	6.9
Learmonth 1	2327.5	2327.5	Meta-sediment	15000	12672.5	GDA94	-22.183150	114.061892	No Temperature Data				

North Ballythanna Corehole 1	198.1	198.1	Meta-sediment	4000	3801.9	CLARKE	-25.927778	115.663889	No Temperature Data				
North Ballythanna Corehole 2	182.9	182.9	Meta-sediment	4000	3817.1	CLARKE	-25.932778	115.647222	No Temperature Data				
North Ballythanna Corehole 3	211.8	211.8	Meta-sediment	4000	3788.2	CLARKE	-25.936111	115.633333	No Temperature Data				
North Ballythanna Corehole 4	156.9	156.9	Meta-sediment	4000	3843.1	CLARKE	-25.922222	115.679167	No Temperature Data				
Rosette 1	3279.0	2570.0	Granite	15000	12430	GDA94	-20.655242	115.575266	y	y	5	55	5.7
Rough Range 01A (Re-Entry)	1107.3	1107.3	Meta-sediment	5000	3892.7	GDA94	-22.417597	114.083561	n	y	3	74	5.1
Rough Range 02	1243.3	1243.3	Meta-sediment	5000	3756.7	CLARKE	-22.431967	114.069936	No Temperature Data				
Rough Range 03	1193.3	1193.3	Meta-sediment	5000	3806.7	CLARKE	-22.412528	114.087703	No Temperature Data				
Rough Range 04	1146.0	1146.0	Meta-sediment	5500	4354	CLARKE	-22.424525	114.083386	No Temperature Data				
Rough Range 05	1149.7	1149.7	Meta-sediment	5000	3850.3	CLARKE	-22.420086	114.077756	No Temperature Data				
Rough Range 06	1126.8	1126.8	Meta-sediment	5000	3873.2	CLARKE	-22.421606	114.082047	No Temperature Data				
Rough Range 07	1304.8	1304.8	Meta-sediment	5000	3695.2	CLARKE	-22.445867	114.070222	No Temperature Data				
Rough Range 08	1194.5	1194.5	Meta-sediment	5000	3805.5	CLARKE	-22.447522	114.064111	No Temperature Data				
Rough Range 09	1171.7	1171.7	Meta-sediment	6000	4828.3	CLARKE	-22.448639	114.074661	No Temperature Data				
Rough Range South 1	873.9	873.9	Meta-sediment	5500	4626.1	CLARKE	-22.622383	113.962044	No Temperature Data				
Rough Range South 5	1450.8	1450.8	Meta-sediment	6000	4549.2	CLARKE	-22.574908	113.989519	n	n	2	45	2.1
Saddleback 1	148.0	148.0	Meta-sediment	1000	852	GDA94	-21.440350	115.776340	No Temperature Data				
Saladin 13H	2240.0	1103.7	Meta-sediment	12000	10896.3	GDA94	-21.463009	115.019037	n	n	2	52	4.6
Saladin 13H ST1	2252.0	1110.6	Meta-sediment	12000	10889.4	GDA94	-21.463009	115.019037	n	n	2	52	4.6
Saladin 14	2571.0	1083.0	Meta-sediment	12000	10917	GDA94	-21.459043	115.024481	n	n	2	54	4.9
Saladin 18M	2229.0	1102.8	Meta-sediment	12000	10897.2	GDA94	-21.462848	115.019042	n	n	2	61	5.8

Saladin 19M ST1	2650.0	1100.0	Meta-sediment	12000	10900	GDA94	-21.462848	115.019034	n	n	2	60	5.7
Saladin 24	2145.0	1130.5	Granite	15000	13869.5	GDA94	-21.463098	115.018909	n	n	2	50	5.3
Tanami 3 ST1	3080.0	1867.2	Granite	15000	13132.8	GDA94	-20.653557	115.579662	n	n	2	52	5.6
Tanami 3 ST2	2815.0	1901.5	Granite	15000	13098.5	GDA94	-20.653557	115.579662	n	n	2	52	5.5
Windoo 1A	218.5	218.5	Meta-sediment	4000	3781.5	GDA94	-21.353684	115.683281	n	n	2	95	24.6
Woorawa 1	202.4	202.4	Meta-sediment	2000	1797.6	GDA94	-21.364043	115.793893	No Temperature Data				
Yardie East 1	5594.0	4127.0	Meta-sediment	16000	11873	GDA94	-22.006484	113.927321	n	y	3	47	3.5

Attachment J: Estimated isotherm depths and basement temperatures for wells in the Carnarvon Basin. *Purple hue indicates isotherm depth is modelled to a known formation as reported in the well completion report.

Well Name	Total Depth (mMD)	Total Depth (mTVD)	Datum	Latitude (°)	Longitude (°)	Heat Flow (mW/m^2)	uncertainty ± (mW/m^2)	Temp at 5,000 m (°C)	Depth to 100°C (m)	Fm	Depth to 150°C (m)	Fm	Depth to 200°C (m)	Fm
Crest 1 Deepening	2037.0	1751.0	GDA94	-21.456001	115.021362	50	4.1	198.9	2210	Dingo Claystone	3467	Mungaroo Formation	5025	Locker Shale
Crest 2	1686.5	1349.1	GDA94	-21.456126	115.021309	55	4.8	217.0	2056	Dingo Claystone	3106	Dingo Claystone	4630	Locker Shale
Crest 5	1433.0	1200.0	GDA94	-21.451615	115.006626	42	3.4	170.7	2527	Dingo Claystone	4397	Mungaroo Formation	5844	Locker Shale
Crest 6	1954.5	1157.0	GDA94	-21.455995	115.021362	52	4.6	206.3	2143	Dingo Claystone	3276	Mungaroo Formation	4855	Locker Shale
GSWA Ballythanna 1	465.2	465.2	GDA94	-26.060395	115.671110	55	11.4	126.9	3498	Lower Cretaceous-Ordovician (undif.)	6453	Basement (meta-sediment)	9716	Basement (metasediment)
GSWA Barrabiddy 1A	782.9	782.9	GDA94	-23.831222	114.334691	70	5.2	149.1	2691	Tumblagooda Sandstone	5043	Basement (meta-sediment)	7426	Basement (metasediment)
GSWA Mooka 1	418.0	418.0	GDA94	-24.975387	114.806934	65	7.1	138.3	3129	Tumblagooda Sandstone	5604	Basement (meta-sediment)	8177	Basement (metasediment)
GSWA Woodleigh 2A	618.3	618.3	GDA94	-26.056461	114.527581	70	6.9	159.0	2494	Tumblagooda Sandstone	4590	Basement (meta-sediment)	6839	Basement (metasediment)
Rosette 1	3279.0	2570.0	GDA94	-20.655242	115.575266	55	5.7	228.9	1901	Flag Sandstone	3343	Dingo Claystone	4393	Dingo Claystone
Rough Range 01A (Re-Entry)	1107.3	1107.3	GDA94	-22.417597	114.083561	74	5.1	237.4	1453	Lyons Group	3115	Carboniferous-Devonian (undif.)	4237	Gneudna Formation
Rough Range South 5	1450.8	1450.8	CLARKE	-22.574908	113.989519	45	2.1	143.6	2874	Lyons Group	5302	Lyons Group	8462	Basement (metasediment)
Saladin 13H	2240.0	1103.7	GDA94	-21.463009	115.019037	52	4.6	196.1	2344	Dupuy Formation	3521	Dingo Claystone	5090	Locker Shale
Saladin 13H ST1	2252.0	1110.6	GDA94	-21.463009	115.019037	52	4.6	196.2	2339	Dupuy Formation	3519	Dingo Claystone	5087	Locker Shale

Saladin 14	2571.0	1083.0	GDA94	-21.459043	115.024481	54	4.9	202.6	2249	Dupuy Formation	3426	Dingo Claystone	4942	Locker Shale
Saladin 18M	2229.0	1102.8	GDA94	-21.462848	115.019042	61	5.8	226.4	1942	Dupuy Formation	3125	Dingo Claystone	4335	Mungaroo Formation
Saladin 19M ST1	2650.0	1100.0	GDA94	-21.462848	115.019034	60	5.7	222.8	1985	Dupuy Formation	3166	Dingo Claystone	4428	Mungaroo Formation
Saladin 24	2145.0	1130.5	GDA94	-21.463098	115.018909	50	5.3	190.6	2503	Dupuy Formation	3753	Dingo Claystone	5346	Mungaroo Formation
Tanami 3 ST1	3080.0	1867.2	GDA94	-20.653557	115.579662	52	5.6	215.9	2176	Lower Barrow Group	3536	Dingo Claystone	4647	Dingo Claystone
Tanami 3 ST2	2815.0	1901.5	GDA94	-20.653557	115.579662	52	5.5	215.9	2175	Lower Barrow Group	3535	Dingo Claystone	4646	Dingo Claystone
Windoo 1A	218.5	218.5	GDA94	-21.353684	115.683281	95	24.6	245.7	1622	Lower Carboniferous-Ordovician (undif.)	2732	Lower Carboniferous-Ordovician (undif.)	3765	Lower Carboniferous-Ordovician (undif.)
Yardie East 1	5594.0	4127.0	GDA94	-22.006484	113.927321	47	3.5	191.6	2166	Dingo Claystone	3394	Dingo Claystone	5329	Mungaroo Formation

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Appendix 2

Thermal conductivity of core samples DIR089-DIR207

An appendix to the report Geothermal Energy Potential in Selected Areas of Western Australia (Carnarvon Basin)

Prepared for the Department of Mines and Petroleum, Western Australia

July 2010

Executive Summary

The Western Australian Department of Mines and Petroleum (DMP) commissioned Hot Dry Rocks Pty Ltd (HDR) to measure the thermal conductivity of 119 rock specimens collected from the DMP Perth Core Library and Geoscience Australia Canberra Core Library in April 2010. These specimens came from the Bonaparte, Browse, Carnarvon and Officer basins. Measurements were made on the specimens using a steady state divided bar apparatus calibrated for the range 1.4–9.8 W/mK. Up to three samples were prepared from each specimen to investigate variation in thermal conductivity over short distance scales and to determine mean conductivity and uncertainty. All values were measured at a standard temperature of 30°C. The uncertainties are dependent upon sample quality and preparation method..

HDR considers the following points to be important:

- While the specimens were chosen to represent the cored geological sections from which they came, there is no guarantee that the sections themselves are typical of the overall geological formations.
- It is to be expected that the thermal conductivity of a given formation will vary from place to place if the porosity of the formation varies.
- Thermal conductivity of rocks is sensitive to temperature. This should be kept in mind when developing models of in situ thermal conductivity.

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1. Introduction

Thermal conductivity is the physical property that controls the rate at which heat energy flows through a material in a given thermal gradient. In the S.I. system of units, it is measured in watts per metre-kelvin (W/mK). In the Earth, thermal conductivity controls the rate at which temperature increases with depth for a given heat flow. The thermal conductivity distribution within a section of crust must be known in order to calculate crustal heat flow from temperature gradient data, or to predict temperature distribution from a given heat flow.

The Western Australian Department of Mines and Petroleum (DMP) commissioned Hot Dry Rocks Pty Ltd (HDR) to undertake heat flow modelling in the Bonaparte, Browse, Carnarvon, and Officer basins. HDR collected 119 specimens[1] from the DMP Perth Core Library and Geoscience Australia Canberra Core Library in April 2010 (Table 1). Thermal conductivity measurements were made on these specimens using a steady state divided bar apparatus calibrated for the range 1.4–9.8 W/mK.

Thermal conductivity is sensitive to temperature (e.g. Vosteen and Schellschmidt, 2003[2]), in general decreasing as temperature increases. The measurements contained in this report were made within ± 2°C of 30°C.

[1] In this report the word "specimen" refers to a raw piece of rock delivered to HDR, while "sample" refers to part of a specimen prepared for conductivity measurement. In general, three samples are prepared from each specimen.

[2] **Vosteen, H.-D. and Schellschmidt, R.** (2003). Influence of temperature on thermal conductivity, thermal capacity and thermal diffusivity for different types of rock. *Physics and Chemistry of the Earth*, 28, 499–509.

Table 1. Specimens presented for thermal conductivity measurement.

Well	Basin	Formation	Lithology	Depth From (m)	Depth To (m)	Depth From (')	Depth To (')	HDR sample ID
Coburn 1	Carnarvon	Toolonga Calcilutite	light grey marl	73.70	73.92			DIR089
Coburn 1	Carnarvon	Birdrong Sandstone	light brown carbonaceous fine-grained sst	172.70	172.85			DIR090
Coburn 1	Carnarvon	Kopke Sandstone	grey light brown sst with finely laminated	212.70	212.85			DIR091
Coburn 1	Carnarvon	Kopke Sandstone	red bed sst finely laminated, similar to DIR091 but red	404.40	404.55			DIR092
Coburn 1	Carnarvon	Kopke Sandstone	red/green/grey mottled slt/cst - differing oxidising regimes	475.40	475.50			DIR093
Coburn 1	Carnarvon	Faure Formation	bioturbated grey/red/brown cst	564.60	564.80			DIR094
Coburn 1	Carnarvon	Coburn Formation, Dirk Hartog Group	blue/grey (light and dark laminations) dolomitic cst	616.70	616.85			DIR095
Coburn 1	Carnarvon	Coburn Formation, Dirk Hartog Group	blue/grey (light and dark laminations) dolomitic cst	685.50	685.65			DIR096
Coburn 1	Carnarvon	Yaringa Formation, Dirk Hartog Group	blue/grey (light and dark banding) dolomitic cst/slt	794.40	794.65			DIR097
Coburn 1	Carnarvon	Ajana Formation, Dirk Hartog Group	blue/grey (light and dark laminations) dolomitic cst	893.75	893.90			DIR098
Coburn 1	Carnarvon	Marron Member, Ajana Formation	dark blue/grey cst	920.30	920.45			DIR099
Coburn 1	Carnarvon	Marron Member, Ajana Formation	pale tan cst with numerous grey salt patches	951.70	951.90			DIR100
Coburn 1	Carnarvon	Tumblagooda Sandstone	dark brown/red slt beds [10% of cored interval]	1011.40	1011.65			DIR101
Coburn 1	Carnarvon	Tumblagooda Sandstone	pale pink to pink-red medium-grained to granule sst [90% of cored interval]; predom quartz and orthoclase grains	1030.00	1030.20			DIR102

Coburn 1	Carnarvon	Windalia Sandstone Member	sst [friable]	150.80	151.00			DIR103
Coburn 1	Carnarvon	Muderong Shale	mst	166.30	166.50			DIR104
GSWA Ballythanna 1	Carnarvon	Keogh Formation	medium-grained to granule sst common cross beds	35.90	36.10			DIR105
GSWA Ballythanna 1	Carnarvon	Ballythanna Sandstone Member	light tan fine-grained to medium-grained sst [50% of cored interval]	131.90	132.05			DIR106
GSWA Ballythanna 1	Carnarvon	Ballythanna Sandstone Member	fine-grained sst with common carbonaceous flaser interbeds, whisps and slumped layers; pyritic; bioturbated [50% of cored interval]	292.30	292.43			DIR107
GSWA Ballythanna 1	Carnarvon	Callytharra Formation	dark grey very fossiliferous shale	358.75	358.90			DIR108
GSWA Ballythanna 1	Carnarvon	Lyons Group	fine-grained sst cream coloured	397.55	397.70			DIR109
GSWA Ballythanna 1	Carnarvon	Lyons Group	light grey fine-grained sst with common flaser beds of dark grey slt	453.40	453.55			DIR110
GSWA Ballythanna 1	Carnarvon	Lyons Group	dark grey interbedded slt/fine-grained sst	461.70	461.85			DIR111
Giralia 1	Carnarvon	Billidee Formation	dark grey slt, fine-grained sst heterolithic	682.10	682.22			DIR112
Giralia 1	Carnarvon	Cordalia Formation	dark grey cst?	919.00	919.10			DIR113
Kennedy Range 1	Carnarvon	Coolkilya Sandstone	tan grey medium-grained sst			1530'	1530' 9"	DIR114
Kennedy Range 1	Carnarvon	Baker Formation	reddish brown medium-grained sst			2005'	2005' 9"	DIR115
Kennedy Range 1	Carnarvon	Nalbia Sandstone	brown medium-grained sst, occasional bioturbation			2015' 6"	2016' 3"	DIR116
Kennedy Range 1	Carnarvon	Wandagee Formation	dark brown slt/sst, heavily bioturbated			2210'	2210' 6"	DIR117
Kennedy Range 1	Carnarvon	Cundlego Formation	dark grey/light grey sst, finely laminated, pin stripe laminations [50% of cored interval]			2817'	2817' 9"	DIR118

Kennedy Range 1	Carnarvon	Cundlego Formation	dark brown slt/sst, heavily bioturbated [50% of cored interval]			2819' 6"	2820' 3"	DIR119
Kennedy Range 1	Carnarvon	Bulgadoo Shale	brown slt			4163' 6"	4164' 3"	DIR120
Kennedy Range 1	Carnarvon	Mallens Sandstone	dark grey/light grey sst, finely laminated, pin stripe laminations [25% of cored interval]			4711'	4711' 6"	DIR121
Kennedy Range 1	Carnarvon	Mallens Sandstone	dark brown slt/sst, heavily bioturbated [75% of cored interval]			5104'	5104' 9"	DIR122
Kennedy Range 1	Carnarvon	Coyrie Formation	brown sst, minor bioturbation			5484' 3"	5484' 10"	DIR123
Kennedy Range 1	Carnarvon	Coyrie Formation	pale pink/tan sst, no bioturbation			5537' 3"	5538'	DIR124
Linda 2	Carnarvon	Dingo Claystone	dark grey cst/slt with thin stringers of light grey slt/sst - lenticular bedding	2814.80	2815.05			DIR125
Kennedy Range 1	Carnarvon	Moogooloo Sandstone	light tan grey coarse-grained sst with minor carbonaceous flecks			6606'	6606' 9"	DIR126
GSWA Barrabiddy 1A	Carnarvon	Nannyarra Sandstone	green grey mottled sst/slt	781.70	781.95			DIR127
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation	light grey fine-grained sst with rare slt flasers, some slumping in adjacent core	773.90	774.10			DIR128
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation	green-grey to light grey calcareous? Sst; highly fossiliferous	759.55	759.70			DIR129
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation	light blue/grey lst with common stylolites	669.35	669.55			DIR130
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation	dark green/grey slt/cst	616.90	617.10			DIR131
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation	dark green/grey slt/cst; highly fossiliferous	617.65	617.90			DIR132
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation; Point Maud Member	tan coloured lst; vugs/borings rare [10% of cored interval]	551.75	551.95			DIR133
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation; Point Maud Member	tan coloured lst; ubiquitous vugs/borings [90% of cored interval]	467.00	467.20			DIR134

GSWA Barrabiddy 1A	Carnarvon	Munabia Formation	light grey fine- to medium-grained sst with common flaser slt beds [~29 m = 34% of cored interval]	213.20	213.45			DIR135
GSWA Barrabiddy 1A	Carnarvon	Munabia Formation	dark green/grey mst, mottled [~56 m = 66% of cored interval]	246.25	246.40			DIR136
Quail 1	Carnarvon	Yindagindy Formation	dark blue/grey calcareous mst			8649'	8649' 9"	DIR137
Quail 1	Carnarvon	Quail Formation	reddish brown medium-grained sst			7319'	7319' 9"	DIR138
Onslow 1	Carnarvon	Mungaroo Formation	grey mottled slt			3781' 3"	3782'	DIR139
Onslow 1	Carnarvon	Mungaroo Formation	pale grey/buff sst			4279' 9"	4280' 6"	DIR140
Onslow 1	Carnarvon	Locker Shale	light brown sst			5706'	5706' 9"	DIR141
Onslow 1	Carnarvon	Locker Shale	dark grey shale			6631'	6631' 9"	DIR142
Learmonth 2	Carnarvon	Learmonth Formation	cream medium-grained sst			5375'	5375' 9"	DIR143
Pluto 3	Carnarvon	Brigadier Formation	dark grey sly, highly bioturbated, thin whisps of fine-grained sst	3056.70	3057.00			DIR144
Pluto 3	Carnarvon	Brigadier Formation	heterolithic fine-grained yellow/buff sst and dark grey slt; occasional bioturbation	3067.20	3067.50			DIR145
Calliance 1	Browse	Montara Formation	heterolithic fine-grained yellow/buff sst and dark grey slt; highly biotur-bated; occasional reddish brown nodules/diagenetic overprint?	3776.00	3776.30			DIR146
Brecknock 2	Browse	Plover Formation	yellow fine-grained sst	3786.80	3787.00			DIR147
Calliance 1	Browse	Plover Formation	grey slt; mottled [bioturbated]	3797.20	3797.40			DIR148
Brecknock 2	Browse	Nome Formation	dark grey slt; high-ly fractured [healed? Doubtful drilling induced?]	3825.70	3825.90			DIR149
Yowalga 2	Officer	Kanpa Formation	reddish finely la-minated interbed-ded slt/sst; thick quartz veins			2796'	2796' 9"	DIR150
Yowalga 2	Officer	Kanpa Formation	cream to light grey finely laminated interbedded slt/sst			3242'	3242' 9"	DIR151

Bonaparte 1A	Bonaparte	Point Spring Sandstone	salmon pink medium-grained sst			576' 4"/ 578' 4"	576' 8"/ 578' 8"	DIR152
Bonaparte 1A	Bonaparte	Tanmurra Formation	grey slt			689' 8"	690'	DIR153
Bonaparte 2	Bonaparte	Milligans Formation	heterolithic fine-grained light grey sst and dark grey slt; slumping features; whispy slt in the sst			3948' 4"/ 3940' 4"	3948' 8"/ 3940' 8"	DIR154
Bonaparte 1A	Bonaparte	Burt Range Formation	heterolithic fine-grained cream sst and greenish grey slt			9267' 4"/ 9263' 4"	9267' 8"/ 9263' 8"	DIR155
Bonaparte 1A	Bonaparte	Cockatoo Group	?grey quartzite			10476' 4"	10476' 8"	DIR156
Laminaria East 1	Bonaparte	Frigate Shale	grey shale	3249.70	3249.90			DIR157
GSWA Barrabiddy 1A	Carnarvon	Gearle Siltstone	dark grey friable mst	66.00	66.30			DIR158
GSWA Barrabiddy 1A	Carnarvon	Windalia Radiolarite	grey mst, not dense	127.75	127.95			DIR159
GSWA Barrabiddy 1A	Carnarvon	Windalia Sandstone Member	green slt to fine-grained sst; glauconitic	157.30	157.45			DIR160
Turtle 1	Bonaparte	Bonaparte Formation	grey fine- to medium-grained sst	2488.20	2488.50			DIR161
Turtle 1	Bonaparte	Keyling Formation	sst, oil impregnated; no non oil sands within core	929.00	929.30			DIR162
Turtle 1	Bonaparte	Keyling Formation	heterolithic dark grey slt/light grey sst; whispy slt	932.45	932.70			DIR163
Turtle 1	Bonaparte	Treachery Shale	interbedded light grey sst and dark grey slt	1441.65	1441.85			DIR164
Turtle 1	Bonaparte	Kuriyippi Formation	light grey sst	1599.65	1599.95			DIR165
Turtle 1	Bonaparte	Kuriyippi Formation	light grey sst and dark grey slt; mottled/bioturbated	1601.50	1601.75			DIR166
Turtle 1	Bonaparte	Kuriyippi Formation	grey diamictite?	1612.00	1612.30			DIR167
GSWA Empress 1A	Officer	Lennis Sandstone	partially friable yellow medium-grained sst	165.90	166.10			DIR168
GSWA Empress 1A	Officer	Paterson Formation	buff to tan medium-grained sst	127.05	127.20			DIR169
GSWA Empress 1A	Officer	Paterson Formation	matrix supported pebble cgl; coarse-grained sst matrix	116.15	116.40			DIR170
GSWA Empress 1A	Officer	Unnamed Sandstone	reddish brown medium-grained sst	294.25	294.60			DIR171

GSWA Empress 1A	Officer	Paterson Formation	light grey slt	106.70	107.00			DIR172
GSWA Empress 1A	Officer	Table Hill Volcanics	reddish grey basalt	284.70	284.90			DIR173
GSWA Empress 1A	Officer	Wahlgu Formation	red cst	367.80	368.00			DIR174
GSWA Empress 1A	Officer	Wahlgu Formation	red medium-grained sst	351.80	352.00			DIR175
GSWA Empress 1A	Officer	Wahlgu Formation	dark brown cst chips	431.50	431.70			DIR176
GSWA Empress 1A	Officer	Steptoe Formation	grey dolomite	504.65	504.85			DIR177
GSWA Empress 1A	Officer	Steptoe Formation	dark brown cst chips	603.80	604.00			DIR178
GSWA Empress 1A	Officer	Steptoe Formation	red sst	568.30	568.50			DIR179
GSWA Empress 1A	Officer	Kanpa Formation	grey dolomite	651.40	651.70			DIR180
GSWA Empress 1A	Officer	Kanpa Formation	light grey sst	743.50	743.80			DIR181
GSWA Empress 1A	Officer	Kanpa Formation	mst	805.90	806.10			DIR182
GSWA Empress 1A	Officer	Hussar Formation	interbedded mst/slt/sst	931.00	931.30			DIR183
GSWA Empress 1A	Officer	Hussar Formation	sst	1122.10	1122.40			DIR184
GSWA Empress 1A	Officer	Hussar Formation	mst	1091.10	1091.30			DIR185
GSWA Empress 1A	Officer	Hussar Formation	dolomite	1075.90	1076.20			DIR186
GSWA Empress 1A	Officer	Hussar Formation	mst/slt	1223.30	1223.55			DIR187
GSWA Empress 1A	Officer	Browne Formation	halite	1309.65	1309.80			DIR188
GSWA Empress 1A	Officer	Browne Formation	dolomite, slt	1409.40	1409.55			DIR189

GSWA Empress 1A	Officer	Browne Formation	dolomite, slt	1403.75	1403.95			DIR190
GSWA Empress 1A	Officer	Lefroy Formation	heavily fractured maroon to grey slt	1531.70	1531.90			DIR191
GSWA Empress 1A	Officer	Basement	basalt	1603.60	1603.80			DIR192
GSWA Empress 1A	Officer	Basement	dark grey/black finely laminated silty shale	1558.90	1559.20			DIR193
Boondawari 1	Officer	Mundadjini Formation	red cst	302.20	302.40			DIR194
Boondawari 1	Officer	Spearhole Formation	red sst	613.30	613.50			DIR195
Boondawari 1	Officer	Spearhole Formation	red slt/cst	612.35	612.60			DIR196
Boondawari 1	Officer	Table Hill Volcanics	dolerite	1365.40	1365.60			DIR197
Boondawari 1	Officer	Brassey Range Formation	interbedded red slt/sst	834.60	834.80			DIR198
Boondawari 1	Officer	Spearhole Formation	red slt	349.60	349.80			DIR199
BMR Browne 1	Officer	Bejah Claystone	salmon pink to cream cst with frequent pink-purple mottling; very light and almost porcelaneous			30' 11"	31' 7"	DIR200
BMR Browne 1	Officer	Samuel Formation	dark grey to yellow-grey laminated cst, slt and fine-grained sst; sulphorous, occasional bioturbation, micaceous, glauconite?			325'	325' 6"	DIR201
BMR Browne 1	Officer	Samuel Formation	reddish-brown to ochre slt, cst with finely laminated interbeds of whispy fine-grained sst			192' 1"	192' 7"	DIR202
BMR Neale 1A-1B	Officer	Wanna Formation	tan fine-grained sst; occasional reddish brown mottling; feint cross-bedding			369' 11"	369' 11"	DIR203
BMR Neale 1A-1B	Officer	McFadden Formation	grey to tan/grey fine-grained sst			327'	327' 7"	DIR204
BMR Neale 1A-1B	Officer	McFadden Formation	brick red slt			308'	308' 9"	DIR205
BMR Throssell 1	Officer	Kanpa Formation	grey cst with abundant gypsum crystal; chicken-wire appearance?			200'	200' 10"	DIR206

BMR Glenburgh 9	Carnarvon	Madeline Formation	dark grey slt, cst; rare fossiliferous [graptolite?]			192'	192' 6"	DIR207

2. Methodology

Three sample preparation methods were undertaken to measure the thermal conductivity of specimens DIR089—DIR207, depending on specimen quality and quantity. In this report these three methods are referred to as 'Whole rock', 'Hollow cell, whole rock', or 'Hollow cell, matrix'. Up to three samples were prepared from each specimen to investigate variation in thermal conductivity over short distance scales and to determine mean conductivity and uncertainty.

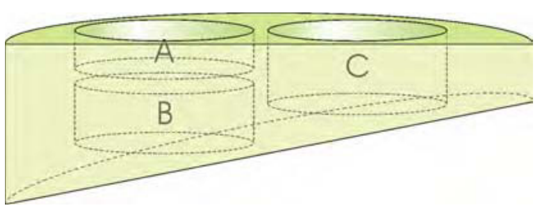
Where possible, three prisms were cut from each core specimen, each approximately ⅓ to ½ the length of the sample in thickness, and each sample was ground flat and polished. These are indicated on Table 2 by the description 'Whole rock'.

In cases where the core specimens were of a relatively unconsolidated lithology (such as clays, muds, and marls) showing significant susceptibility to deterioration during saturation, samples were prepared using hollow cells. These are indicated on Table 2 by the description 'Hollow cell, whole rock'.

In cases where the core specimens were either crushed or highly fragmented, making it impossible to measure the sample in its whole-rock state, thermal conductivity was measured as a matrix within a hollow cell with water. In such cases, the net conductivity of the rock matrix was calculated from the gross conductivity of the rock-water aggregate. These are indicated on table 2 by the description 'Hollow cell, matrix'. Colloquially, these samples are referred to as 'chips' or 'cuttings'.

All samples were evacuated under >95% vacuum for a minimum of three hours. Samples were then submerged in water prior to returning to atmospheric pressure. Saturation continued at atmospheric pressure for a minimum of twelve hours, and all samples were left submerged in water until just prior to conductivity measurement.

Figure 1. The average conductivity of samples in series (e.g. A and B) is found using the harmonic mean. The average conductivity of samples in parallel (e.g. A and C) is found using the arithmetic mean.



Samples were then measured for thermal conductivity measurement in a divided bar apparatus[3]. The thermal conductivity was measured along the long axis of the core provided for all samples prepared either as 'Whole rock' or 'Hollow cell, whole rock'. Values were measured at a standard temperature of 30°C (± 2°C). Harmonic mean conductivity (Figure 1) and one standard deviation uncertainty were calculated for each specimen. Results are presented in the next section.

[3] Divided bar apparatus: An instrument that places an unknown sample in series with a standard of known thermal conductivity, then imposes a constant thermal gradient across the combination in order to derive the conductivity of the unknown sample.

3. Results

Table 2 displays the thermal conductivity for each individual sample, and the harmonic mean conductivity and standard deviation for each specimen. All values are for a standard temperature of 30°C. The uncertainty for individual samples is approximately ± 2% for non-friable whole rock samples (based on the instrument precision of the divided bar apparatus). Uncertainties for thermal conductivity measurements are shown in Table 2.

Table 2. Thermal conductivity of samples at 30°C, with well name, depth, uncertainty, sample type, and harmonic mean and uncertainty[4] for each specimen.

Well	Depth From (m)	Depth To (m)	Depth From (')	Depth To (')	Uncertainty (%)	Sample type	HDR sample ID			Conductivity (W/mK), harmonic mean, standard deviation		
Coburn 1	73.70	73.92			5	Hollow cell, whole rock	DIR089	A	1.51	1.48	±	0.03
								B	1.46			
								C	1.48			
Coburn 1	172.70	172.85			5	Hollow cell, whole rock	DIR090	A	2.49	2.47	±	0.06
								B	2.51			
								C	2.40			
Coburn 1	212.70	212.85			5	Hollow cell, whole rock	DIR091	A	3.26	3.12	±	0.19
								B	3.22			
								C	2.91			
Coburn 1	404.40	404.55			3.5	Whole rock	DIR092	A	3.57	3.64	±	0.07
								B	3.64			
								C	3.70			
Coburn 1	475.40	475.50			5	Hollow cell, whole rock	DIR093	A	1.67	1.61	±	0.06
								B	1.61			
								C	1.55			
Coburn 1	564.60	564.80			3.5	Whole rock	DIR094	A	2.12	2.14	±	0.08
								B	2.08			
								C	2.22			
Coburn 1	616.70	616.85			3.5	Whole rock	DIR095	A	3.37	3.50	±	0.17
								B	3.69			
								C	3.45			
Coburn 1	685.50	685.65			3.5	Whole rock	DIR096	A	2.48	2.53	±	0.04
								B	2.55			
								C	2.55			
Coburn 1	794.40	794.65			3.5	Whole rock	DIR097	A	3.08	3.16	±	0.08
								B	3.17			
								C	3.24			

[4] Uncertainty of the thermal conductivity for each specimen is one standard deviation of the measured values.

								A	2.34			
Coburn 1	893.75	893.90			3.5	Whole rock	DIR098	B	2.48	2.48	±	0.15
								C	2.65			
								A	1.93			
Coburn 1	920.30	920.45			3.5	Whole rock	DIR099	B	1.95	2.00	±	0.12
								C	2.15			
								A	3.99			
Coburn 1	951.70	951.90			3.5	Whole rock	DIR100	B	3.42	3.93	±	0.57
								C	4.55			
								A	2.55			
Coburn 1	1011.40	1011.65			3.5	Whole rock	DIR101	B	2.70	2.65	±	0.10
								C	2.72			
								A	2.99			
Coburn 1	1030.00	1030.20			3.5	Whole rock	DIR102	B	2.98	2.90	±	0.14
								C	2.75			
								A	2.60			
Coburn 1	150.80	151.00			5	Hollow cell, whole rock	DIR103	B	2.57	2.56	±	0.04
								C	2.52			
								A	1.64			
Coburn 1	166.30	166.50			5	Hollow cell, whole rock	DIR104	B	1.93	1.75	±	0.15
								C	1.70			
								A	3.28			
GSWA Ballythanna 1	35.90	36.10			3.5	Whole rock	DIR105	B	2.80	3.24	±	0.50
								C	3.79			
								A	3.15			
GSWA Ballythanna 1	131.90	132.05			3.5	Whole rock	DIR106	B	3.17	3.18	±	0.05
								C	3.24			
								A	3.22			
GSWA Ballythanna 1	292.30	292.43			3.5	Whole rock	DIR107	B	3.02	3.21	±	0.19
								C	3.40			
								A	1.61			
GSWA Ballythanna 1	358.75	358.90			3.5	Whole rock	DIR108	B	1.74	1.70	±	0.08
								C	1.75			
								A	3.17			
GSWA Ballythanna 1	397.55	397.70			3.5	Whole rock	DIR109	B	3.03	3.08	±	0.07
								C	3.05			
								A	2.87			
GSWA Ballythanna 1	453.40	453.55			3.5	Whole rock	DIR110	B	2.63	2.67	±	0.17
								C	2.55			
								A	2.69			
GSWA Ballythanna 1	461.70	461.85			3.5	Whole rock	DIR111	B	2.38	2.56	±	0.16
								C	2.62			

Giralia 1	682.10	682.22			3.5	Whole rock	DIR112	A	2.51	2.60	±	0.30
								B	2.97			
								C	2.39			
Giralia 1	919.00	919.10			3.5	Whole rock	DIR113	A	1.91	1.98	±	0.18
								B	1.87			
								C	2.19			
Kennedy Range 1			1530'	1530' 9"	3.5	Whole rock	DIR114	A	2.99	2.86	±	0.11
								B	2.79			
								C	2.81			
Kennedy Range 1			2005'	2005' 9"	3.5	Whole rock	DIR115	A	3.51	3.51	±	0.05
								B	3.46			
								C	3.55			
Kennedy Range 1			2015' 6"	2016' 3"	3.5	Whole rock	DIR116	A	2.98	2.99	±	0.07
								B	3.06			
								C	2.93			
Kennedy Range 1			2210'	2210' 6"	5	Hollow cell, whole rock	DIR117	A	1.84	1.77	±	0.14
								B	1.62			
								C	1.87			
Kennedy Range 1			2817'	2817' 9"	3.5	Whole rock	DIR118	A	3.13	2.93	±	0.17
								B	2.84			
								C	2.84			
Kennedy Range 1			2819' 6"	2820' 3"	3.5	Whole rock	DIR119	A	2.40	2.23	±	0.15
								B	2.14			
								C	2.16			
Kennedy Range 1			4163' 6"	4164' 3"	3.5	Whole rock	DIR120	A	1.23	1.27	±	0.13
								B	1.18			
								C	1.43			
Kennedy Range 1			4711'	4711' 6"	3.5	Whole rock	DIR121	A	2.83	2.75	±	0.14
								B	2.59			
								C	2.84			
Kennedy Range 1			5104'	5104' 9"	3.5	Whole rock	DIR122	A	2.53	2.64	±	0.15
								B	2.82			
								C	2.60			
Kennedy Range 1			5484' 3"	5484' 10"	3.5	Whole rock	DIR123	A	2.37	2.29	±	0.07
								B	2.25			
								C	2.26			
Kennedy Range 1			5537' 3"	5538'	3.5	Whole rock	DIR124	A	2.96	3.04	±	0.09
								B	3.15			
								C	3.02			
Linda 2	2814.80	2815.05			15	Hollow cell, matrix	DIR125	A	1.42	1.15	±	0.18
								B	1.09			
								C	0.99			
					5	Whole rock		D	1.18			

Kennedy Range 1			6606'	6606' 9"	3.5	Whole rock	DIR126	A	4.63	4.76	±	0.13
								B	4.80			
								C	4.87			
GSWA Barrabiddy 1A	781.70	781.95			3.5	Whole rock	DIR127	A	2.44	2.50	±	0.14
								B	2.40			
								C	2.66			
GSWA Barrabiddy 1A	773.90	774.10			3.5	Whole rock	DIR128	A	3.22	3.37	±	0.13
								B	3.48			
								C	3.42			
GSWA Barrabiddy 1A	759.55	759.70			3.5	Whole rock	DIR129	A	2.14	1.80	±	0.30
								B	1.81			
								C	1.55			
GSWA Barrabiddy 1A	669.35	669.55			3.5	Whole rock	DIR130	A	2.52	2.49	±	0.05
								B	2.43			
								C	2.51			
GSWA Barrabiddy 1A	616.90	617.10			3.5	Whole rock	DIR131	A	1.75	1.93	±	0.25
								B	1.86			
								C	2.22			
GSWA Barrabiddy 1A	617.65	617.90			5	Hollow cell, whole rock	DIR132	B	0.64	0.64	±	0.00
								C	0.64			
GSWA Barrabiddy 1A	551.75	551.95			3.5	Whole rock	DIR133	A	4.00	3.93	±	0.08
								B	3.85			
								C	3.93			
GSWA Barrabiddy 1A	467.00	467.20			3.5	Whole rock	DIR134	A	4.03	3.80	±	0.29
								B	3.92			
								C	3.49			
GSWA Barrabiddy 1A	213.20	213.45			3.5	Whole rock	DIR135	A	2.72	2.55	±	0.18
								B	2.59			
								C	2.36			
GSWA Barrabiddy 1A	246.25	246.40			5	Hollow cell, whole rock	DIR136	B	1.45	1.42	±	0.04
								C	1.40			
Quail 1			8649'	8649' 9"	3.5	Whole rock	DIR137	B	2.43	2.45	±	0.03
								C	2.47			
Quail 1			7319'	7319' 9"	3.5	Whole rock	DIR138	A	4.82	4.97	±	0.24
								B	4.87			
								C	5.25			
Onslow 1			3781' 3"	3782'	5	Hollow cell, whole rock	DIR139	A	2.09	2.02	±	0.09
								B	1.96			
								C	0.00			
Onslow 1			4279' 9"	4280' 6"	3.5	Whole rock	DIR140	A	3.06	2.91	±	0.17
								B	2.73			
								C	2.96			

Onslow 1			5706'	5706' 9"	3.5	Whole rock	DIR141	A	3.16	3.08	±	0.09
								B	2.98			
								C	3.11			
Onslow 1			6631'	6631' 9"	5	Hollow cell, whole rock	DIR142	A	1.23	1.19	±	0.08
								B	1.25			
								C	1.10			
Learmonth 2			5375'	5375' 9"	3.5	Whole rock	DIR143	A	3.27	3.42	±	0.33
								B	3.23			
								C	3.83			
Pluto 3	3056.70	3057.00			3.5	Whole rock	DIR144	A	1.32	1.35	±	0.09
								B	1.45			
								C	1.28			
Pluto 3	3067.20	3067.50			3.5	Whole rock	DIR145	A	2.38	1.84	±	0.45
								B	1.50			
								C	1.78			
Calliance 1	3776.00	3776.30			3.5	Whole rock	DIR146	A	3.47	3.33	±	0.15
								B	3.18			
								C	3.35			
Brecknock 2	3786.80	3787.00			3.5	Whole rock	DIR147	A	4.47	4.51	±	0.10
								B	4.43			
								C	4.62			
Calliance 1	3797.20	3797.40			3.5	Whole rock	DIR148	A	2.72	2.82	±	0.12
								B	2.80			
								C	2.95			
Brecknock 2	3825.70	3825.90			3.5	Whole rock	DIR149	A	2.48	2.29	±	0.17
								B	2.24			
								C	2.16			
Yowalga 2			2796'	2796' 9"	3.5	Whole rock	DIR150	A	2.37	2.56	±	0.18
								B	2.61			
								C	2.71			
Yowalga 2			3242'	3242' 9"	5	Hollow cell, whole rock	DIR151	A	2.77	2.93	±	0.24
								B	3.11			
Bonaparte 1A			576' 4"/ 578' 4"	576' 8"/ 578' 8"	3.5	Whole rock	DIR152	A	3.14	2.94	±	0.32
								B	3.16			
								C	2.59			
Bonaparte 1A			689' 8"	690'	3.5	Whole rock	DIR153	A	2.20	2.19	±	0.02
								B	2.17			
								C	2.20			
Bonaparte 2			3948' 4"/ 3940' 4"	3948' 8"/ 3940' 8"	3.5	Whole rock	DIR154	A	4.24	3.92	±	0.58
								B	4.39			
								C	3.32			

Bonaparte 1A			9267' 4"/ 9263' 4"	9267' 8"/ 9263' 8"	3.5	Whole rock	DIR155	A	1.77	1.73	±	0.06
								B	1.76			
								C	1.66			
Bonaparte 1A			10476' 4"	10476' 8"	3.5	Whole rock	DIR156	A	5.67	5.09	±	0.51
								B	4.67			
								C	5.04			
Laminaria East 1	3249.70	3249.90			3.5	Whole rock	DIR157	A	1.26	1.24	±	0.03
								B	1.21			
GSWA Barrabiddy 1A	66.00	66.30			15	Hollow cell, matrix	DIR158	A	1.21	1.19	±	0.03
								B	1.21			
								C	1.16			
GSWA Barrabiddy 1A	127.75	127.95			3.5	Whole rock	DIR159	A	1.40	1.31	±	0.10
								B	1.35			
								C	1.20			
GSWA Barrabiddy 1A	157.30	157.45			5	Hollow cell, whole rock	DIR160	A	1.81	1.79	±	0.05
								B	1.74			
								C	1.82			
Turtle 1	2488.20	2488.50			3.5	Whole rock	DIR161	A	4.20	4.11	±	0.08
								B	4.05			
								C	4.08			
Turtle 1	929.00	929.30			3.5	Whole rock	DIR162	A	2.59	2.60	±	0.05
								B	2.65			
								C	2.56			
Turtle 1	932.45	932.70			5	Hollow cell, whole rock	DIR163	A	2.34	2.38	±	0.05
								B	2.36			
								C	2.44			
Turtle 1	1441.65	1441.85			3.5	Whole rock	DIR164	A	2.14	2.29	±	0.31
								B	2.67			
								C	2.13			
Turtle 1	1599.65	1599.95			3.5	Whole rock	DIR165	A	3.17	3.19	±	0.05
								B	3.24			
								C	3.15			
Turtle 1	1601.50	1601.75			3.5	Whole rock	DIR166	A	2.32	2.35	±	0.09
								B	2.45			
								C	2.28			
Turtle 1	1612.00	1612.30			3.5	Whole rock	DIR167	A	2.71	2.87	±	0.39
								B	2.66			
								C	3.35			
GSWA Empress 1A	165.90	166.10			5	Hollow cell, whole rock	DIR168	A	2.71	2.56	±	0.14
								B	2.53			
								C	2.44			

GSWA Empress 1A	127.05	127.20			5	Hollow cell, whole rock	DIR169	A	2.28	2.19	±	0.10
								B	2.21			
								C	2.09			
GSWA Empress 1A	116.15	116.40			3.5	Whole rock	DIR170	A	3.32	3.27	±	0.07
								B	3.22			
GSWA Empress 1A	294.25	294.60			5	Hollow cell, whole rock	DIR171	A	2.49	2.44	±	0.05
								B	2.38			
								C	2.44			
GSWA Empress 1A	106.70	107.00			5	Hollow cell, whole rock	DIR172	A	2.47	2.49	±	0.05
								B	2.44			
								C	2.54			
GSWA Empress 1A	284.70	284.90			3.5	Whole rock	DIR173	A	1.55	1.57	±	0.02
								B	1.58			
								C	1.58			
GSWA Empress 1A	367.80	368.00			5	Hollow cell, whole rock	DIR174	A	2.21	2.26	±	0.07
								B	2.31			
GSWA Empress 1A	351.80	352.00			5	Hollow cell, whole rock	DIR175	A	3.07	3.05	±	0.05
								B	2.99			
								C	3.09			
GSWA Empress 1A	431.50	431.70			15	Hollow cell, matrix	DIR176	A	1.61	1.55	±	0.21
								B	1.75			
								C	1.34			
GSWA Empress 1A	504.65	504.85			3.5	Whole rock	DIR177	A	4.68	4.61	±	0.23
								B	4.80			
								C	4.36			
GSWA Empress 1A	603.80	604.00			15	Hollow cell, matrix	DIR178	A	1.43	1.43	±	0.16
								B	1.29			
								C	1.60			
GSWA Empress 1A	568.30	568.50			3.5	Whole rock	DIR179	A	3.04	2.96	±	0.12
								B	3.03			
								C	2.83			
GSWA Empress 1A	651.40	651.70			3.5	Whole rock	DIR180	A	3.87	4.02	±	0.25
								B	4.32			
								C	3.90			
GSWA Empress 1A	743.50	743.80			3.5	Whole rock	DIR181	A	2.13	3.02	±	0.99
								B	3.71			
								C	3.95			
GSWA Empress 1A	805.90	806.10			3.5	Whole rock	DIR182	A	2.78	2.41	±	0.34
								B	2.10			
								C	2.44			
GSWA Empress 1A	931.00	931.30			3.5	Whole rock	DIR183	A	3.97	4.18	±	0.19
								B	4.34			
								C	4.25			

GSWA Empress 1A	1122.10	1122.40			3.5	Whole rock	DIR184	A	4.34	4.24	±	0.25
								B	4.44			
								C	3.97			
GSWA Empress 1A	1091.10	1091.30			3.5	Whole rock	DIR185	A	1.78	1.78	±	0.36
								B	2.22			
								C	1.50			
GSWA Empress 1A	1075.90	1076.20			3.5	Whole rock	DIR186	A	5.65	5.54	±	0.11
								B	5.53			
								C	5.43			
GSWA Empress 1A	1223.30	1223.55			3.5	Whole rock	DIR187	A	2.14	2.18	±	0.06
								B	2.16			
								C	2.25			
GSWA Empress 1A	1309.65	1309.80			3.5	Whole rock	DIR188	A	5.65	5.25	±	0.37
								B	5.25			
								C	4.92			
GSWA Empress 1A	1409.40	1409.55			3.5	Whole rock	DIR189	A	2.60	2.68	±	0.12
								B	2.82			
								C	2.63			
GSWA Empress 1A	1403.75	1403.95			5	Hollow cell, whole rock	DIR190	A	2.13	2.09	±	0.06
								C	2.04			
GSWA Empress 1A	1531.70	1531.90			3.5	Whole rock	DIR191	A	1.65	1.61	±	0.04
								B	1.57			
								C	1.62			
GSWA Empress 1A	1603.60	1603.80			3.5	Whole rock	DIR192	A	2.34	2.30	±	0.05
								B	2.25			
								C	2.30			
GSWA Empress 1A	1558.90	1559.20			3.5	Whole rock	DIR193	A	2.09	2.05	±	0.05
								B	2.08			
								C	1.99			
Boondawari 1	302.20	302.40			3.5	Whole rock	DIR194	A	4.37	4.45	±	0.09
								B	4.55			
								C	4.44			
Boondawari 1	613.30	613.50			3.5	Whole rock	DIR195	A	1.47	1.43	±	0.04
								B	1.40			
								C	1.43			
Boondawari 1	612.35	612.60			3.5	Whole rock	DIR196	A	4.80	4.81	±	0.09
								B	4.90			
								C	4.73			
Boondawari 1	1365.40	1365.60			3.5	Whole rock	DIR197	A	2.18	2.25	±	0.07
								B	2.32			
								C	2.26			
Boondawari 1	834.60	834.80			3.5	Whole rock	DIR198	A	4.19	4.45	±	0.30
								B	4.42			
								C	4.79			

Boondawari 1	349.60	349.80			3.5	Whole rock	DIR199	A	2.22	2.17	±	0.08
								B	2.08			
								C	2.23			
BMR Browne 1			30' 11"	31' 7"	3.5	Whole rock	DIR200	A	1.34	1.33	±	0.01
								B	1.31			
								C	1.33			
BMR Browne 1			325'	325' 6"	5	Hollow cell, whole rock	DIR201	A	1.32	1.30	±	0.04
								B	1.25			
								C	1.34			
BMR Browne 1			192' 1"	192' 7"	5	Hollow cell, whole rock	DIR202	A	1.27	1.25	±	0.03
								B	1.23			
BMR Neale 1A-1B			369' 11"	369' 11"	3.5	Whole rock	DIR203	A	2.52	2.60	±	0.08
								B	2.68			
								C	2.61			
BMR Neale 1A-1B			327'	327' 7"	3.5	Whole rock	DIR204	B	1.73	2.16	±	0.81
								D	2.87			
BMR Neale 1A-1B			308'	308' 9"	5	Hollow cell, whole rock	DIR205	A	1.59	1.59	±	0.05
								B	1.55			
								C	1.64			
BMR Throssell 1			200'	200' 10"	3.5	Whole rock	DIR206	Specimen not measured				
BMR Glenburgh 9			192'	192' 6"	3.5	Whole rock	DIR207	A	1.50	1.53	±	0.05
								B	1.58			
								C	1.50			

4. Discussion and Conclusions

4.1 Bonaparte Basin

The range of thermal conductivity values from the Bonaparte basin is from 1.24–5.09 W/mK, shown by specimens DIR157 and DIR156 respectively, which is a variability of up to a 79% from mean basin conductivity of 2.84 W/mK. The standard deviation between all 13 samples representing the Bonaparte basin is approximately 1.04σ.

4.2 Browse Basin

The range of thermal conductivity values from the Browse basin is from 2.29–4.51 W/mK, shown by specimens DIR149 and DIR147 respectively, which is a variability of up to a 39% from the mean basin conductivity of 3.24 W/mK. The standard deviation between all four samples representing the Browse basin is approximately 0.82σ.

4.3 Carnarvon Basin

The range of thermal conductivity values for the Carnarvon basin is from 0.64–4.97 W/mK, shown by specimens DIR138 and DIR132 respectively, which is a variability of up to a 97% from the mean basin conductivity of 2.52 W/mK. The standard deviation between all 61 samples representing the Carnarvon basin is approximately 0.89σ.

4.4 Officer Basin

The range of thermal conductivity values for the Officer basin is from 1.25–5.54 W/mK, shown by specimens DIR202 and DIR186 respectively, which is a variability of up to 103% from the mean basin conductivity of 2.73 W/mK. The standard deviation between all 40 samples representing the Officer basin is approximately 1.17σ. Thermal conductivity of specimen DIR206 was not measured due to poor sample quality.

The following additional points must be considered if extrapolating the results in this report to *in situ* formations:

1. The samples upon which the thermal conductivity measurements were made are only several square centimetres in surface area. While the specimens were chosen to represent the geological sections from which they came, there is no guarantee that the sections themselves are typical of the overall geological formations. This is especially true for heterogeneous formations. This introduces an unquantifiable random error into the results.
2. Porosity exerts a primary influence on the thermal conductivity of a rock. Water is substantially less conductive than typical mineral grains[5], and water saturated pores act to reduce the bulk thermal conductivity of the rock. Gas-filled pores reduce the bulk conductivity even more dramatically. Results reported in this document are whole-rock measurements. No adjustments were made for porosity. It is to be expected that the thermal conductivity of a given formation will vary from place to place if the porosity of the formation varies (conductivity decreases with increasing porosity).
3. Thermal conductivity of rocks is sensitive to temperature[2], typically decreasing at a rate of around 0.16% per °C. This should be kept in mind when developing models of in situ thermal conductivity.

[5] **Beardsmore, G.R. and Cull, J.P.** (2001). *Crustal heat flow: A guide to measurement and modelling*. Cambridge University Press, Cambridge. 324pp.

Appendix 1

Heat flow models and temperature data used for 21 wells in the Carnarvon Basin
Report DMP0260909

HDR

July 2010

An appendix to the report - Geothermal Energy Potential in Selected Areas of Western Australia (Carnarvon Basin); prepared for the Department of Mines and Petroleum, Western Australia.

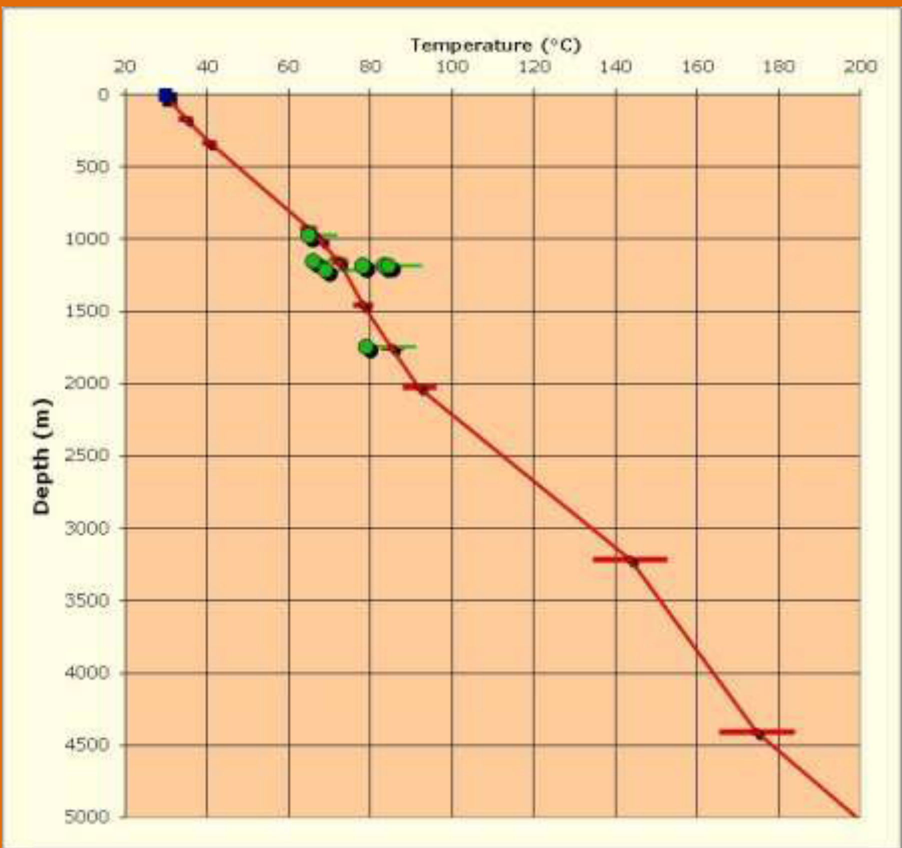
Number of layers	20	Up to 50	Heat flow: 50 ± 1.9 mW/m2
"Depth" to ground level	4.5	"KB height"	
Total Depth (m)	12001	From driling datum	
Surface temp. (°C)	30	Crest 1 Deepening	
Uncertainty in surface T	1.5	±°C	

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A ($\mu W/m^3$)	Thickness (m)
1	Tertiary [undif. carbonates]	4.5	1.68 ± 0.34	0	157.5
2	Toolonga Calcilutite	162	1.45 ± 0.06	0	165
3	Gearle Siltstone	327	1.23 ± 0.05	0	593
4	Windalia Radiolarite	920	1.45 ± 0.10	0	90.7
5	Muderong Shale	1010.7	1.69 ± 0.13	0	130.9
6	Mardie Greensand Member	1141.6	1.79 ± 0.36	0	15.8
7	Barrow Group (Flacourt Fm)	1157.4	2.83 ± 0.57	0	295.9
8	Dupuy Formation	1453.3	2.29 ± 0.46	0	297.7
9	Dupuy Formation	1751	2.29 ± 0.46	0	274
10	Dingo Claystone	2025	1.15 ± 0.18	0	1193
11	Mungaroo Formation	3218	2.39 ± 0.12	0	1193
12	Locker Shale	4411	1.27 ± 0.11	0	1089
13	Locker Shale	5500	1.27 ± 0.11	0	1000
14	Locker Shale	6500	1.27 ± 0.11	0	1164
15	Kennedy Group	7664	2.86 ± 0.11	0	867
16	Lyons Group/Callytharra Formation	8531	2.17 ± 0.43	0	867
17	Lower Carboniferous-Ordovician (undif.)	9398	2.49 ± 0.50	0	602
18	Lower Carboniferous-Ordovician (undif.)	10000	2.49 ± 0.50	0	1000
19	Lower Carboniferous-Ordovician (undif.)	11000	2.49 ± 0.50	0	1000
20	Basement (metasediment)	12000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
1741	79	0	12.187	BHT [time since circ unknown]
970.5	65	0	6.7935	BHT [time since circ unknown]
1148.3	66	0	8.0381	BHT [time since circ unknown]
1210.8	69	0	8.4756	BHT [time since circ unknown]
1182.25	78.3	0	8.2758	BHT [time since circ unknown]
1181.25	83.3	0	8.2688	BHT [time since circ unknown]
1179.33	84.4	0	8.2553	BHT [time since circ unknown]

DEVIATED WELL



Crest 1 deepening

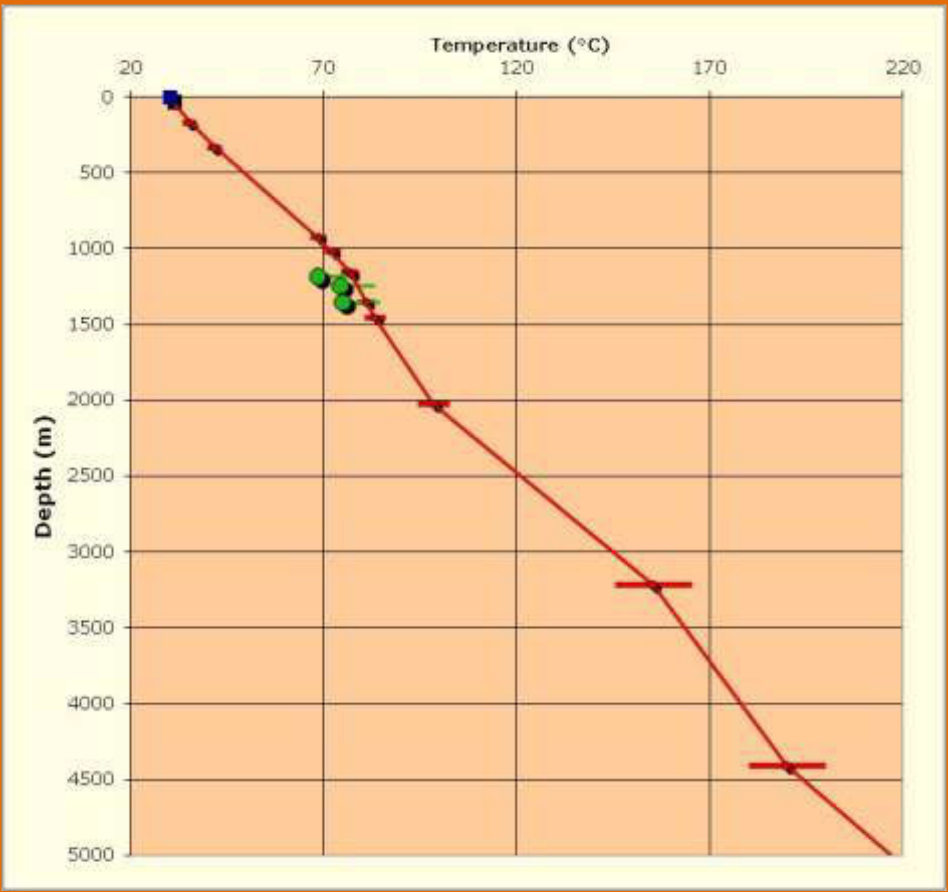
Number of layers	20	Up to 50	Heat flow: 55 ± 2.2 mW/m2
"Depth" to ground level	5.2	"KB height"	
Total Depth (m)	12001	From driling datum	
Surface temp. (°C)	30	Crest 2	
Uncertainty in surface T	1.5	±°C	

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A ($\mu W/m^3$)	Thickness (m)
1	Tertiary [undif. carbonates]	5.2	1.68 ± 0.34	0	156.8
2	Toolonga Calcilutite	162	1.45 ± 0.06	0	166
3	Gearle Siltstone	328	1.23 ± 0.05	0	597
4	Windalia Radiolarite	925	1.45 ± 0.10	0	93.7
5	Muderong Shale	1018.7	1.69 ± 0.13	0	127.3
6	Mardie Greensand Member	1146	1.79 ± 0.36	0	15.5
7	Barrow Group (Flacourt Fm)	1161.5	2.83 ± 0.57	0	187.6
8	Barrow Group (Flacourt Fm)	1349.1	2.83 ± 0.57	0	100.9
9	Dupuy Formation	1450	2.29 ± 0.46	0	575
10	Dingo Claystone	2025	1.15 ± 0.18	0	1193
11	Mungaroo Formation	3218	2.39 ± 0.12	0	1193
12	Locker Shale	4411	1.27 ± 0.11	0	1089
13	Locker Shale	5500	1.27 ± 0.11	0	1000
14	Locker Shale	6500	1.27 ± 0.11	0	1164
15	Kennedy Group	7664	2.86 ± 0.11	0	867
16	Lyons Group/Callytharra Formation	8531	2.17 ± 0.43	0	867
17	Lower Carboniferous-Ordovician (undif.)	9398	2.49 ± 0.50	0	602
18	Lower Carboniferous-Ordovician (undif.)	10000	2.49 ± 0.50	0	1000
19	Lower Carboniferous-Ordovician (undif.)	11000	2.49 ± 0.50	0	1000
20	Basement (metasediment)	12000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
1182.34	68.33	0	8.2764	BHT [time since circ unknown]
1241	74.44	0	8.687	BHT [time since circ unknown]
1349.04	75	0	9.4433	BHT [time since circ unknown]

DEVIATED WELL



Crest 2

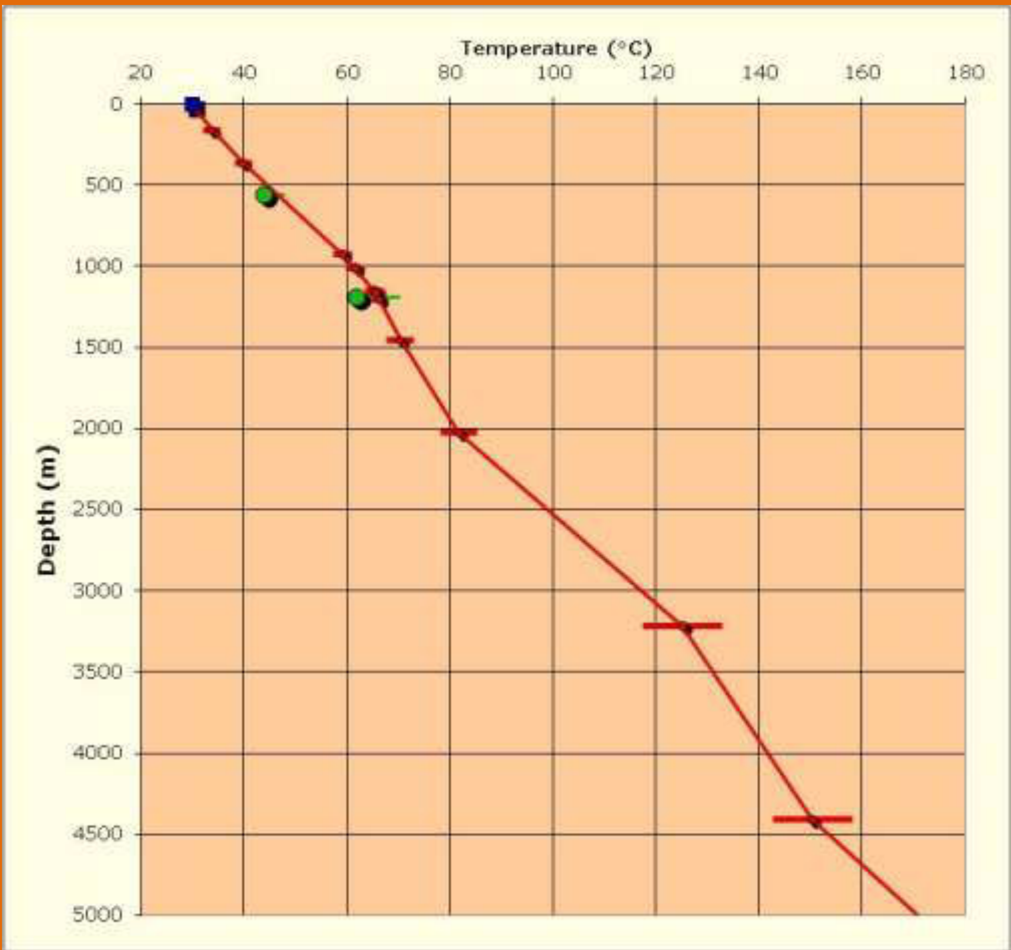
Number of layers	20	Up to 50	Heat flow: 42 ± 1.6 mW/m2
"Depth" to ground level	5.1	"KB height"	
Total Depth (m)	12001	From driling datum	
Surface temp. (°C)	30	Crest 5	
Uncertainty in surface T	1.5	±°C	

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A (μW/m³)	Thickness (m)
1	Tertiary [undif. carbonates]	5.1	1.68 ± 0.34	0	149.9
2	Toolonga Calcilutite	155	1.45 ± 0.06	0	204
3	Gearle Siltstone	359	1.23 ± 0.05	0	565.5
4	Windalia Radiolarite	924.5	1.45 ± 0.10	0	83.5
5	Muderong Shale	1008	1.69 ± 0.13	0	140.2
6	Mardie Greensand Member	1148.2	1.79 ± 0.36	0	16.8
7	Barrow Group (Flacourt Fm)	1165	2.83 ± 0.57	0	35
8	Barrow Group (Flacourt Fm)	1200	2.83 ± 0.57	0	250
9	Dupuy Formation	1450	2.29 ± 0.46	0	575
10	Dingo Claystone	2025	1.15 ± 0.18	0	1193
11	Mungaroo Formation	3218	2.39 ± 0.12	0	1193
12	Locker Shale	4411	1.27 ± 0.11	0	1089
13	Locker Shale	5500	1.27 ± 0.11	0	1000
14	Locker Shale	6500	1.27 ± 0.11	0	1164
15	Kennedy Group	7664	2.86 ± 0.11	0	867
16	Lyons Group/Callytharra Formation	8531	2.17 ± 0.43	0	867
17	Lower Carboniferous-Ordovician (undif.)	9398	2.49 ± 0.50	0	602
18	Lower Carboniferous-Ordovician (undif.)	10000	2.49 ± 0.50	0	1000
19	Lower Carboniferous-Ordovician (undif.)	11000	2.49 ± 0.50	0	1000
20	Basement (metasediment)	12000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
555.7	44	0	3.8899	BHT [time since circ unknown]
1187	62	0	8.309	BHT [time since circ unknown]

DEVIATED WELL



Crest 5

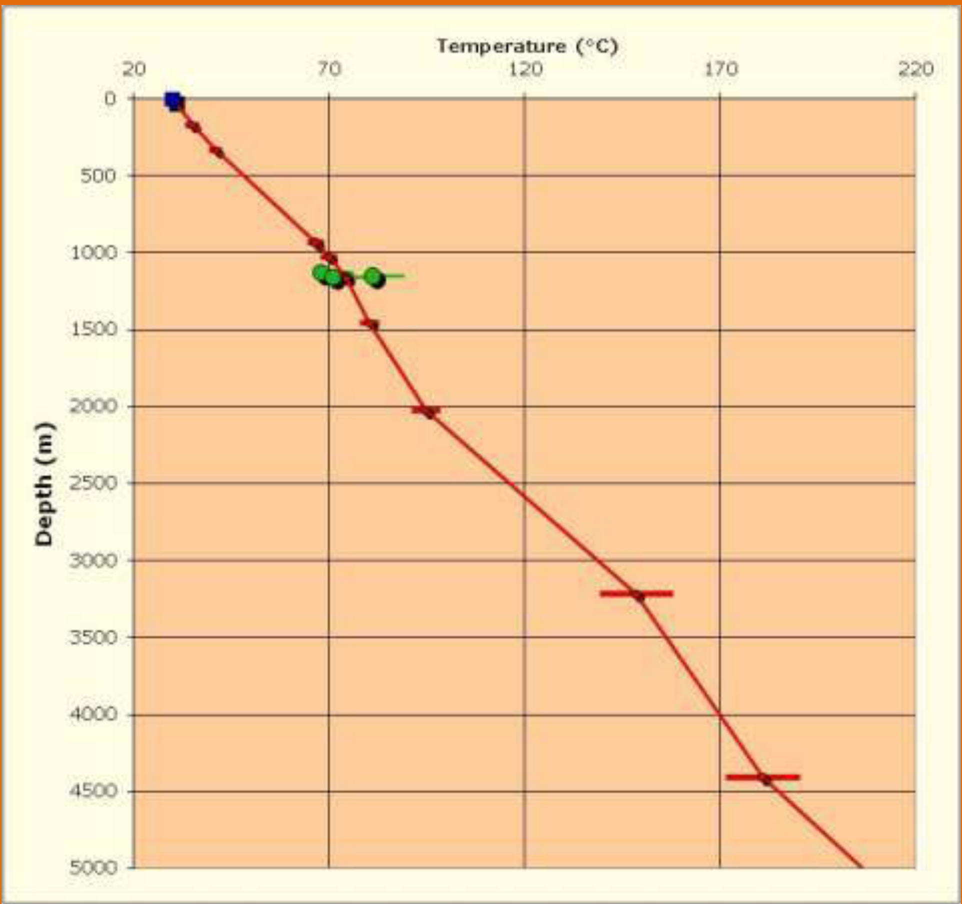
Number of layers	20	Up to 50	**Heat flow:**	52 ± 2.0 mW/m2
"Depth" to ground level	4.5	"KB height"		
Total Depth (m)	12001	From driling datum		
Surface temp. (°C)	30	**Crest 6**		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A (μW/m^3)	Thickness (m)
1	Tertiary [undif. carbonates]	4.5	1.68 ± 0.34	0	157.5
2	Toolonga Calcilutite	162	1.45 ± 0.06	0	165
3	Gearle Siltstone	327	1.23 ± 0.05	0	603
4	Windalia Radiolarite	930	1.45 ± 0.10	0	91.5
5	Muderong Shale	1021.5	1.69 ± 0.13	0	129.2
6	Mardie Greensand Member	1150.7	1.79 ± 0.36	0	6.3
7	Mardie Greensand Member	1157	1.79 ± 0.36	0	3
8	Barrow Group (Flacourt Fm)	1160	2.83 ± 0.57	0	290
9	Dupuy Formation	1450	2.29 ± 0.46	0	575
10	Dingo Claystone	2025	1.15 ± 0.18	0	1193
11	Mungaroo Formation	3218	2.39 ± 0.12	0	1193
12	Locker Shale	4411	1.27 ± 0.11	0	1089
13	Locker Shale	5500	1.27 ± 0.11	0	1000
14	Locker Shale	6500	1.27 ± 0.11	0	1164
15	Kennedy Group	7664	2.86 ± 0.11	0	867
16	Lyons Group/Callytharra Formation	8531	2.17 ± 0.43	0	867
17	Lower Carboniferous-Ordovician (undif.)	9398	2.49 ± 0.50	0	602
18	Lower Carboniferous-Ordovician (undif.)	10000	2.49 ± 0.50	0	1000
19	Lower Carboniferous-Ordovician (undif.)	11000	2.49 ± 0.50	0	1000
20	Basement (metasediment)	12000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
1128.51	68	0	7.8996	BHT [time since circ unknown]
1156.8	71	0	8.0976	BHT [time since circ unknown]
1150.1	81.2	0	8.0507	BHT [time since circ unknown]

DEVIATED WELL



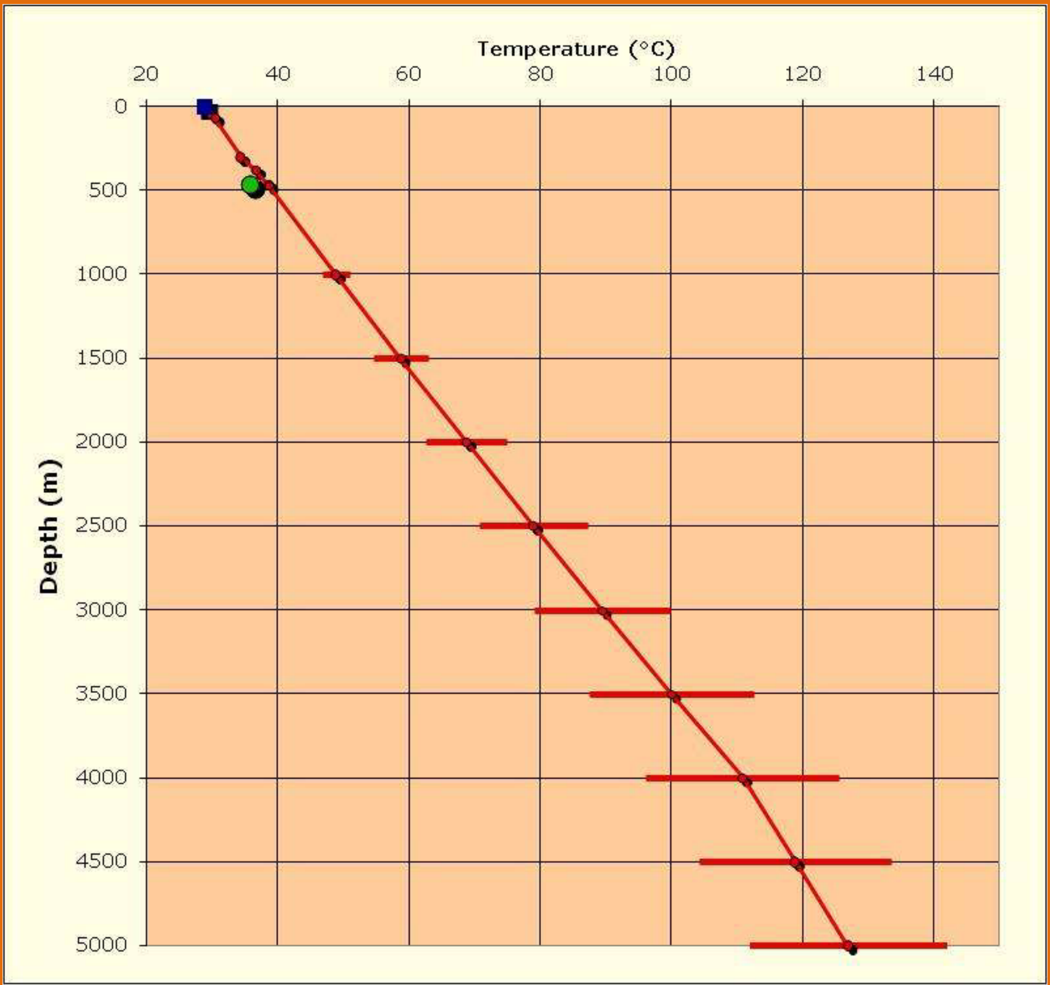
Crest 6

Number of layers	17	Up to 50	**Heat flow:**	55 ± 3.1 mW/m2
"Depth" to ground level	0	"KB height"		
Total Depth (m)	5001	From driling datum		
Surface temp. (°C)	29	**GSWA Ballythanna 1**		
Uncertainty in surface T	0.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A (µW/m^3)	Thickness (m)
1	Alluvium	0	1.42 ± 0.14	0	1
2	Keogh Formation	1	2.93 ± 0.27	0	44
3	Callytharra Formation	45	1.87 ± 0.11	0	20
4	Ballythanna Sandstone Member	65	3.36 ± 0.18	0	233
5	Callytharra Formation	298	1.87 ± 0.11	0	79
6	Lyons Group	377	2.59 ± 0.15	0	88.2
7	Lyons Group	465.2	2.59 ± 0.15	0	0.8
8	Lwr Cretaceous-Ordovician (undif.)	466	2.96 ± 0.60	0	534
9	Lwr Cretaceous-Ordovician (undif.)	1000	2.96 ± 0.60	0	500
10	Lwr Cretaceous-Ordovician (undif.)	1500	2.96 ± 0.60	0	500
11	Lwr Cretaceous-Ordovician (undif.)	2000	2.96 ± 0.60	0	500
12	Lwr Cretaceous-Ordovician (undif.)	2500	2.96 ± 0.60	0	500
13	Lwr Cretaceous-Ordovician (undif.)	3000	2.96 ± 0.60	0	500
14	Lwr Cretaceous-Ordovician (undif.)	3500	2.96 ± 0.60	0	500
15	Basement (metasediment)	4000	4.10 ± 0.10	2.1	500
16	Basement (metasediment)	4500	4.10 ± 0.10	2.1	500
17	Basement (metasediment)	5000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
465.5	36	0	3.2585	BHT [time since circ. 5:00 hours]
465.5	36	0	3.2585	BHT [time since circ. 6:30 hours]



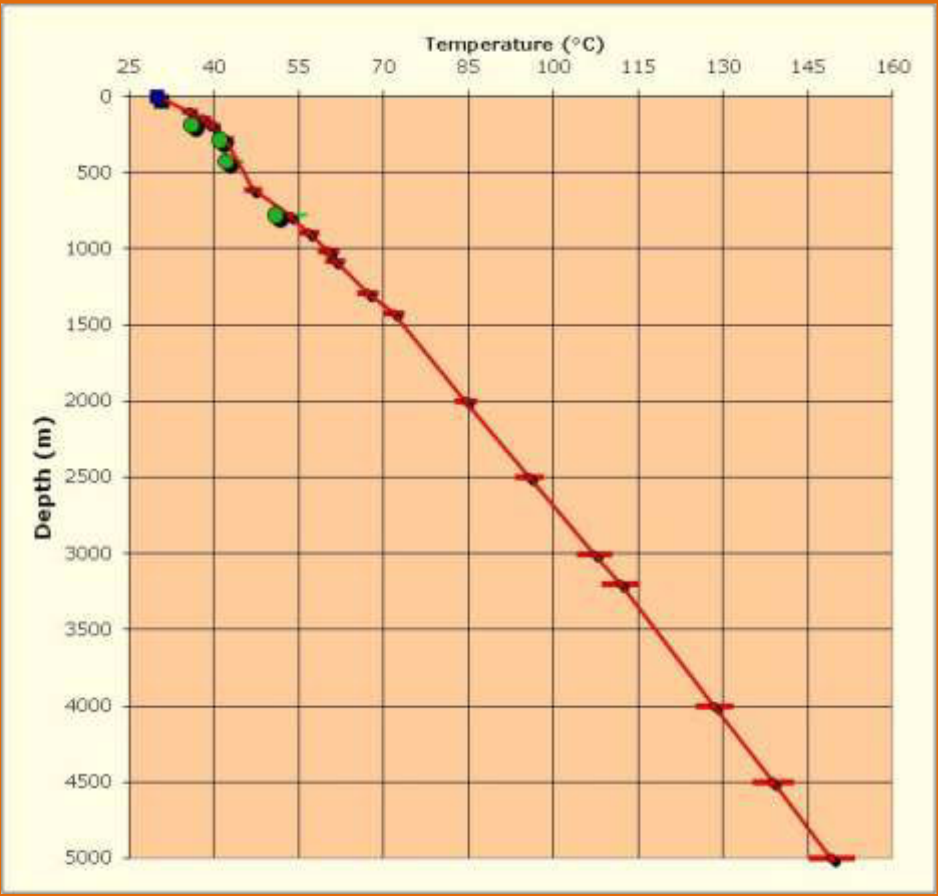
GSWA Ballythanna 1

Number of layers	23	Up to 50	Heat flow:	70 ± 0.8 mW/m2
"Depth" to ground level	0.3	"KB height"		
Total Depth (m)	5001	From driling datum		
Surface temp. (°C)	30	GSWA Barrabiddy 1A		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A ($\mu W/m^3$)	Thickness (m)
1	Alluvium	0.3	1.42 ± 0.14	0	0.7
2	Gearle Siltstone	1	1.23 ± 0.05	0	97
3	Windalia Radiolarite	98	1.45 ± 0.10	0	47
4	Windalia Sandstone Member	145	2.26 ± 0.09	0	27
5	Muderong Shale	172	1.69 ± 0.13	0	18
6	Birdrong Sandstone	190	2.83 ± 0.14	0	1
7	Munabia Formation	191	2.55 ± 0.15	0	85
8	Point Maud Member	276	5.00 ± 0.28	0	331
9	Gneudna Formation	607	1.91 ± 0.11	0	171
10	Nannyarra Sandstone	778	2.50 ± 0.16	0	4.9
11	Nannyarra Sandstone	782.9	2.50 ± 0.16	0	111.1
12	Coburn Formation	894	2.59 ± 0.12	0	121
13	Yaringa Formation	1015	4.13 ± 0.19	0	60
14	Ajana Formation	1075	2.78 ± 0.17	0	216
15	Marron Member	1291	2.09 ± 0.16	0	128
16	Tumblagooda Sandstone	1419	3.57 ± 0.18	0	581
17	Tumblagooda Sandstone	2000	3.57 ± 0.18	0	500
18	Tumblagooda Sandstone	2500	3.57 ± 0.18	0	500
19	Tumblagooda Sandstone	3000	3.57 ± 0.18	0	200
20	Basement (metasediment)	3200	4.10 ± 0.10	2.1	800
21	Basement (metasediment)	4000	4.10 ± 0.10	2.1	500
22	Basement (metasediment)	4500	4.10 ± 0.10	2.1	500
23	Basement (metasediment)	5000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
180	36	0	1.26	BHT [time since circ. 1:30 hours]
285	41	0	1.995	BHT [time since circ unknown]
421	42	0	2.947	BHT [time since circ unknown]
777	51	0	5.439	BHT [time since circ unknown]



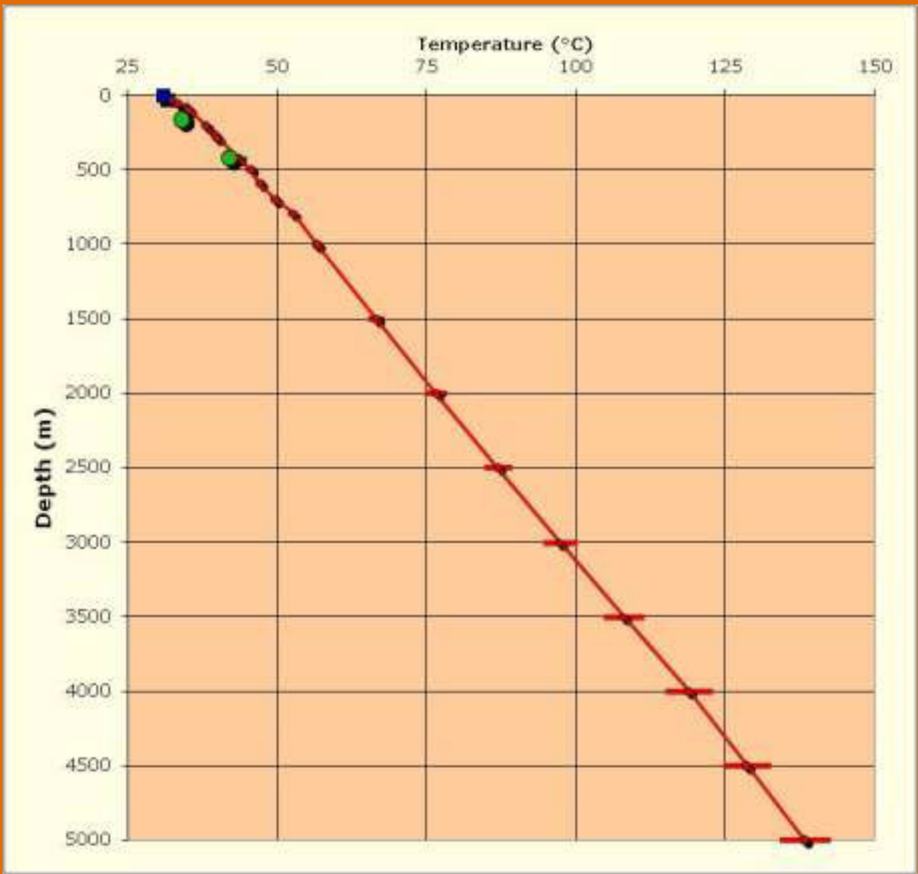
GSWA Barrabiddy 1A

Number of layers	23	Up to 50	**Heat flow:**	65 ± 0.9 mW/m2
"Depth" to ground level	0.3	"KB height"		
Total Depth (m)	5001	From driling datum		
Surface temp. (°C)	31	**GSWA Mooka 1**		
Uncertainty in surface T	0.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A ($\mu W/m^3$)	Thickness (m)
1	Alluvium	0.3	1.42 ± 0.14	0	23.2
2	Gearle Siltstone	23.5	1.23 ± 0.05	0	23.5
3	Windalia Radiolarite	47	1.45 ± 0.10	0	30
4	Muderong Shale	77	1.69 ± 0.13	0	3.5
5	Birdrong Sandstone	80.5	2.83 ± 0.14	0	12.5
6	Nannyarra Sandstone	93	2.50 ± 0.16	0	107.6
7	Sweeney Mia Formation	200.6	2.78 ± 0.56	0	59.9
8	?Kopke Sandstone	260.5	2.99 ± 0.17	0	20.5
9	Coburn Formation	281	2.59 ± 0.12	0	137
10	Coburn Formation	418	2.59 ± 0.12	0	79
11	Yaringa Formation	497	4.13 ± 0.19	0	93
12	Ajana Formation	590	2.78 ± 0.17	0	108
13	Marron Member	698	2.09 ± 0.16	0	89
14	Tumblagooda Sandstone	787	3.57 ± 0.18	0	213
15	Tumblagooda Sandstone	1000	3.57 ± 0.18	0	500
16	Tumblagooda Sandstone	1500	3.57 ± 0.18	0	500
17	Tumblagooda Sandstone	2000	3.57 ± 0.18	0	500
18	Tumblagooda Sandstone	2500	3.57 ± 0.18	0	500
19	Tumblagooda Sandstone	3000	3.57 ± 0.18	0	500
20	Tumblagooda Sandstone	3500	3.57 ± 0.18	0	500
21	Basement (metasediment)	4000	4.10 ± 0.10	2.1	500
22	Basement (metasediment)	4500	4.10 ± 0.10	2.1	500
23	Basement (metasediment)	5000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
160	34	0	1.12	BHT [time since circ. 1:00 hour]
160	34	0	1.12	BHT [time since circ. 2:00 hours]
418.6	42	0	2.9302	BHT [time since circ 11:30 hours]
418.6	42	0	2.9302	BHT [time since circ. 17:30 hours]



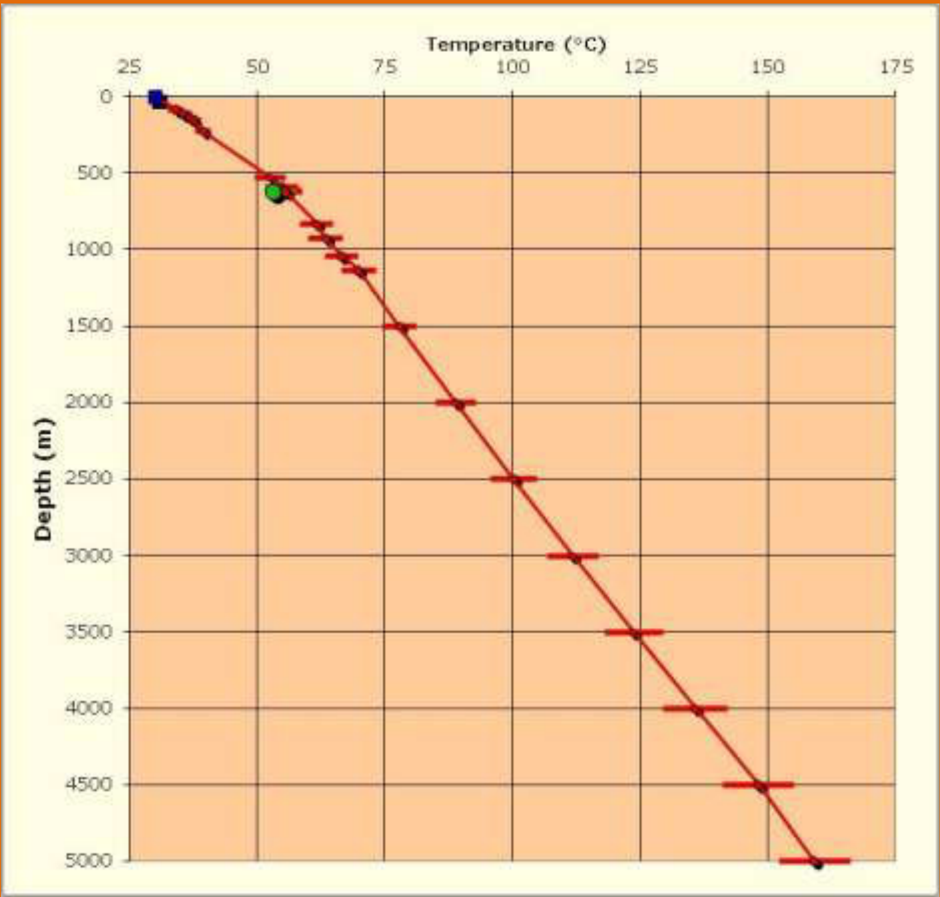
GSWA Mooka 1

Number of layers	23	Up to 50	**Heat flow:**	70 ± 1.7 mW/m2
"Depth" to ground level	0	"KB height"		
Total Depth (m)	5001	From driling datum		
Surface temp. (°C)	30	**GSWA Woodleigh 2A**		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A (μW/m^3)	Thickness (m)
1	Alluvium	0	1.42 ± 0.14	0	14
2	Toolonga Calcilutite	14	1.45 ± 0.06	0	65
3	Gearle Siltstone	79	1.23 ± 0.05	0	27
4	Windalia Radiolarite	106	1.45 ± 0.10	0	28
5	Muderong Shale	134	1.69 ± 0.13	0	14
6	Birdrong Sandstone	148	2.83 ± 0.14	0	75
7	Woodleigh Formation	223	1.63 ± 0.33	0	298.3
8	un-named paraconglomerate	521.3	2.10 ± 0.42	0	65.9
9	un-named dolomite breccia	587.2	2.59 ± 0.12	0	13.75
10	Coburn Formation	600.95	2.59 ± 0.12	0	17.35
11	Coburn Formation	618.3	2.59 ± 0.12	0	208.7
12	Yaringa Formation	827	4.13 ± 0.19	0	98
13	Ajana Formation	925	2.78 ± 0.17	0	113
14	Marron Member	1038	2.09 ± 0.16	0	94
15	Tumblagooda Sandstone	1132	3.57 ± 0.18	0	368
16	Tumblagooda Sandstone	1500	3.57 ± 0.18	0	500
17	Tumblagooda Sandstone	2000	3.57 ± 0.18	0	500
18	Tumblagooda Sandstone	2500	3.57 ± 0.18	0	500
19	Tumblagooda Sandstone	3000	3.57 ± 0.18	0	500
20	Tumblagooda Sandstone	3500	3.57 ± 0.18	0	500
21	Tumblagooda Sandstone	4000	3.57 ± 0.18	0	500
22	Basement (metasediment)	4500	4.10 ± 0.10	2.1	500
23	Basement (metasediment)	5000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
618.5	53	0	4.3295	BHT [time since circ. 11:30 hours]



GSWA Woodleigh 2A

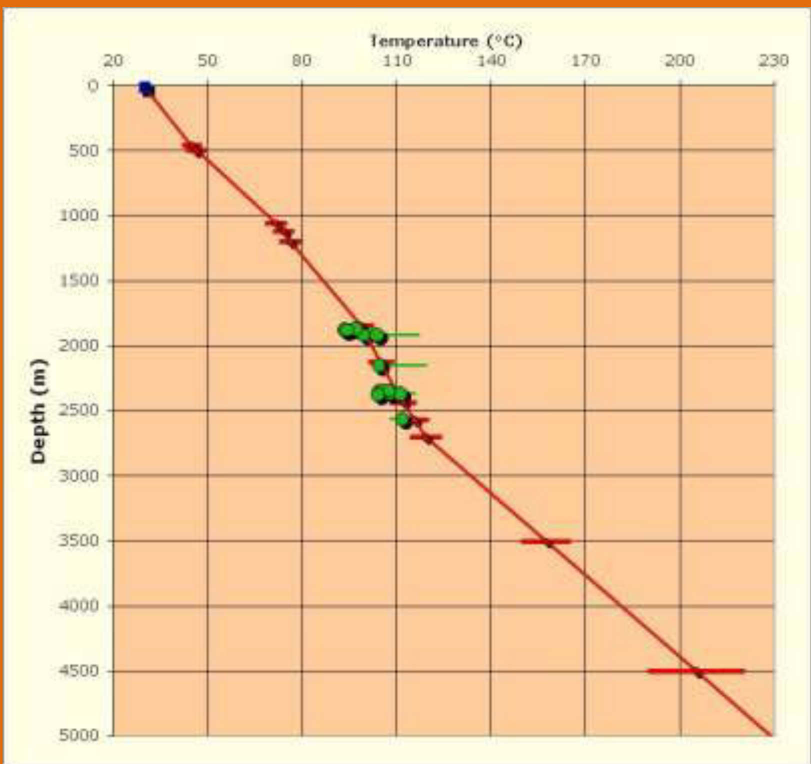
Number of layers	25	Up to 50	Heat flow:	55 ± 2.3 mW/m2
"Depth" to ground level	6.49	"KB height"		
Total Depth (m)	15001	From drilling datum		
Surface temp. (°C)	30	Rosette 1/ST1		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A ($\mu W/m^3$)	Thickness (m)
1	Tertiary [undif. carbonates]	6.49	1.68 ± 0.34	0	448.51
2	Toolonga Calcilutite	455	1.45 ± 0.06	0	37
3	Gearle Siltstone	492	1.23 ± 0.05	0	561
4	Windalia Radiolarite	1053	1.45 ± 0.10	0	63
5	Windalia Sandstone Member	1116	2.26 ± 0.09	0	81
6	Muderong Shale	1197	1.69 ± 0.13	0	648.5
7	Flag Sandstone	1845.5	2.83 ± 0.57	0	281
8	Lower Barrow Gp [intr. cst/sst]	2126.5	2.83 ± 0.57	0	310.5
9	Dupuy Sandstone	2437	2.29 ± 0.46	0	133
10	Dupuy Sandstone	2570	2.29 ± 0.46	0	130
11	Dingo Claystone	2700	1.15 ± 0.18	0	800
12	Dingo Claystone	3500	1.15 ± 0.18	0	1000
13	Dingo Claystone	4500	1.15 ± 0.18	0	1000
14	Mungaroo Formation	5500	2.39 ± 0.12	0	1000
15	Mungaroo Formation	6500	2.39 ± 0.12	0	600
16	Locker Shale	7100	1.27 ± 0.11	0	1000
17	Kennedy Group	8100	2.86 ± 0.11	0	400
18	Byro Group	8500	2.12 ± 0.42	0	600
19	Early Permian-Ordovician (undif.)	9100	2.35 ± 0.48	0	900
20	Early Permian-Ordovician (undif.)	10000	2.35 ± 0.48	0	1000
21	Early Permian-Ordovician (undif.)	11000	2.35 ± 0.48	0	1000
22	Early Permian-Ordovician (undif.)	12000	2.35 ± 0.48	0	1000
23	Early Permian-Ordovician (undif.)	13000	2.35 ± 0.48	0	1000
24	Early Permian-Ordovician (undif.)	14000	2.35 ± 0.48	0	1000
25	Basement (granite)	15000	4.48 ± 0.28	2.74	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
1909.2	99.62	3	3	Horner [4 values]
2362.3	107.83	4	4	Horner [3 values]
1910.7	103.9	0	13.375	BHT [time since circ 57:25]
2558.3	111.77	4	4	Horner [3 values]
1864.5	97.2	5	5	Horner [2 values]
2367.3	111.15	5	5	Horner [2 values]
2149.5	104.4	0	15.047	BHT [time since circ 21:30]
2337.45	104.86	0	2	DST1 [tight]
2337.45	105.82	0	2	DST1A [tight]
2337.45	107.62	0	2	DST1B [tight]
2370.25	104	0	2	DST2 [produced oil 1.5 stb/d]
1876.85	93.9	0	2	DST3A [produced oil 130 bpd; .25" choke; 65% water cut; GOR 610 scf/stb]
1876.3	93.4	0	2	DST4 [produced oil 152 bpd, .125" choke, .1 mmscf/d; 4.6% water cut; GOR 791 scf/stb]
1870.35	94.5	0	2	DST5 [produced 18.4 mmscf/d; 326 bcpd; .625" choke; condensate 59.7API]

DEVIATED WELL



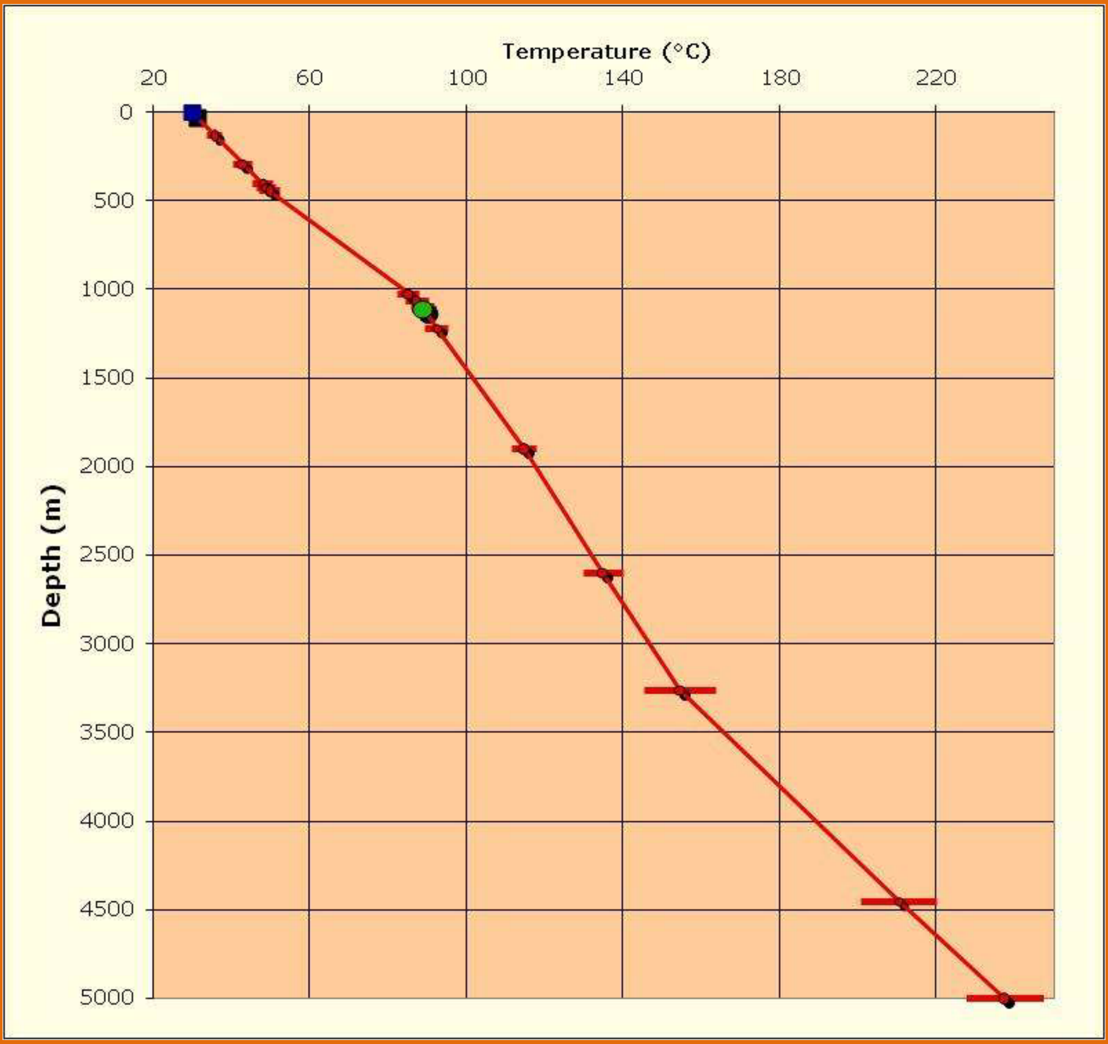
Rosette 1 ST1

Number of layers	17	Up to 50	Heat flow:	74 ± 2.6 mW/m2
"Depth" to ground level	2.7	"KB height"		
Total Depth (m)	5001	From driling datum		
Surface temp. (°C)	30	Rough Range 1A re-entry		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A ($\mu W/m^3$)	Thickness (m)
1	?Trealla Limestone	2.7	1.68 ± 0.34	0	123
2	Giralia Calcarenite	125.7	1.68 ± 0.34	0	163.3
3	Cardabia Group	289	1.68 ± 0.34	0	114
4	Korojon Calcarenite	403	1.68 ± 0.34	0	17.1
5	Toolonga Calcilutite	420.1	1.45 ± 0.06	0	18.9
6	Gearle Siltstone	439	1.23 ± 0.05	0	582.6
7	Windalia Radiolarite	1021.6	1.45 ± 0.10	0	41.8
8	Muderong Shale	1063.4	1.69 ± 0.13	0	34
9	Birdrong Sandstone	1097.4	2.83 ± 0.14	0	9.9
10	Birdrong Sandstone	1107.3	2.83 ± 0.14	0	1.7
11	Wogatti Sandstone - Rough Range 1	1109	2.83 ± 0.57	0	107
12	Lyons Gp - Rough Range 1	1216	2.59 ± 0.15	0	681
13	Carboniferous-Devonian (undif.) - Rough Range 1	1897	3.12 ± 0.62	0	703
14	Carboniferous-Devonian (undif.) - Rough Range 1	2600	3.12 ± 0.62	0	663
15	Gneudna Fm - Rough Range 1	3263	1.91 ± 0.11	0	1189
16	Gneudna Fm - Rough Range 1 TD	4452	1.91 ± 0.11	0	548
17	Basement (metasediment)	5000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
1105.3	89.02	3	3	Horner [4 values]



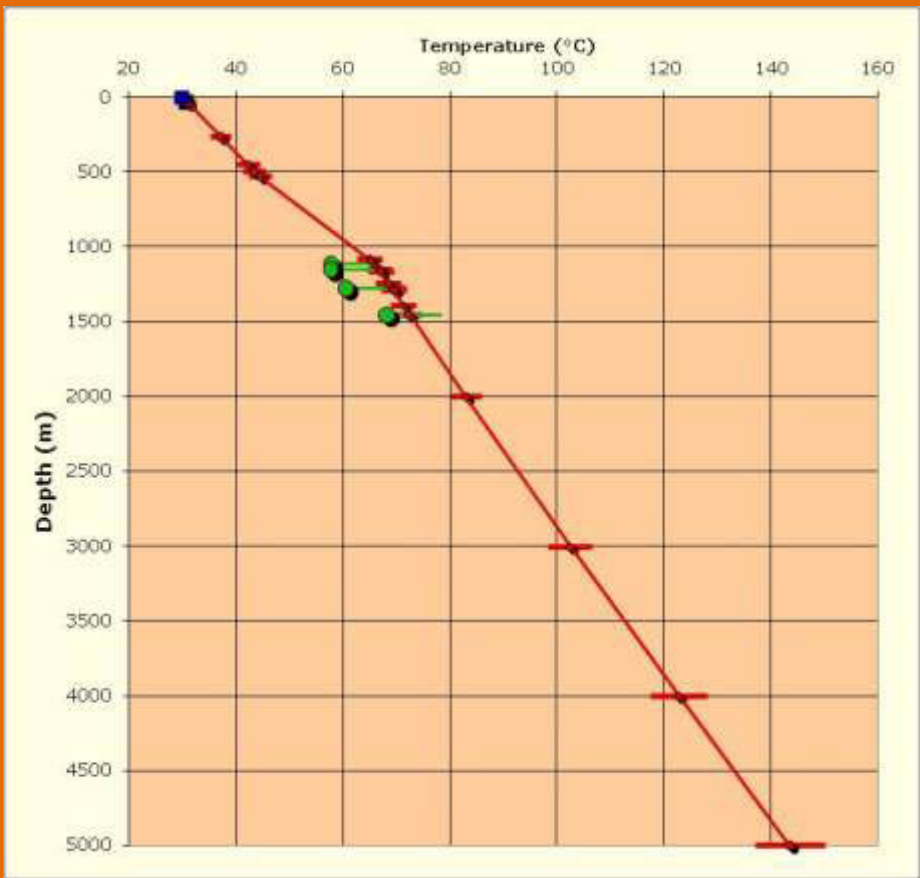
Rough Range 1A re-entry

Number of layers	20	Up to 50	Heat flow:	45 ± 1.0 mW/m2
"Depth" to ground level	2.74	"KB height"		
Total Depth (m)	6001	From driling datum		
Surface temp. (°C)	30	Rough Range South 5		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A ($\mu W/m^3$)	Thickness (m)
1	Exmouth Sandstone	2.74	1.42 ± 0.14	0	33.76
2	Trealla/Mandu/Giralia Calcarenite	36.5	1.68 ± 0.34	0	222.5
3	Cardabia Group	259	1.68 ± 0.34	0	190
4	Korojon Calcarenite	449	1.68 ± 0.34	0	45
5	Toolonga Calcilutite	494	1.45 ± 0.06	0	31
6	Gearle Siltstone	525	1.23 ± 0.05	0	555
7	Windalia Radiolarite	1080	1.45 ± 0.10	0	7
8	Muderong Shale	1087	1.69 ± 0.13	0	62
9	Birdrong Sandstone	1149	2.83 ± 0.14	0	15
10	Wogatti Sandstone	1164	2.83 ± 0.57	0	79
11	Muderong Shale	1243	1.69 ± 0.13	0	28
12	Birdrong Sandstone	1271	2.83 ± 0.14	0	16
13	Wogatti Sandstone	1287	2.83 ± 0.57	0	99
14	Lyons Group	1386	2.59 ± 0.15	0	64.8
15	Lyons Group	1450.8	2.59 ± 0.15	0	549.2
16	Lyons Group	2000	2.59 ± 0.15	0	1000
17	Lyons Group	3000	2.59 ± 0.15	0	1000
18	Lyons Group	4000	2.59 ± 0.15	0	1000
19	Lyons Group	5000	2.59 ± 0.15	0	1000
20	Basement (metasediment)	6000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
1110.08	57.78	0	7.7706	BHT [time since circ unknown]
1151.53	57.78	0	8.0607	BHT [time since circ unknown]
1275.58	60.56	0	8.9291	BHT [time since circ unknown]
1451.15	68.33	0	10.158	BHT [time since circ unknown]



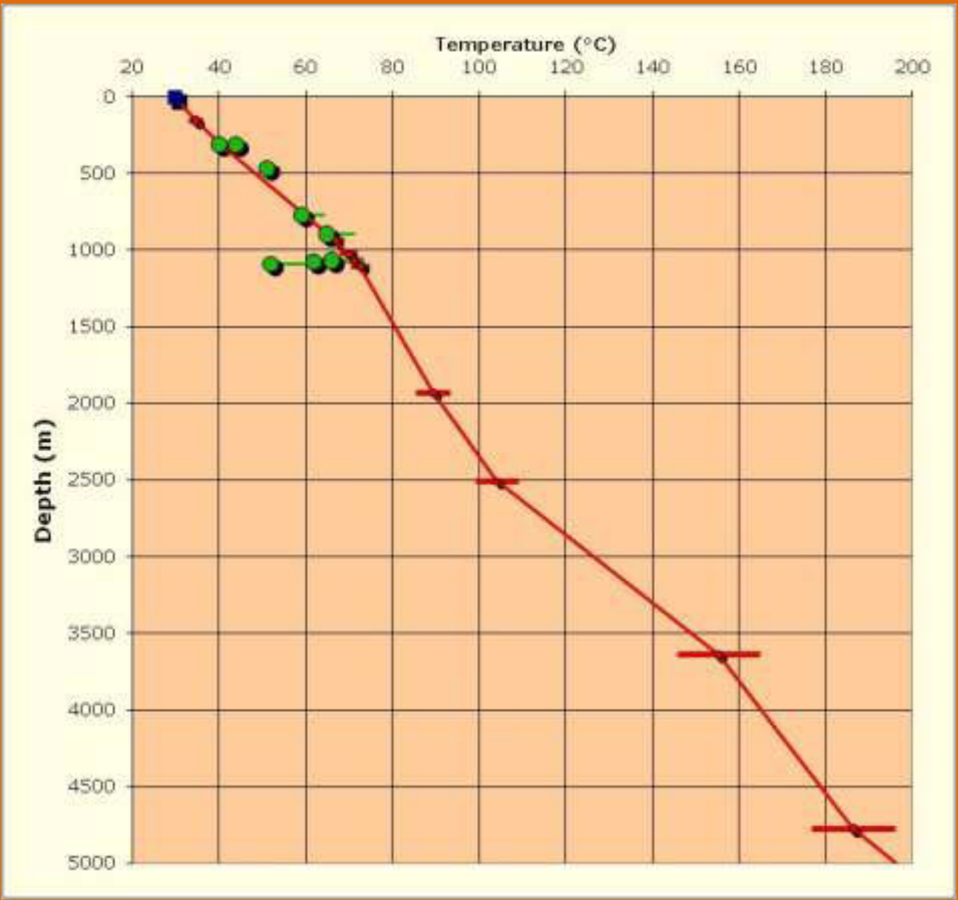
Rough Range South 5

Number of layers	21	Up to 50	**Heat flow:**	52 ± 2.0 mW/m2
"Depth" to ground level	5.2	"KB height"		
Total Depth (m)	12001	From driling datum		
Surface temp. (°C)	30	**Saladin 13H**		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A (μW/m³)	Thickness (m)
1	Alluvium	5.2	1.42 ± 0.14	0	5.8
2	Tertiary [undif. carbonates]	11	1.68 ± 0.34	0	139
3	Toolonga Calcilutite	150	1.45 ± 0.06	0	171
4	Gearle Siltstone	321	1.23 ± 0.05	0	611.5
5	Windalia Radiolarite	932.5	1.45 ± 0.10	0	85
6	Muderong Shale	1017.5	1.69 ± 0.13	0	42.5
7	Mardie Greensand Member	1060	1.79 ± 0.36	0	43.7
8	Mardie Greensand Member	1103.7	1.79 ± 0.36	0	1.3
9	Barrow Group (Flacourt Fm)	1105	2.83 ± 0.57	0	821
10	Dupuy Formation	1926	2.29 ± 0.46	0	575
11	Dingo Claystone	2501	1.15 ± 0.18	0	1136
12	Mungaroo Formation	3637	2.39 ± 0.12	0	1136
13	Locker Shale	4773	1.27 ± 0.11	0	1027
14	Locker Shale	5800	1.27 ± 0.11	0	1000
15	Locker Shale	6800	1.27 ± 0.11	0	1071
16	Kennedy Group	7871	2.86 ± 0.11	0	826
17	Lyons Group/Callytharra Formation	8697	2.17 ± 0.43	0	826
18	Lower Carboniferous-Ordovician (undif.)	9523	2.49 ± 0.50	0	477
19	Lower Carboniferous-Ordovician (undif.)	10000	2.49 ± 0.50	0	1000
20	Lower Carboniferous-Ordovician (undif.)	11000	2.49 ± 0.50	0	1000
21	Basement (metasediment)	12000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
307	40	0	2.149	drill mud data
307	44	0	2.149	drill mud data
462.28	51	0	3.236	drill mud data
765.72	59	0	5.36	drill mud data
893.91	65	0	6.2574	drill mud data
1073.78	62	0	7.5165	drill mud data
1082.46	52	0	7.5772	drill mud data
1065.62	66	0	7.4593	drill mud data



Saladin 13H

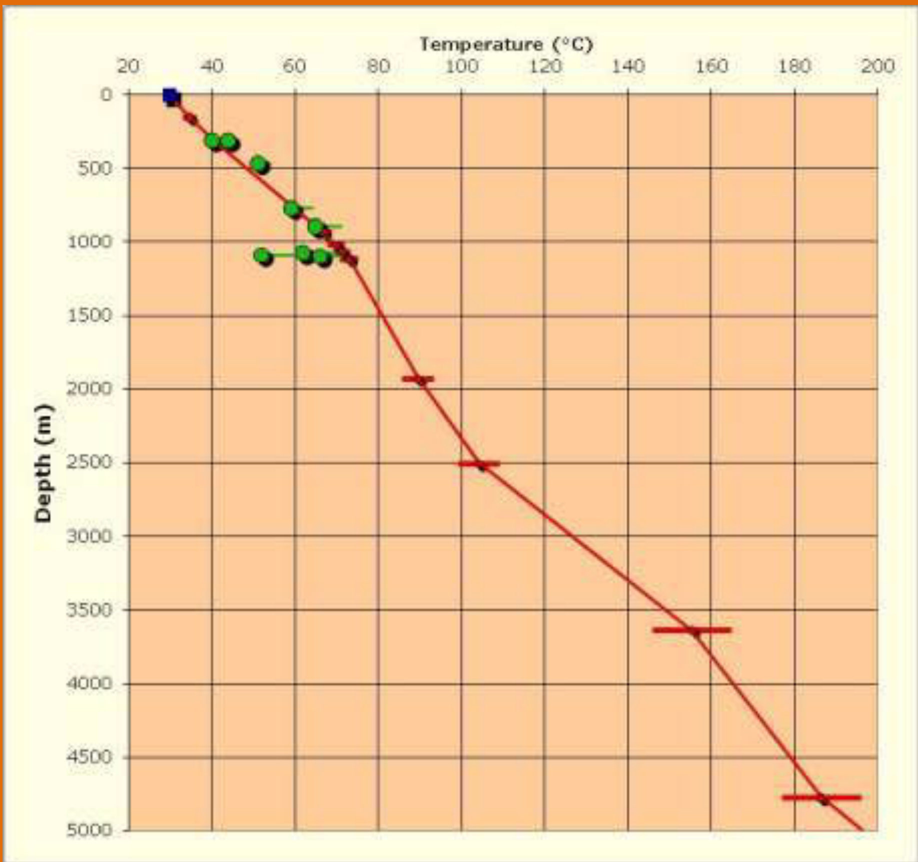
Number of layers	21	Up to 50	Heat flow: 52 ± 2.0 mW/m2
"Depth" to ground level	5.2	"KB height"	
Total Depth (m)	12001	From driling datum	
Surface temp. (°C)	30	Saladin 13H ST1	
Uncertainty in surface T	1.5	±°C	

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A (µW/m³)	Thickness (m)
1	Alluvium	5.2	1.42 ± 0.14	0	5.8
2	Tertiary [undif. carbonates]	11	1.68 ± 0.34	0	139
3	Toolonga Calcilutite	150	1.45 ± 0.06	0	171
4	Gearle Siltstone	321	1.23 ± 0.05	0	611.5
5	Windalia Radiolarite	932.5	1.45 ± 0.10	0	85
6	Muderong Shale	1017.5	1.69 ± 0.13	0	42.5
7	Mardie Greensand Member	1060	1.79 ± 0.36	0	50.6
8	Mardie Greensand Member	1110.6	1.79 ± 0.36	0	4.4
9	Barrow Group (Flacourt Fm)	1115	2.83 ± 0.57	0	811
10	Dupuy Formation	1926	2.29 ± 0.46	0	575
11	Dingo Claystone	2501	1.15 ± 0.18	0	1136
12	Mungaroo Formation	3637	2.39 ± 0.12	0	1136
13	Locker Shale	4773	1.27 ± 0.11	0	1027
14	Locker Shale	5800	1.27 ± 0.11	0	1000
15	Locker Shale	6800	1.27 ± 0.11	0	1071
16	Kennedy Group	7871	2.86 ± 0.11	0	826
17	Lyons Group/Callytharra Formation	8697	2.17 ± 0.43	0	826
18	Lower Carboniferous-Ordovician (undif.)	9523	2.49 ± 0.50	0	477
19	Lower Carboniferous-Ordovician (undif.)	10000	2.49 ± 0.50	0	1000
20	Lower Carboniferous-Ordovician (undif.)	11000	2.49 ± 0.50	0	1000
21	Basement (metasediment)	12000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
307	40	0	2.149	drill mud data
307	44	0	2.149	drill mud data
462.28	51	0	3.236	drill mud data
765.72	59	0	5.36	drill mud data
893.91	65	0	6.2574	drill mud data
1073.78	62	0	7.5165	drill mud data
1082.46	52	0	7.5772	drill mud data
1089.92	66	0	7.6294	drill mud data

HORIZONTAL WELL



Saladin 13H ST1

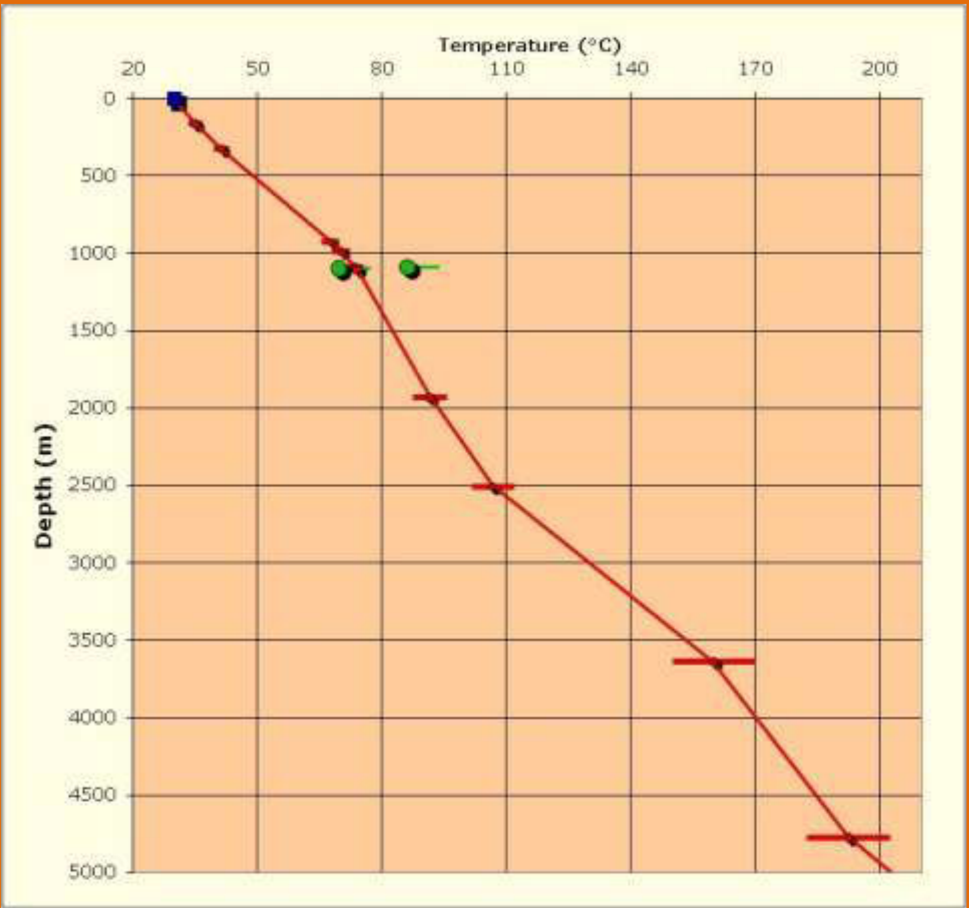
Number of layers	20	Up to 50	**Heat flow:** 54 ± 2.1 mW/m2
"Depth" to ground level	5.2	"KB height"	
Total Depth (m)	12001	From driling datum	
Surface temp. (°C)	30	**Saladin 14**	
Uncertainty in surface T	1.5	±°C	

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A (μW/m³)	Thickness (m)
1	Tertiary [undif. carbonates]	5.2	1.68 ± 0.34	0	154.5
2	Toolonga Calcilutite	159.7	1.45 ± 0.06	0	165.3
3	Gearle Siltstone	325	1.23 ± 0.05	0	595
4	Windalia Radiolarite	920	1.45 ± 0.10	0	67.5
5	Muderong Shale	987.5	1.69 ± 0.13	0	96.5
6	Mardie Greensand Member	1084	1.79 ± 0.36	0	0.1
7	Mardie Greensand Member	1084.1	1.79 ± 0.36	0	20.9
8	Barrow Group (Flacourt Fm)	1105	2.83 ± 0.57	0	821
9	Dupuy Formation	1926	2.29 ± 0.46	0	575
10	Dingo Claystone	2501	1.15 ± 0.18	0	1136
11	Mungaroo Formation	3637	2.39 ± 0.12	0	1136
12	Locker Shale	4773	1.27 ± 0.11	0	1027
13	Locker Shale	5800	1.27 ± 0.11	0	1000
14	Locker Shale	6800	1.27 ± 0.11	0	1071
15	Kennedy Group	7871	2.86 ± 0.11	0	826
16	Lyons Group/Callytharra Formation	8697	2.17 ± 0.43	0	826
17	Lower Carboniferous-Ordovician (undif.)	9523	2.49 ± 0.50	0	477
18	Lower Carboniferous-Ordovician (undif.)	10000	2.49 ± 0.50	0	1000
19	Lower Carboniferous-Ordovician (undif.)	11000	2.49 ± 0.50	0	1000
20	Basement (metasediment)	12000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
1094.3	69.6	0	7.6601	BHT [time since circ unknown]
1082.98	86.1	0	7.5809	BHT [time since circ unknown]

HORIZONTAL WELL



Saladin 14

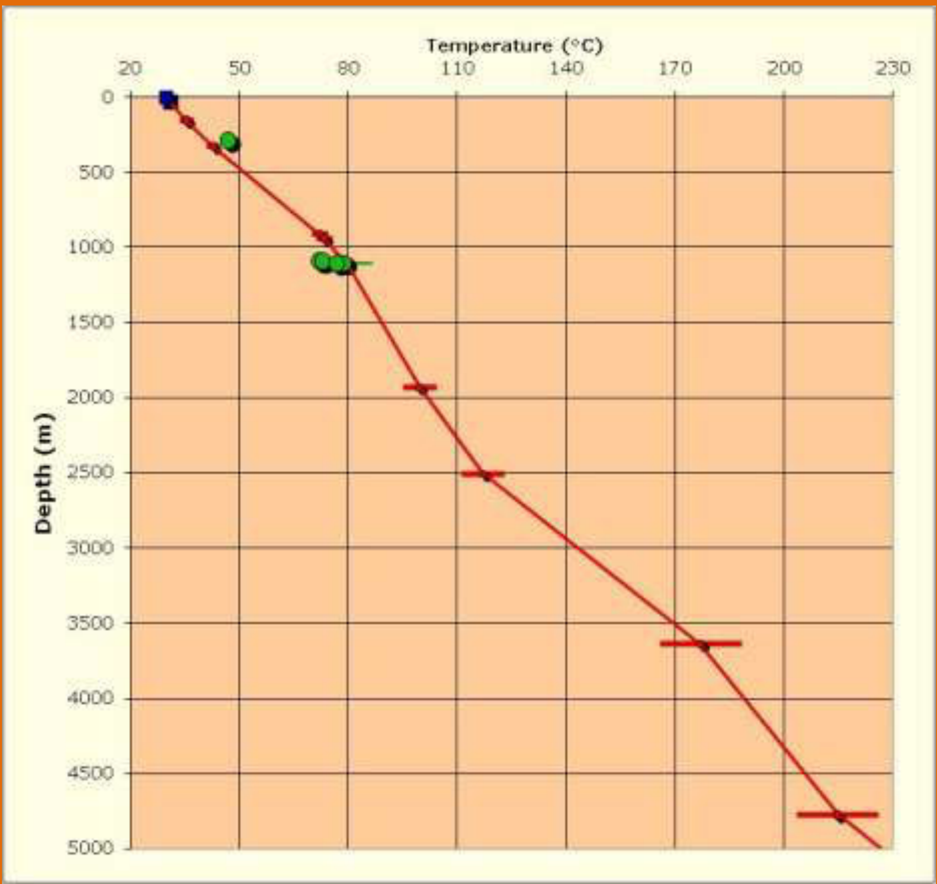
Number of layers	20	Up to 50	**Heat flow:**	61 ± 2.4 mW/m2
"Depth" to ground level	4.14	"KB height"		
Total Depth (m)	12001	From driling datum		
Surface temp. (°C)	30	**Saladin 18M**		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A (μW/m^3)	Thickness (m)
1	Tertiary [undif. carbonates]	4.14	1.68 ± 0.34	0	146.26
2	Toolonga Calcilutite	150.4	1.45 ± 0.06	0	172.1
3	Gearle Siltstone	322.5	1.23 ± 0.05	0	587.5
4	Windalia Radiolarite	910	1.45 ± 0.10	0	31
5	Muderong Shale	941	1.69 ± 0.13	0	143.5
6	Mardie Greensand Member	1084.5	1.79 ± 0.36	0	18.3
7	Mardie Greensand Member	1102.8	1.79 ± 0.36	0	2.2
8	Barrow Group (Flacourt Fm)	1105	2.83 ± 0.57	0	821
9	Dupuy Formation	1926	2.29 ± 0.46	0	575
10	Dingo Claystone	2501	1.15 ± 0.18	0	1136
11	Mungaroo Formation	3637	2.39 ± 0.12	0	1136
12	Locker Shale	4773	1.27 ± 0.11	0	1027
13	Locker Shale	5800	1.27 ± 0.11	0	1000
14	Locker Shale	6800	1.27 ± 0.11	0	1071
15	Kennedy Group	7871	2.86 ± 0.11	0	826
16	Lyons Group/Callytharra Formation	8697	2.17 ± 0.43	0	826
17	Lower Carboniferous-Ordovician (undif.)	9523	2.49 ± 0.50	0	477
18	Lower Carboniferous-Ordovician (undif.)	10000	2.49 ± 0.50	0	1000
19	Lower Carboniferous-Ordovician (undif.)	11000	2.49 ± 0.50	0	1000
20	Basement (metasediment)	12000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C): **Maximum 20 values**

Depth (m)	Value	-uncert	+uncert	Comment:
285.23	47	0	1.9966	BHT [time since circ unknown]
1087.87	72	0	7.6151	BHT [time since circ unknown]
1087.87	73	0	7.6151	BHT [time since circ unknown]
1100.03	79	0	7.7002	BHT [time since circ unknown]
1102.8	76.9	0	7.7196	BHT [time since circ unknown]

HORIZONTAL WELL



Saladin 18M

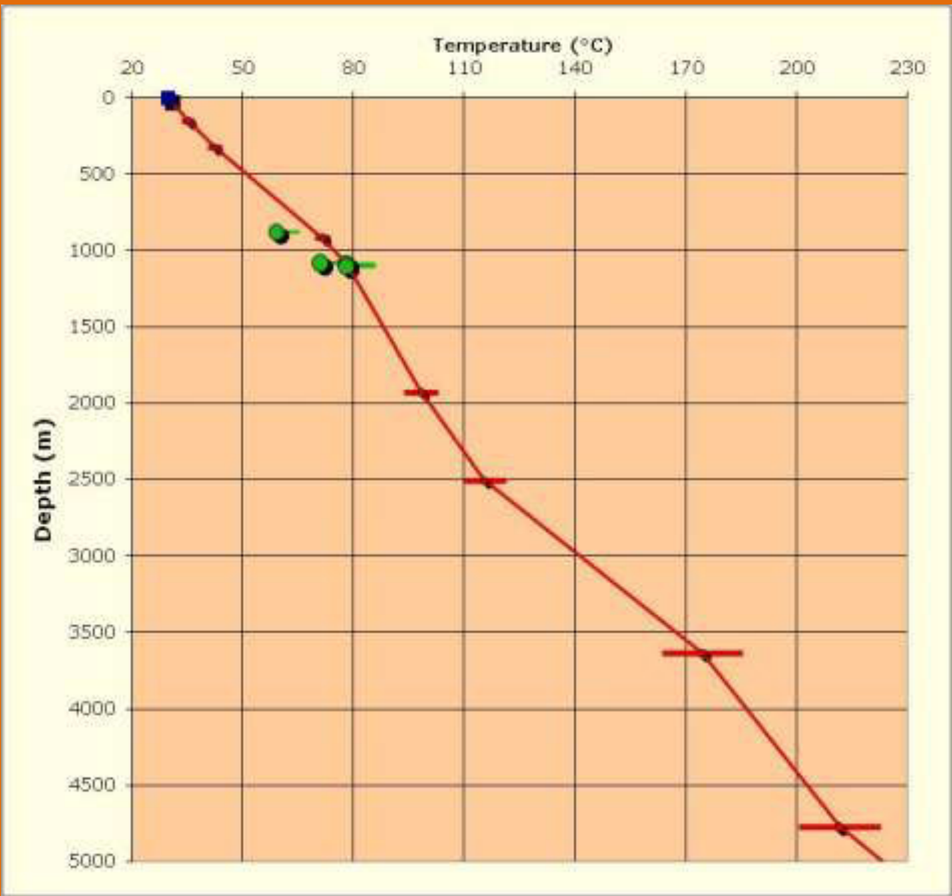
Number of layers	19	Up to 50	**Heat flow:**	60 ± 2.4 mW/m2
"Depth" to ground level	4.14	"KB height"		
Total Depth (m)	12001	From driling datum		
Surface temp. (°C)	30	**Saladin 19M ST1**		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A ($\mu W/m^3$)	Thickness (m)
1	Tertiary [undif. carbonates]	4.14	1.68 ± 0.34	0	144.26
2	Toolonga Calcilutite	148.4	1.45 ± 0.06	0	170.6
3	Gearle Siltstone	319	1.23 ± 0.05	0	596
4	Muderong Shale	915	1.69 ± 0.13	0	161
5	Mardie Greensand Member	1076	1.79 ± 0.36	0	24
6	Mardie Greensand Member	1100	1.79 ± 0.36	0	5
7	Barrow Group (Flacourt Fm)	1105	2.83 ± 0.57	0	821
8	Dupuy Formation	1926	2.29 ± 0.46	0	575
9	Dingo Claystone	2501	1.15 ± 0.18	0	1136
10	Mungaroo Formation	3637	2.39 ± 0.12	0	1136
11	Locker Shale	4773	1.27 ± 0.11	0	1027
12	Locker Shale	5800	1.27 ± 0.11	0	1000
13	Locker Shale	6800	1.27 ± 0.11	0	1071
14	Kennedy Group	7871	2.86 ± 0.11	0	826
15	Lyons Group/Callytharra Formation	8697	2.17 ± 0.43	0	826
16	Lower Carboniferous-Ordovician (undif.)	9523	2.49 ± 0.50	0	477
17	Lower Carboniferous-Ordovician (undif.)	10000	2.49 ± 0.50	0	1000
18	Lower Carboniferous-Ordovician (undif.)	11000	2.49 ± 0.50	0	1000
19	Basement (metasediment)	12000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
875.35	59	0	6.1275	BHT [time since circ unknown]
1079.81	71	0	7.5587	BHT [time since circ unknown]
1088.84	78.1	0	7.6219	BHT [time since circ unknown]
1100	78.1	0	7.7	BHT [time since circ unknown]

HORIZONTAL WELL



Saladin 19M ST1

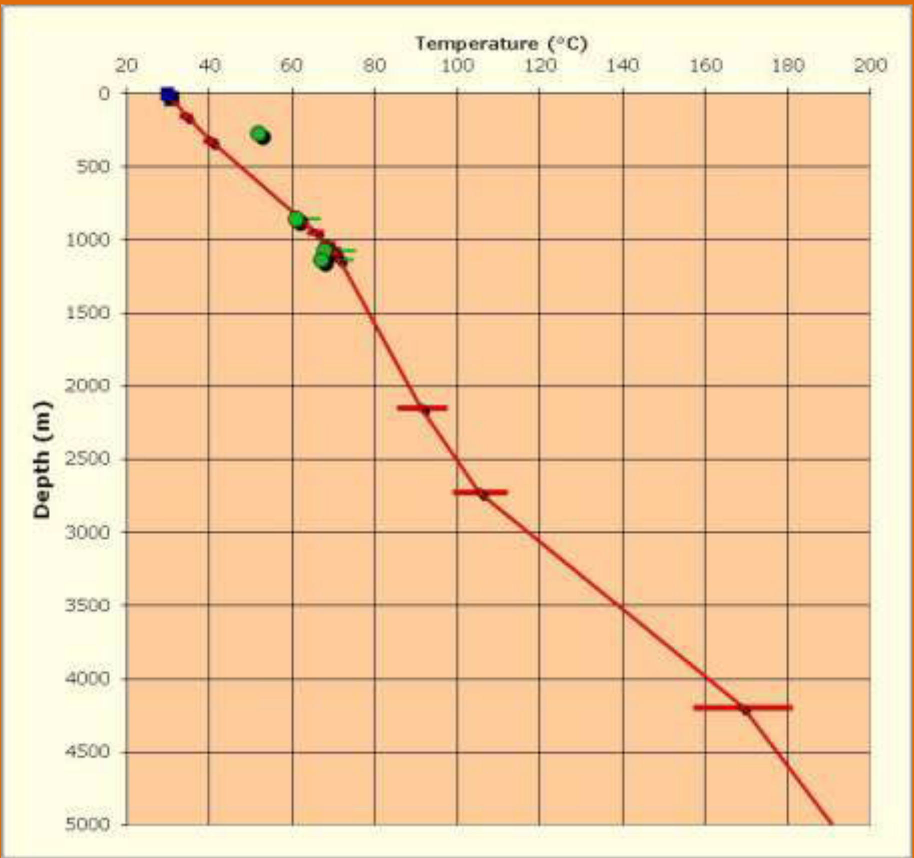
Number of layers	21	Up to 50	**Heat flow:**	50 ± 1.9 mW/m2
"Depth" to ground level	4.14	"KB height"		
Total Depth (m)	15001	From driling datum		
Surface temp. (°C)	30	**Saladin 24**		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A ($\mu W/m^3$)	Thickness (m)
1	Tertiary [undif. carbonates]	4.14	1.68 ± 0.34	0	144.26
2	Toolonga Calcilutite	148.4	1.45 ± 0.06	0	172.6
3	Gearle Siltstone	321	1.23 ± 0.05	0	621
4	Windalia Radiolarite	942	1.45 ± 0.10	0	78.7
5	Muderong Shale	1020.7	1.69 ± 0.13	0	44.9
6	Mardie Greensand Member	1065.6	1.79 ± 0.36	0	17.4
7	Barrow Group (Flacourt Fm)	1083	2.83 ± 0.57	0	47.5
8	Barrow Group (Flacourt Fm)	1130.5	2.83 ± 0.57	0	1019.5
9	Dupuy Formation	2150	2.29 ± 0.46	0	575
10	Dingo Claystone	2725	1.15 ± 0.18	0	1468
11	Mungaroo Formation	4193	2.39 ± 0.12	0	1468
12	Locker Shale	5661	1.27 ± 0.11	0	939
13	Locker Shale	6600	1.27 ± 0.11	0	1000
14	Locker Shale	7600	1.27 ± 0.11	0	1000
15	Locker Shale	8600	1.27 ± 0.11	0	1064
16	Kennedy Group	9664	2.86 ± 0.11	0	1067
17	Lyons Group/Callytharra Formation	10731	2.17 ± 0.43	0	1067
18	Lower Carboniferous-Ordovician (undif.)	11798	2.49 ± 0.50	0	1202
19	Lower Carboniferous-Ordovician (undif.)	13000	2.49 ± 0.50	0	1000
20	Lower Carboniferous-Ordovician (undif.)	14000	2.49 ± 0.50	0	1000
21	Basement (granite)	15000	4.48 ± 0.28	2.74	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
267.77	52	0	1.8744	BHT [time since circ unknown]
853.57	61	0	5.975	BHT [time since circ unknown]
1073.37	68	0	7.5136	BHT [time since circ unknown]
1130.5	67	0	7.9135	BHT [time since circ unknown]

HORIZONTAL WELL



Saladin 24

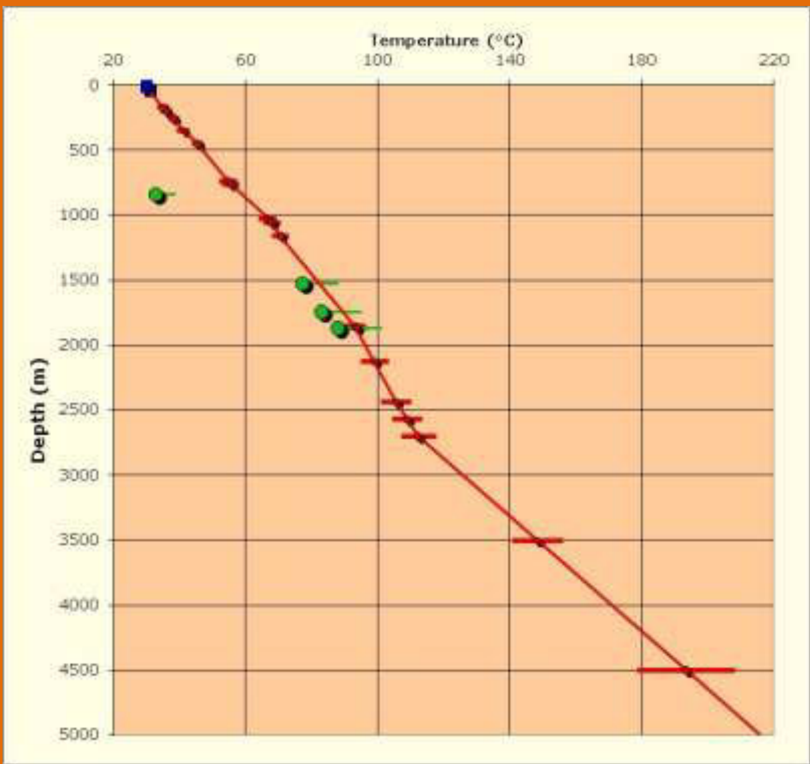
Number of layers	31	Up to 50	**Heat flow:**	52 ± 2.2 mW/m2
"Depth" to ground level	9.3	"KB height"		
Total Depth (m)	15001	From driling datum		
Surface temp. (°C)	30	**Tanami 3 ST1**		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A ($\mu W/m^3$)	Thickness (m)
1	Cape Range Group	9.3	1.68 ± 0.34	0	157.7
2	Giralia Calcarenite	167	1.68 ± 0.34	0	31
3	Wilcox Formation	198	1.23 ± 0.05	0	54
4	Cardabia Group	252	1.68 ± 0.34	0	90
5	Lambert Formation	342	1.23 ± 0.05	0	103.3
6	Korojon Calcarenite	445.3	1.68 ± 0.34	0	288.5
7	Toolonga Calcilutite	733.8	1.45 ± 0.06	0	23.03
8	Gearle Siltstone	756.83	1.23 ± 0.05	0	263.23
9	Windalia Radiolarite	1020.06	1.45 ± 0.10	0	35.55
10	Windalia Sandstone Member	1055.61	2.26 ± 0.09	0	100.36
11	Muderong Shale	1155.97	1.69 ± 0.13	0	694.99
12	Flag Sandstone	1850.96	2.83 ± 0.57	0	16.24
13	Flag Sandstone	1867.2	2.83 ± 0.57	0	259.3
14	Lower Barrow Gp [intr. cst/sst]	2126.5	2.83 ± 0.57	0	310.5
15	Dupuy Sandstone	2437	2.29 ± 0.46	0	133
16	Dupuy Sandstone	2570	2.29 ± 0.46	0	130
17	Dingo Claystone	2700	1.15 ± 0.18	0	800
18	Dingo Claystone	3500	1.15 ± 0.18	0	1000
19	Dingo Claystone	4500	1.15 ± 0.18	0	1000
20	Mungaroo Formation	5500	2.39 ± 0.12	0	1000
21	Mungaroo Formation	6500	2.39 ± 0.12	0	600
22	Locker Shale	7100	1.27 ± 0.11	0	1000
23	Kennedy Group	8100	2.86 ± 0.11	0	400
24	Byro Group	8500	2.12 ± 0.42	0	600
25	Early Permian-Ordovician (undif.)	9100	2.35 ± 0.48	0	900
26	Early Permian-Ordovician (undif.)	10000	2.35 ± 0.48	0	1000
27	Early Permian-Ordovician (undif.)	11000	2.35 ± 0.48	0	1000
28	Early Permian-Ordovician (undif.)	12000	2.35 ± 0.48	0	1000
29	Early Permian-Ordovician (undif.)	13000	2.35 ± 0.48	0	1000
30	Early Permian-Ordovician (undif.)	14000	2.35 ± 0.48	0	1000
31	Basement (granite)	15000	4.48 ± 0.28	2.74	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
835.22	32.8	0	5.8465	BHT [time since circ unknown]
1520.7	77.3	0	10.645	BHT [time since circ unknown]
1742.98	83	0	12.201	BHT [time since circ unknown]
1867.22	88	0	13.071	BHT [time since circ unknown]

HORIZONTAL WELL



Tanami 3 ST1

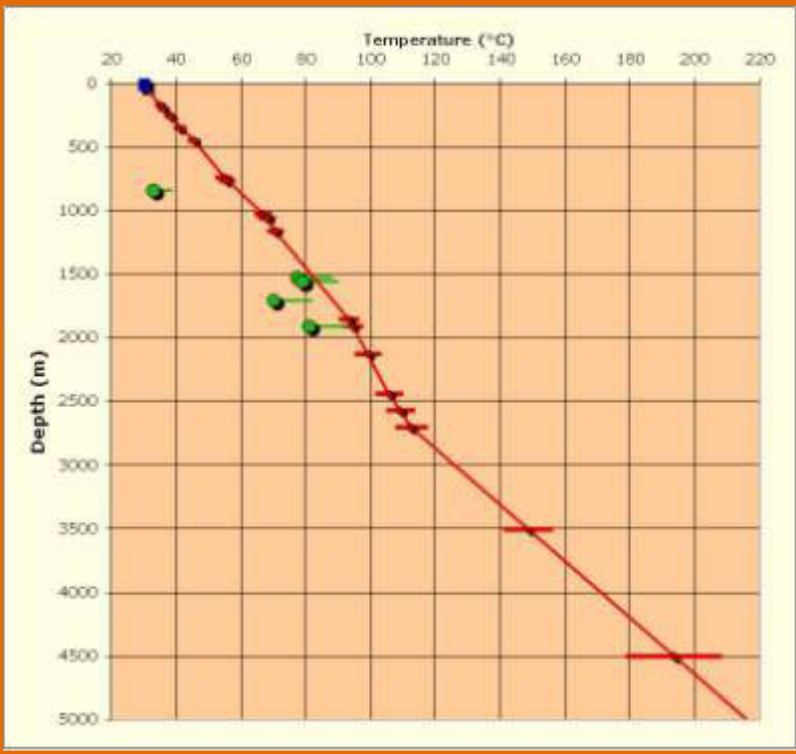
Number of layers	31	Up to 50	Heat flow:	52 ± 2.2 mW/m2
"Depth" to ground level	9.3	"KB height"		
Total Depth (m)	15001	From driling datum		
Surface temp. (°C)	30	Tanami 3 ST2		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A (μW/m³)	Thickness (m)
1	Cape Range Group	9.3	1.68 ± 0.34	0	157.7
2	Giralia Calcarenite	167	1.68 ± 0.34	0	31
3	Wilcox Formation	198	1.23 ± 0.05	0	54
4	Cardabia Group	252	1.68 ± 0.34	0	90
5	Lambert Formation	342	1.23 ± 0.05	0	103.3
6	Korojon Calcarenite	445.3	1.68 ± 0.34	0	288.5
7	Toolonga Calcilutite	733.8	1.45 ± 0.06	0	23.03
8	Gearle Siltstone	756.83	1.23 ± 0.05	0	263.23
9	Windalia Radiolarite	1020.06	1.45 ± 0.10	0	35.55
10	Windalia Sandstone Member	1055.61	2.26 ± 0.09	0	100.36
11	Muderong Shale	1155.97	1.69 ± 0.13	0	697.15
12	Flag Sandstone	1853.12	2.83 ± 0.57	0	48.38
13	Flag Sandstone	1901.5	2.83 ± 0.57	0	225
14	Lower Barrow Gp [intr. cst/sst]	2126.5	2.83 ± 0.57	0	310.5
15	Dupuy Sandstone	2437	2.29 ± 0.46	0	133
16	Dupuy Sandstone	2570	2.29 ± 0.46	0	130
17	Dingo Claystone	2700	1.15 ± 0.18	0	800
18	Dingo Claystone	3500	1.15 ± 0.18	0	1000
19	Dingo Claystone	4500	1.15 ± 0.18	0	1000
20	Mungaroo Formation	5500	2.39 ± 0.12	0	1000
21	Mungaroo Formation	6500	2.39 ± 0.12	0	600
22	Locker Shale	7100	1.27 ± 0.11	0	1000
23	Kennedy Group	8100	2.86 ± 0.11	0	400
24	Byro Group	8500	2.12 ± 0.42	0	600
25	Early Permian-Ordovician (undif.)	9100	2.35 ± 0.48	0	900
26	Early Permian-Ordovician (undif.)	10000	2.35 ± 0.48	0	1000
27	Early Permian-Ordovician (undif.)	11000	2.35 ± 0.48	0	1000
28	Early Permian-Ordovician (undif.)	12000	2.35 ± 0.48	0	1000
29	Early Permian-Ordovician (undif.)	13000	2.35 ± 0.48	0	1000
30	Early Permian-Ordovician (undif.)	14000	2.35 ± 0.48	0	1000
31	Basement (granite)	15000	4.48 ± 0.28	2.74	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
835.22	32.8	0	5.8465	BHT [time since circ unknown]
1520.7	77.3	0	10.645	BHT [time since circ unknown]
1550.17	79	0	10.851	BHT [time since circ unknown]
1698.91	70	0	11.892	BHT [time since circ unknown]
1901.46	81	0	13.31	BHT [time since circ unknown]

HORIZONTAL WELL



Tanami 3 ST2

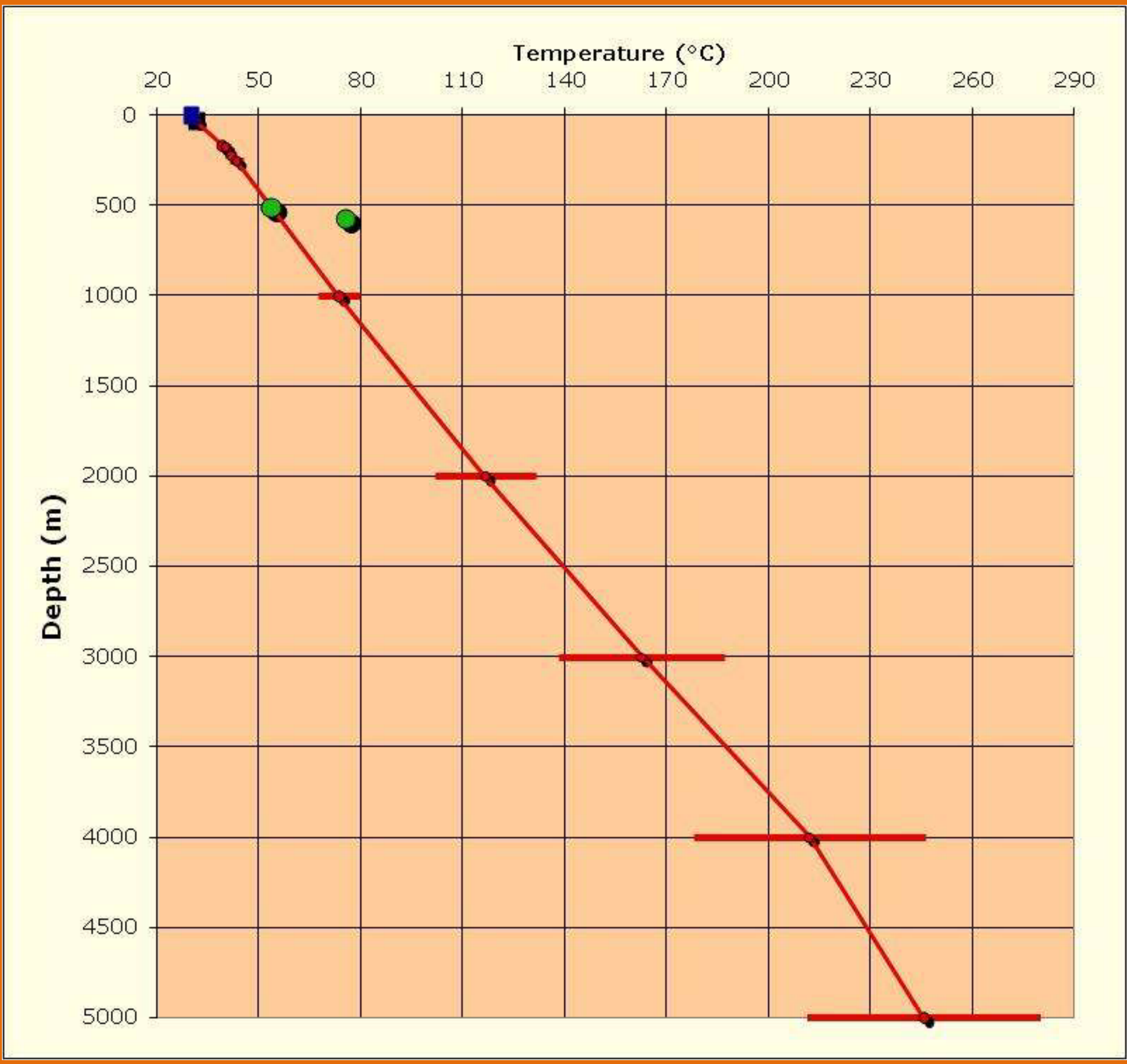
Number of layers	11	Up to 50	**Heat flow:**	95 ± 7.6 mW/m2
"Depth" to ground level	2.13	"KB height"		
Total Depth (m)	5001	From driling datum		
Surface temp. (°C)	30	**Windoo 1A**		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A ($\mu W/m^3$)	Thickness (m)
1	Trealla Limestone	2.13	1.68 ± 0.34	0	24.87
2	Muderong Shale	27	1.69 ± 0.13	0	138
3	Mardie Greensand Member	165	1.79 ± 0.36	0	12
4	Yarraloola Conglomerate	177	2.10 ± 0.42	0	41.5
5	Yarraloola Conglomerate	218.5	2.10 ± 0.42	0	31.5
6	Lower Carboniferous-Ordovician (undif.)	250	2.49 ± 0.50	0	750
7	Lower Carboniferous-Ordovician (undif.)	1000	2.49 ± 0.50	0	1000
8	Lower Carboniferous-Ordovician (undif.)	2000	2.49 ± 0.50	0	1000
9	Lower Carboniferous-Ordovician (undif.)	3000	2.49 ± 0.50	0	1000
10	Basement (metasediment)	4000	4.10 ± 0.10	2.1	1000
11	Basement (metasediment)	5000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
509	53.9	0	3.563	BHT [time since circ unknown]
570	75.6	0	3.99	BHT [time since circ unknown]

Formation tops in DMP database incomplete [used cuttings descriptions]



Windoo 1A

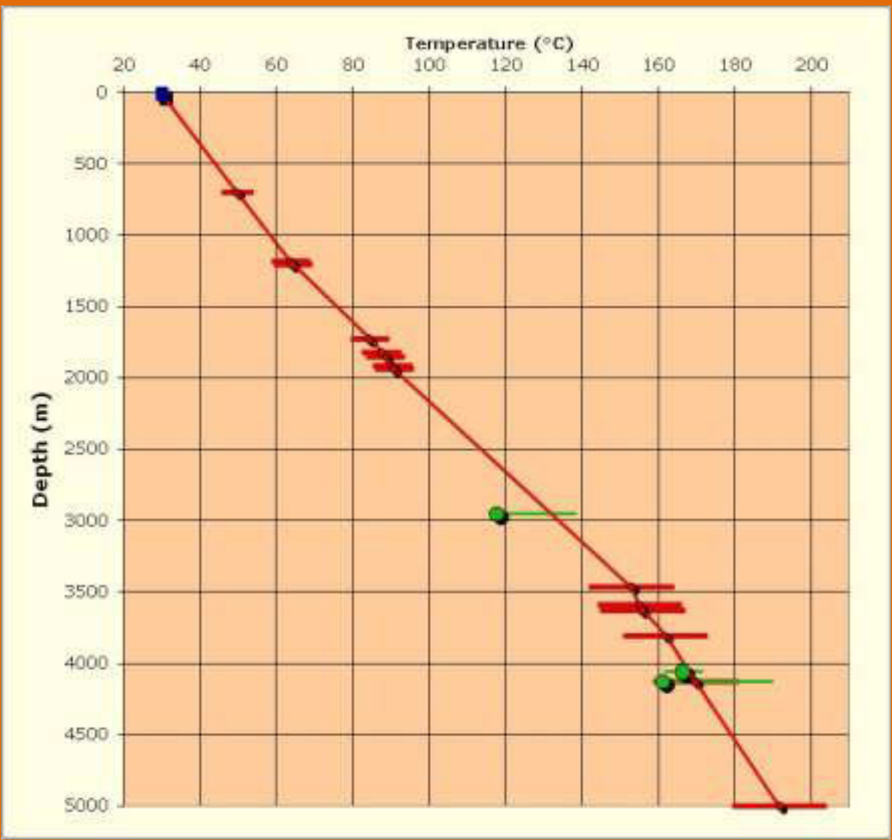
Number of layers	25	Up to 50	**Heat flow:**	47 ± 1.7 mW/m2
"Depth" to ground level	9.3	"KB height"		
Total Depth (m)	16001	From driling datum		
Surface temp. (°C)	30	**Yardie East 1**		
Uncertainty in surface T	1.5	±°C		

	Formation Name	Top (m)	Cond @ 30°C (W/mK)	A (μW/m³)	Thickness (m)
1	Tertiary [undif. carbonates]	9.3	1.68 ± 0.34	0	689.7
2	Cardabia Group	699	1.68 ± 0.34	0	483
3	Miria Formation	1182	1.68 ± 0.34	0	20
4	Gearle Siltstone	1202	1.23 ± 0.05	0	523
5	Windalia Radiolarite	1725	1.45 ± 0.10	0	92
6	Muderong Shale	1817	1.69 ± 0.13	0	34
7	Mardie Greensand Member	1851	1.79 ± 0.36	0	64
8	Birdrong Sandstone	1915	2.83 ± 0.14	0	24
9	Dingo Claystone	1939	1.15 ± 0.18	0	1525
10	Learmonth Formation	3464	3.42 ± 0.33	0	121
11	un-named carbonate	3585	3.42 ± 0.33	0	42
12	Brigadier Formation	3627	1.56 ± 0.22	0	177
13	Mungaroo Formation	3804	2.39 ± 0.12	0	323
14	Mungaroo Formation	4127	2.39 ± 0.12	0	873
15	Mungaroo Formation	5000	2.39 ± 0.12	0	1000
16	Mungaroo Formation	6000	2.39 ± 0.12	0	1600
17	Locker Shale	7600	1.27 ± 0.11	0	1000
18	Locker Shale	8600	1.27 ± 0.11	0	1000
19	Locker Shale	9600	1.27 ± 0.11	0	1095
20	Kennedy Group	10695	2.86 ± 0.11	0	1061
21	Lyons Group/Callytharra Formation	11756	2.17 ± 0.43	0	1061
22	Lower Carboniferous-Ordovician (undif.)	12817	2.49 ± 0.50	0	1183
23	Lower Carboniferous-Ordovician (undif.)	14000	2.49 ± 0.50	0	1000
24	Lower Carboniferous-Ordovician (undif.)	15000	2.49 ± 0.50	0	1000
25	Basement (metasediment)	16000	4.10 ± 0.10	2.1	1

Downhole temperature data (°C):

Depth (m)	Value	-uncert	+uncert	Comment:
2946.8	117.7	0	20.628	BHT [time since circ. 17:20 hours]
4123	161.1	0	28.861	BHT [time since circ. 17:00 hours]
4059.5	166.51	5	5	Horner [2 values]

DEVIATED WELL
Mungaroo Fm 35 mMD dolerite
Brigadier Fm 12 mMD dolerite
Dingo Cst 37 mMD dolerite



Yardie East 1

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Appendix 2

Thermal conductivity of core samples DIR089-DIR207

An appendix to the report Geothermal Energy Potential in Selected Areas of Western Australia (Carnarvon Basin)

Prepared for the Department of Mines and Petroleum, Western Australia

July 2010

Executive Summary

The Western Australian Department of Mines and Petroleum (DMP) commissioned Hot Dry Rocks Pty Ltd (HDR) to measure the thermal conductivity of 119 rock specimens collected from the DMP Perth Core Library and Geoscience Australia Canberra Core Library in April 2010. These specimens came from the Bonaparte, Browse, Carnarvon and Officer basins. Measurements were made on the specimens using a steady state divided bar apparatus calibrated for the range 1.4–9.8 W/mK. Up to three samples were prepared from each specimen to investigate variation in thermal conductivity over short distance scales and to determine mean conductivity and uncertainty. All values were measured at a standard temperature of 30°C. The uncertainties are dependent upon sample quality and preparation method..

HDR considers the following points to be important:

- While the specimens were chosen to represent the cored geological sections from which they came, there is no guarantee that the sections themselves are typical of the overall geological formations.
- It is to be expected that the thermal conductivity of a given formation will vary from place to place if the porosity of the formation varies.
- Thermal conductivity of rocks is sensitive to temperature. This should be kept in mind when developing models of in situ thermal conductivity.

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1. Introduction

Thermal conductivity is the physical property that controls the rate at which heat energy flows through a material in a given thermal gradient. In the S.I. system of units, it is measured in watts per metre-kelvin (W/mK). In the Earth, thermal conductivity controls the rate at which temperature increases with depth for a given heat flow. The thermal conductivity distribution within a section of crust must be known in order to calculate crustal heat flow from temperature gradient data, or to predict temperature distribution from a given heat flow.

The Western Australian Department of Mines and Petroleum (DMP) commissioned Hot Dry Rocks Pty Ltd (HDR) to undertake heat flow modelling in the Bonaparte, Browse, Carnarvon, and Officer basins. HDR collected 119 specimens[1] from the DMP Perth Core Library and Geoscience Australia Canberra Core Library in April 2010 (Table 1). Thermal conductivity measurements were made on these specimens using a steady state divided bar apparatus calibrated for the range 1.4–9.8 W/mK.

Thermal conductivity is sensitive to temperature (e.g. Vosteen and Schellschmidt, 2003[2]), in general decreasing as temperature increases. The measurements contained in this report were made within ± 2°C of 30°C.

[1] In this report the word "specimen" refers to a raw piece of rock delivered to HDR, while "sample" refers to part of a specimen prepared for conductivity measurement. In general, three samples are prepared from each specimen.

[2] **Vosteen, H.-D. and Schellschmidt, R.** (2003). Influence of temperature on thermal conductivity, thermal capacity and thermal diffusivity for different types of rock. *Physics and Chemistry of the Earth*, 28, 499–509.

Table 1. Specimens presented for thermal conductivity measurement.

Well	Basin	Formation	Lithology	Depth From (m)	Depth To (m)	Depth From (')	Depth To (')	HDR sample ID
Coburn 1	Carnarvon	Toolonga Calcilutite	light grey marl	73.70	73.92			DIR089
Coburn 1	Carnarvon	Birdrong Sandstone	light brown carbo-naceous fine-grained sst	172.70	172.85			DIR090
Coburn 1	Carnarvon	Kopke Sandstone	grey light brown sst with finely laminated	212.70	212.85			DIR091
Coburn 1	Carnarvon	Kopke Sandstone	red bed sst finely laminated, similar to DIR091 but red	404.40	404.55			DIR092
Coburn 1	Carnarvon	Kopke Sandstone	red/green/grey mottled slt/cst - differing oxidising regimes	475.40	475.50			DIR093
Coburn 1	Carnarvon	Faure Formation	bioturbated grey/red/brown cst	564.60	564.80			DIR094
Coburn 1	Carnarvon	Coburn Formation, Dirk Hartog Group	blue/grey (light and dark lamina-tions) dolomitic cst	616.70	616.85			DIR095
Coburn 1	Carnarvon	Coburn Formation, Dirk Hartog Group	blue/grey (light and dark lamina-tions) dolomitic cst	685.50	685.65			DIR096
Coburn 1	Carnarvon	Yaringa Formation, Dirk Hartog Group	blue/grey (light and dark banding) dolomitic cst/slt	794.40	794.65			DIR097
Coburn 1	Carnarvon	Ajana Formation, Dirk Hartog Group	blue/grey (light and dark lamina-tions) dolomitic cst	893.75	893.90			DIR098
Coburn 1	Carnarvon	Marron Member, Ajana Formation	dark blue/grey cst	920.30	920.45			DIR099
Coburn 1	Carnarvon	Marron Member, Ajana Formation	pale tan cst with numerous grey salt patches	951.70	951.90			DIR100
Coburn 1	Carnarvon	Tumblagooda Sandstone	dark brown/red slt beds [10% of cored interval]	1011.40	1011.65			DIR101
Coburn 1	Carnarvon	Tumblagooda Sandstone	pale pink to pink-red medium-grained to granule sst [90% of cored interval]; predom quartz and orthoc-lase grains	1030.00	1030.20			DIR102

Coburn 1	Carnarvon	Windalia Sandstone Member	sst [friable]	150.80	151.00			DIR103
Coburn 1	Carnarvon	Muderong Shale	mst	166.30	166.50			DIR104
GSWA Ballythanna 1	Carnarvon	Keogh Formation	medium-grained to granule sst common cross beds	35.90	36.10			DIR105
GSWA Ballythanna 1	Carnarvon	Ballythanna Sandstone Member	light tan fine-grained to medium-grained sst [50% of cored interval]	131.90	132.05			DIR106
GSWA Ballythanna 1	Carnarvon	Ballythanna Sandstone Member	fine-grained sst with common carbonaceous flaser interbeds, whisps and slumped layers; pyritic; bioturbated [50% of cored interval]	292.30	292.43			DIR107
GSWA Ballythanna 1	Carnarvon	Callytharra Formation	dark grey very fossiliferous shale	358.75	358.90			DIR108
GSWA Ballythanna 1	Carnarvon	Lyons Group	fine-grained sst cream coloured	397.55	397.70			DIR109
GSWA Ballythanna 1	Carnarvon	Lyons Group	light grey fine-grained sst with common flaser beds of dark grey slt	453.40	453.55			DIR110
GSWA Ballythanna 1	Carnarvon	Lyons Group	dark grey interbedded slt/fine-grained sst	461.70	461.85			DIR111
Giralia 1	Carnarvon	Billidee Formation	dark grey slt, fine-grained sst heterolithic	682.10	682.22			DIR112
Giralia 1	Carnarvon	Cordalia Formation	dark grey cst?	919.00	919.10			DIR113
Kennedy Range 1	Carnarvon	Coolkilya Sandstone	tan grey medium-grained sst			1530'	1530' 9"	DIR114
Kennedy Range 1	Carnarvon	Baker Formation	reddish brown medium-grained sst			2005'	2005' 9"	DIR115
Kennedy Range 1	Carnarvon	Nalbia Sandstone	brown medium-grained sst, occasional bioturbation			2015' 6"	2016' 3"	DIR116
Kennedy Range 1	Carnarvon	Wandagee Formation	dark brown slt/sst, heavily bioturbated			2210'	2210' 6"	DIR117
Kennedy Range 1	Carnarvon	Cundlego Formation	dark grey/light grey sst, finely laminated, pin stripe laminations [50% of cored interval]			2817'	2817' 9"	DIR118

Kennedy Range 1	Carnarvon	Cundlego Formation	dark brown slt/sst, heavily bioturbated [50% of cored interval]			2819' 6"	2820' 3"	DIR119
Kennedy Range 1	Carnarvon	Bulgadoo Shale	brown slt			4163' 6"	4164' 3"	DIR120
Kennedy Range 1	Carnarvon	Mallens Sandstone	dark grey/light grey sst, finely laminated, pin stripe laminations [25% of cored interval]			4711'	4711' 6"	DIR121
Kennedy Range 1	Carnarvon	Mallens Sandstone	dark brown slt/sst, heavily bioturbated [75% of cored interval]			5104'	5104' 9"	DIR122
Kennedy Range 1	Carnarvon	Coyrie Formation	brown sst, minor bioturbation			5484' 3"	5484' 10"	DIR123
Kennedy Range 1	Carnarvon	Coyrie Formation	pale pink/tan sst, no bioturbation			5537' 3"	5538'	DIR124
Linda 2	Carnarvon	Dingo Claystone	dark grey cst/slt with thin stringers of light grey slt/sst - lenticular bedding	2814.80	2815.05			DIR125
Kennedy Range 1	Carnarvon	Moogooloo Sandstone	light tan grey coarse-grained sst with minor carbonaceous flecks			6606'	6606' 9"	DIR126
GSWA Barrabiddy 1A	Carnarvon	Nannyarra Sandstone	green grey mottled sst/slt	781.70	781.95			DIR127
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation	light grey fine-grained sst with rare slt flasers, some slumping in adjacent core	773.90	774.10			DIR128
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation	green-grey to light grey calcareous? Sst; highly fossiliferous	759.55	759.70			DIR129
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation	light blue/grey lst with common stylolites	669.35	669.55			DIR130
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation	dark green/grey slt/cst	616.90	617.10			DIR131
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation	dark green/grey slt/cst; highly fossiliferous	617.65	617.90			DIR132
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation; Point Maud Member	tan coloured lst; vugs/borings rare [10% of cored interval]	551.75	551.95			DIR133
GSWA Barrabiddy 1A	Carnarvon	Gneudna Formation; Point Maud Member	tan coloured lst; ubiquitous vugs/borings [90% of cored interval]	467.00	467.20			DIR134

GSWA Barrabiddy 1A	Carnarvon	Munabia Formation	light grey fine- to medium-grained sst with common flaser slt beds [~29 m = 34% of cored interval]	213.20	213.45			DIR135
GSWA Barrabiddy 1A	Carnarvon	Munabia Formation	dark green/grey mst, mottled [~56 m = 66% of cored interval]	246.25	246.40			DIR136
Quail 1	Carnarvon	Yindagindy Formation	dark blue/grey calcareous mst			8649'	8649' 9"	DIR137
Quail 1	Carnarvon	Quail Formation	reddish brown medium-grained sst			7319'	7319' 9"	DIR138
Onslow 1	Carnarvon	Mungaroo Formation	grey mottled slt			3781' 3"	3782'	DIR139
Onslow 1	Carnarvon	Mungaroo Formation	pale grey/buff sst			4279' 9"	4280' 6"	DIR140
Onslow 1	Carnarvon	Locker Shale	light brown sst			5706'	5706' 9"	DIR141
Onslow 1	Carnarvon	Locker Shale	dark grey shale			6631'	6631' 9"	DIR142
Learmonth 2	Carnarvon	Learmonth Formation	cream medium-grained sst			5375'	5375' 9"	DIR143
Pluto 3	Carnarvon	Brigadier Formation	dark grey sly, highly bioturbated, thin whisps of fine-grained sst	3056.70	3057.00			DIR144
Pluto 3	Carnarvon	Brigadier Formation	heterolithic fine-grained yellow/buff sst and dark grey slt; occasional bioturbation	3067.20	3067.50			DIR145
Calliance 1	Browse	Montara Formation	heterolithic fine-grained yellow/buff sst and dark grey slt; highly biotur-bated; occasional reddish brown nodules/diagenetic overprint?	3776.00	3776.30			DIR146
Brecknock 2	Browse	Plover Formation	yellow fine-grained sst	3786.80	3787.00			DIR147
Calliance 1	Browse	Plover Formation	grey slt; mottled [bioturbated]	3797.20	3797.40			DIR148
Brecknock 2	Browse	Nome Formation	dark grey slt; high-ly fractured [healed? Doubtful drilling induced?]	3825.70	3825.90			DIR149
Yowalga 2	Officer	Kanpa Formation	reddish finely la-minated interbed-ded slt/sst; thick quartz veins			2796'	2796' 9"	DIR150
Yowalga 2	Officer	Kanpa Formation	cream to light grey finely laminated interbedded slt/sst			3242'	3242' 9"	DIR151

Bonaparte 1A	Bonaparte	Point Spring Sandstone	salmon pink medium-grained sst			576' 4"/ 578' 4"	576' 8"/ 578' 8"	DIR152
Bonaparte 1A	Bonaparte	Tanmurra Formation	grey slt			689' 8"	690'	DIR153
Bonaparte 2	Bonaparte	Milligans Formation	heterolithic fine-grained light grey sst and dark grey slt; slumping features; whispy slt in the sst			3948' 4"/ 3940' 4"	3948' 8"/ 3940' 8"	DIR154
Bonaparte 1A	Bonaparte	Burt Range Formation	heterolithic fine-grained cream sst and greenish grey slt			9267' 4"/ 9263' 4"	9267' 8"/ 9263' 8"	DIR155
Bonaparte 1A	Bonaparte	Cockatoo Group	?grey quartzite			10476' 4"	10476' 8"	DIR156
Laminaria East 1	Bonaparte	Frigate Shale	grey shale	3249.70	3249.90			DIR157
GSWA Barrabiddy 1A	Carnarvon	Gearle Siltstone	dark grey friable mst	66.00	66.30			DIR158
GSWA Barrabiddy 1A	Carnarvon	Windalia Radiolarite	grey mst, not dense	127.75	127.95			DIR159
GSWA Barrabiddy 1A	Carnarvon	Windalia Sandstone Member	green slt to fine-grained sst; glauconitic	157.30	157.45			DIR160
Turtle 1	Bonaparte	Bonaparte Formation	grey fine- to medium-grained sst	2488.20	2488.50			DIR161
Turtle 1	Bonaparte	Keyling Formation	sst, oil impregnated; no non oil sands within core	929.00	929.30			DIR162
Turtle 1	Bonaparte	Keyling Formation	heterolithic dark grey slt/light grey sst; whispy slt	932.45	932.70			DIR163
Turtle 1	Bonaparte	Treachery Shale	interbedded light grey sst and dark grey slt	1441.65	1441.85			DIR164
Turtle 1	Bonaparte	Kuriyippi Formation	light grey sst	1599.65	1599.95			DIR165
Turtle 1	Bonaparte	Kuriyippi Formation	light grey sst and dark grey slt; mottled/bioturbated	1601.50	1601.75			DIR166
Turtle 1	Bonaparte	Kuriyippi Formation	grey diamictite?	1612.00	1612.30			DIR167
GSWA Empress 1A	Officer	Lennis Sandstone	partially friable yellow medium-grained sst	165.90	166.10			DIR168
GSWA Empress 1A	Officer	Paterson Formation	buff to tan medium-grained sst	127.05	127.20			DIR169
GSWA Empress 1A	Officer	Paterson Formation	matrix supported pebble cgl; coarse-grained sst matrix	116.15	116.40			DIR170
GSWA Empress 1A	Officer	Unnamed Sandstone	reddish brown medium-grained sst	294.25	294.60			DIR171

GSWA Empress 1A	Officer	Paterson Formation	light grey slt	106.70	107.00			DIR172
GSWA Empress 1A	Officer	Table Hill Volcanics	reddish grey basalt	284.70	284.90			DIR173
GSWA Empress 1A	Officer	Wahlgu Formation	red cst	367.80	368.00			DIR174
GSWA Empress 1A	Officer	Wahlgu Formation	red medium-grained sst	351.80	352.00			DIR175
GSWA Empress 1A	Officer	Wahlgu Formation	dark brown cst chips	431.50	431.70			DIR176
GSWA Empress 1A	Officer	Steptoe Formation	grey dolomite	504.65	504.85			DIR177
GSWA Empress 1A	Officer	Steptoe Formation	dark brown cst chips	603.80	604.00			DIR178
GSWA Empress 1A	Officer	Steptoe Formation	red sst	568.30	568.50			DIR179
GSWA Empress 1A	Officer	Kanpa Formation	grey dolomite	651.40	651.70			DIR180
GSWA Empress 1A	Officer	Kanpa Formation	light grey sst	743.50	743.80			DIR181
GSWA Empress 1A	Officer	Kanpa Formation	mst	805.90	806.10			DIR182
GSWA Empress 1A	Officer	Hussar Formation	interbedded mst/slt/sst	931.00	931.30			DIR183
GSWA Empress 1A	Officer	Hussar Formation	sst	1122.10	1122.40			DIR184
GSWA Empress 1A	Officer	Hussar Formation	mst	1091.10	1091.30			DIR185
GSWA Empress 1A	Officer	Hussar Formation	dolomite	1075.90	1076.20			DIR186
GSWA Empress 1A	Officer	Hussar Formation	mst/slt	1223.30	1223.55			DIR187
GSWA Empress 1A	Officer	Browne Formation	halite	1309.65	1309.80			DIR188
GSWA Empress 1A	Officer	Browne Formation	dolomite, slt	1409.40	1409.55			DIR189

GSWA Empress 1A	Officer	Browne Formation	dolomite, slt	1403.75	1403.95			DIR190
GSWA Empress 1A	Officer	Lefroy Formation	heavily fractured maroon to grey slt	1531.70	1531.90			DIR191
GSWA Empress 1A	Officer	Basement	basalt	1603.60	1603.80			DIR192
GSWA Empress 1A	Officer	Basement	dark grey/black finely laminated silty shale	1558.90	1559.20			DIR193
Boondawari 1	Officer	Mundadjini Formation	red cst	302.20	302.40			DIR194
Boondawari 1	Officer	Spearhole Formation	red sst	613.30	613.50			DIR195
Boondawari 1	Officer	Spearhole Formation	red slt/cst	612.35	612.60			DIR196
Boondawari 1	Officer	Table Hill Volcanics	dolerite	1365.40	1365.60			DIR197
Boondawari 1	Officer	Brassey Range Formation	interbedded red slt/sst	834.60	834.80			DIR198
Boondawari 1	Officer	Spearhole Formation	red slt	349.60	349.80			DIR199
BMR Browne 1	Officer	Bejah Claystone	salmon pink to cream cst with frequent pink-purple mottling; very light and almost porcelaneous			30' 11"	31' 7"	DIR200
BMR Browne 1	Officer	Samuel Formation	dark grey to yellow-grey laminated cst, slt and fine-grained sst; sulphorous, occasional bioturbation, micaceous, glauconite?			325'	325' 6"	DIR201
BMR Browne 1	Officer	Samuel Formation	reddish-brown to ochre slt, cst with finely laminated interbeds of whispy fine-grained sst			192' 1"	192' 7"	DIR202
BMR Neale 1A-1B	Officer	Wanna Formation	tan fine-grained sst; occasional reddish brown mottling; feint cross-bedding			369' 11"	369' 11"	DIR203
BMR Neale 1A-1B	Officer	McFadden Formation	grey to tan/grey fine-grained sst			327'	327' 7"	DIR204
BMR Neale 1A-1B	Officer	McFadden Formation	brick red slt			308'	308' 9"	DIR205
BMR Throssell 1	Officer	Kanpa Formation	grey cst with abundant gypsum crystal; chicken-wire appearance?			200'	200' 10"	DIR206

BMR Glenburgh 9	Carnarvon	Madeline Formation	dark grey slt, cst; rare fossiliferous [graptolite?]			192'	192' 6"	DIR207

2. Methodology

Three sample preparation methods were undertaken to measure the thermal conductivity of specimens DIR089—DIR207, depending on specimen quality and quantity. In this report these three methods are referred to as 'Whole rock', 'Hollow cell, whole rock', or 'Hollow cell, matrix'. Up to three samples were prepared from each specimen to investigate variation in thermal conductivity over short distance scales and to determine mean conductivity and uncertainty.

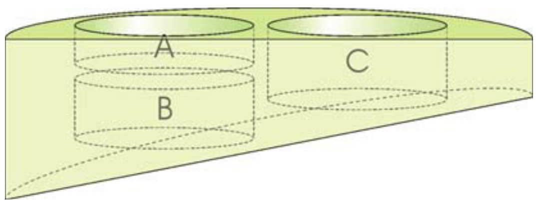
Where possible, three prisms were cut from each core specimen, each approximately ⅓ to ½ the length of the sample in thickness, and each sample was ground flat and polished. These are indicated on Table 2 by the description 'Whole rock'.

In cases where the core specimens were of a relatively unconsolidated lithology (such as clays, muds, and marls) showing significant susceptibility to deterioration during saturation, samples were prepared using hollow cells. These are indicated on Table 2 by the description 'Hollow cell, whole rock'.

In cases where the core specimens were either crushed or highly fragmented, making it impossible to measure the sample in its whole-rock state, thermal conductivity was measured as a matrix within a hollow cell with water. In such cases, the net conductivity of the rock matrix was calculated from the gross conductivity of the rock-water aggregate. These are indicated on table 2 by the description 'Hollow cell, matrix'. Colloquially, these samples are referred to as 'chips' or 'cuttings'.

All samples were evacuated under >95% vacuum for a minimum of three hours. Samples were then submerged in water prior to returning to atmospheric pressure. Saturation continued at atmospheric pressure for a minimum of twelve hours, and all samples were left submerged in water until just prior to conductivity measurement.

Figure 1. The average conductivity of samples in series (e.g. A and B) is found using the harmonic mean. The average conductivity of samples in parallel (e.g. A and C) is found using the arithmetic mean.



Samples were then measured for thermal conductivity measurement in a divided bar apparatus[3]. The thermal conductivity was measured along the long axis of the core provided for all samples prepared either as ‘Whole rock’ or ‘Hollow cell, whole rock’. Values were measured at a standard temperature of 30°C (± 2°C). Harmonic mean conductivity (Figure 1) and one standard deviation uncertainty were calculated for each specimen. Results are presented in the next section.

[3] Divided bar apparatus: An instrument that places an unknown sample in series with a standard of known thermal conductivity, then imposes a constant thermal gradient across the combination in order to derive the conductivity of the unknown sample.

3. Results

Table 2 displays the thermal conductivity for each individual sample, and the harmonic mean conductivity and standard deviation for each specimen. All values are for a standard temperature of 30°C. The uncertainty for individual samples is approximately ± 2% for non-friable whole rock samples (based on the instrument precision of the divided bar apparatus). Uncertainties for thermal conductivity measurements are shown in Table 2.

Table 2. Thermal conductivity of samples at 30°C, with well name, depth, uncertainty, sample type, and harmonic mean and uncertainty[4] for each specimen.

Well	Depth From (m)	Depth To (m)	Depth From (')	Depth To (')	Uncertainty (%)	Sample type	HDR sample ID		Conductivity (W/mK), harmonic mean, standard deviation			
Coburn 1	73.70	73.92			5	Hollow cell, whole rock	DIR089	A	1.51	1.48	±	0.03
								B	1.46			
								C	1.48			
Coburn 1	172.70	172.85			5	Hollow cell, whole rock	DIR090	A	2.49	2.47	±	0.06
								B	2.51			
								C	2.40			
Coburn 1	212.70	212.85			5	Hollow cell, whole rock	DIR091	A	3.26	3.12	±	0.19
								B	3.22			
								C	2.91			
Coburn 1	404.40	404.55			3.5	Whole rock	DIR092	A	3.57	3.64	±	0.07
								B	3.64			
								C	3.70			
Coburn 1	475.40	475.50			5	Hollow cell, whole rock	DIR093	A	1.67	1.61	±	0.06
								B	1.61			
								C	1.55			
Coburn 1	564.60	564.80			3.5	Whole rock	DIR094	A	2.12	2.14	±	0.08
								B	2.08			
								C	2.22			
Coburn 1	616.70	616.85			3.5	Whole rock	DIR095	A	3.37	3.50	±	0.17
								B	3.69			
								C	3.45			
Coburn 1	685.50	685.65			3.5	Whole rock	DIR096	A	2.48	2.53	±	0.04
								B	2.55			
								C	2.55			
Coburn 1	794.40	794.65			3.5	Whole rock	DIR097	A	3.08	3.16	±	0.08
								B	3.17			
								C	3.24			

[4] Uncertainty of the thermal conductivity for each specimen is one standard deviation of the measured values.

Coburn 1	893.75	893.90			3.5	Whole rock	DIR098	A	2.34	2.48	±	0.15
								B	2.48			
								C	2.65			
Coburn 1	920.30	920.45			3.5	Whole rock	DIR099	A	1.93	2.00	±	0.12
								B	1.95			
								C	2.15			
Coburn 1	951.70	951.90			3.5	Whole rock	DIR100	A	3.99	3.93	±	0.57
								B	3.42			
								C	4.55			
Coburn 1	1011.40	1011.65			3.5	Whole rock	DIR101	A	2.55	2.65	±	0.10
								B	2.70			
								C	2.72			
Coburn 1	1030.00	1030.20			3.5	Whole rock	DIR102	A	2.99	2.90	±	0.14
								B	2.98			
								C	2.75			
Coburn 1	150.80	151.00			5	Hollow cell, whole rock	DIR103	A	2.60	2.56	±	0.04
								B	2.57			
								C	2.52			
Coburn 1	166.30	166.50			5	Hollow cell, whole rock	DIR104	A	1.64	1.75	±	0.15
								B	1.93			
								C	1.70			
GSWA Ballythanna 1	35.90	36.10			3.5	Whole rock	DIR105	A	3.28	3.24	±	0.50
								B	2.80			
								C	3.79			
GSWA Ballythanna 1	131.90	132.05			3.5	Whole rock	DIR106	A	3.15	3.18	±	0.05
								B	3.17			
								C	3.24			
GSWA Ballythanna 1	292.30	292.43			3.5	Whole rock	DIR107	A	3.22	3.21	±	0.19
								B	3.02			
								C	3.40			
GSWA Ballythanna 1	358.75	358.90			3.5	Whole rock	DIR108	A	1.61	1.70	±	0.08
								B	1.74			
								C	1.75			
GSWA Ballythanna 1	397.55	397.70			3.5	Whole rock	DIR109	A	3.17	3.08	±	0.07
								B	3.03			
								C	3.05			
GSWA Ballythanna 1	453.40	453.55			3.5	Whole rock	DIR110	A	2.87	2.67	±	0.17
								B	2.63			
								C	2.55			
GSWA Ballythanna 1	461.70	461.85			3.5	Whole rock	DIR111	A	2.69	2.56	±	0.16
								B	2.38			
								C	2.62			

Giralia 1	682.10	682.22			3.5	Whole rock	DIR112	A	2.51	2.60	±	0.30
								B	2.97			
								C	2.39			
Giralia 1	919.00	919.10			3.5	Whole rock	DIR113	A	1.91	1.98	±	0.18
								B	1.87			
								C	2.19			
Kennedy Range 1			1530'	1530' 9"	3.5	Whole rock	DIR114	A	2.99	2.86	±	0.11
								B	2.79			
								C	2.81			
Kennedy Range 1			2005'	2005' 9"	3.5	Whole rock	DIR115	A	3.51	3.51	±	0.05
								B	3.46			
								C	3.55			
Kennedy Range 1			2015' 6"	2016' 3"	3.5	Whole rock	DIR116	A	2.98	2.99	±	0.07
								B	3.06			
								C	2.93			
Kennedy Range 1			2210'	2210' 6"	5	Hollow cell, whole rock	DIR117	A	1.84	1.77	±	0.14
								B	1.62			
								C	1.87			
Kennedy Range 1			2817'	2817' 9"	3.5	Whole rock	DIR118	A	3.13	2.93	±	0.17
								B	2.84			
								C	2.84			
Kennedy Range 1			2819' 6"	2820' 3"	3.5	Whole rock	DIR119	A	2.40	2.23	±	0.15
								B	2.14			
								C	2.16			
Kennedy Range 1			4163' 6"	4164' 3"	3.5	Whole rock	DIR120	A	1.23	1.27	±	0.13
								B	1.18			
								C	1.43			
Kennedy Range 1			4711'	4711' 6"	3.5	Whole rock	DIR121	A	2.83	2.75	±	0.14
								B	2.59			
								C	2.84			
Kennedy Range 1			5104'	5104' 9"	3.5	Whole rock	DIR122	A	2.53	2.64	±	0.15
								B	2.82			
								C	2.60			
Kennedy Range 1			5484' 3"	5484' 10"	3.5	Whole rock	DIR123	A	2.37	2.29	±	0.07
								B	2.25			
								C	2.26			
Kennedy Range 1			5537' 3"	5538'	3.5	Whole rock	DIR124	A	2.96	3.04	±	0.09
								B	3.15			
								C	3.02			
Linda 2	2814.80	2815.05			15	Hollow cell, matrix	DIR125	A	1.42	1.15	±	0.18
								B	1.09			
								C	0.99			
					5	Whole rock		D	1.18			

Kennedy Range 1			6606'	6606' 9"	3.5	Whole rock	DIR126	A	4.63	4.76	±	0.13
								B	4.80			
								C	4.87			
GSWA Barrabiddy 1A	781.70	781.95			3.5	Whole rock	DIR127	A	2.44	2.50	±	0.14
								B	2.40			
								C	2.66			
GSWA Barrabiddy 1A	773.90	774.10			3.5	Whole rock	DIR128	A	3.22	3.37	±	0.13
								B	3.48			
								C	3.42			
GSWA Barrabiddy 1A	759.55	759.70			3.5	Whole rock	DIR129	A	2.14	1.80	±	0.30
								B	1.81			
								C	1.55			
GSWA Barrabiddy 1A	669.35	669.55			3.5	Whole rock	DIR130	A	2.52	2.49	±	0.05
								B	2.43			
								C	2.51			
GSWA Barrabiddy 1A	616.90	617.10			3.5	Whole rock	DIR131	A	1.75	1.93	±	0.25
								B	1.86			
								C	2.22			
GSWA Barrabiddy 1A	617.65	617.90			5	Hollow cell, whole rock	DIR132	B	0.64	0.64	±	0.00
								C	0.64			
GSWA Barrabiddy 1A	551.75	551.95			3.5	Whole rock	DIR133	A	4.00	3.93	±	0.08
								B	3.85			
								C	3.93			
GSWA Barrabiddy 1A	467.00	467.20			3.5	Whole rock	DIR134	A	4.03	3.80	±	0.29
								B	3.92			
								C	3.49			
GSWA Barrabiddy 1A	213.20	213.45			3.5	Whole rock	DIR135	A	2.72	2.55	±	0.18
								B	2.59			
								C	2.36			
GSWA Barrabiddy 1A	246.25	246.40			5	Hollow cell, whole rock	DIR136	B	1.45	1.42	±	0.04
								C	1.40			
Quail 1			8649'	8649' 9"	3.5	Whole rock	DIR137	B	2.43	2.45	±	0.03
								C	2.47			
Quail 1			7319'	7319' 9"	3.5	Whole rock	DIR138	A	4.82	4.97	±	0.24
								B	4.87			
								C	5.25			
Onslow 1			3781' 3"	3782'	5	Hollow cell, whole rock	DIR139	A	2.09	2.02	±	0.09
								B	1.96			
								C	0.00			
Onslow 1			4279' 9"	4280' 6"	3.5	Whole rock	DIR140	A	3.06	2.91	±	0.17
								B	2.73			
								C	2.96			

Onslow 1			5706'	5706' 9"	3.5	Whole rock	DIR141	A	3.16	3.08	±	0.09
								B	2.98			
								C	3.11			
Onslow 1			6631'	6631' 9"	5	Hollow cell, whole rock	DIR142	A	1.23	1.19	±	0.08
								B	1.25			
								C	1.10			
Learmonth 2			5375'	5375' 9"	3.5	Whole rock	DIR143	A	3.27	3.42	±	0.33
								B	3.23			
								C	3.83			
Pluto 3	3056.70	3057.00			3.5	Whole rock	DIR144	A	1.32	1.35	±	0.09
								B	1.45			
								C	1.28			
Pluto 3	3067.20	3067.50			3.5	Whole rock	DIR145	A	2.38	1.84	±	0.45
								B	1.50			
								C	1.78			
Calliance 1	3776.00	3776.30			3.5	Whole rock	DIR146	A	3.47	3.33	±	0.15
								B	3.18			
								C	3.35			
Brecknock 2	3786.80	3787.00			3.5	Whole rock	DIR147	A	4.47	4.51	±	0.10
								B	4.43			
								C	4.62			
Calliance 1	3797.20	3797.40			3.5	Whole rock	DIR148	A	2.72	2.82	±	0.12
								B	2.80			
								C	2.95			
Brecknock 2	3825.70	3825.90			3.5	Whole rock	DIR149	A	2.48	2.29	±	0.17
								B	2.24			
								C	2.16			
Yowalga 2			2796'	2796' 9"	3.5	Whole rock	DIR150	A	2.37	2.56	±	0.18
								B	2.61			
								C	2.71			
Yowalga 2			3242'	3242' 9"	5	Hollow cell, whole rock	DIR151	A	2.77	2.93	±	0.24
								B	3.11			
Bonaparte 1A			576' 4"/ 578' 4"	576' 8"/ 578' 8"	3.5	Whole rock	DIR152	A	3.14	2.94	±	0.32
								B	3.16			
								C	2.59			
Bonaparte 1A			689' 8"	690'	3.5	Whole rock	DIR153	A	2.20	2.19	±	0.02
								B	2.17			
								C	2.20			
Bonaparte 2			3948' 4"/ 3940' 4"	3948' 8"/ 3940' 8"	3.5	Whole rock	DIR154	A	4.24	3.92	±	0.58
								B	4.39			
								C	3.32			

Bonaparte 1A			9267' 4"/ 9263' 4"	9267' 8"/ 9263' 8"	3.5	Whole rock	DIR155	A	1.77	1.73	±	0.06
								B	1.76			
								C	1.66			
Bonaparte 1A			10476' 4"	10476' 8"	3.5	Whole rock	DIR156	A	5.67	5.09	±	0.51
								B	4.67			
								C	5.04			
Laminaria East 1	3249.70	3249.90			3.5	Whole rock	DIR157	A	1.26	1.24	±	0.03
								B	1.21			
GSWA Barrabiddy 1A	66.00	66.30			15	Hollow cell, matrix	DIR158	A	1.21	1.19	±	0.03
								B	1.21			
								C	1.16			
GSWA Barrabiddy 1A	127.75	127.95			3.5	Whole rock	DIR159	A	1.40	1.31	±	0.10
								B	1.35			
								C	1.20			
GSWA Barrabiddy 1A	157.30	157.45			5	Hollow cell, whole rock	DIR160	A	1.81	1.79	±	0.05
								B	1.74			
								C	1.82			
Turtle 1	2488.20	2488.50			3.5	Whole rock	DIR161	A	4.20	4.11	±	0.08
								B	4.05			
								C	4.08			
Turtle 1	929.00	929.30			3.5	Whole rock	DIR162	A	2.59	2.60	±	0.05
								B	2.65			
								C	2.56			
Turtle 1	932.45	932.70			5	Hollow cell, whole rock	DIR163	A	2.34	2.38	±	0.05
								B	2.36			
								C	2.44			
Turtle 1	1441.65	1441.85			3.5	Whole rock	DIR164	A	2.14	2.29	±	0.31
								B	2.67			
								C	2.13			
Turtle 1	1599.65	1599.95			3.5	Whole rock	DIR165	A	3.17	3.19	±	0.05
								B	3.24			
								C	3.15			
Turtle 1	1601.50	1601.75			3.5	Whole rock	DIR166	A	2.32	2.35	±	0.09
								B	2.45			
								C	2.28			
Turtle 1	1612.00	1612.30			3.5	Whole rock	DIR167	A	2.71	2.87	±	0.39
								B	2.66			
								C	3.35			
GSWA Empress 1A	165.90	166.10			5	Hollow cell, whole rock	DIR168	A	2.71	2.56	±	0.14
								B	2.53			
								C	2.44			

GSWA Empress 1A	127.05	127.20			5	Hollow cell, whole rock	DIR169	A	2.28	2.19	±	0.10
								B	2.21			
								C	2.09			
GSWA Empress 1A	116.15	116.40			3.5	Whole rock	DIR170	A	3.32	3.27	±	0.07
								B	3.22			
GSWA Empress 1A	294.25	294.60			5	Hollow cell, whole rock	DIR171	A	2.49	2.44	±	0.05
								B	2.38			
								C	2.44			
GSWA Empress 1A	106.70	107.00			5	Hollow cell, whole rock	DIR172	A	2.47	2.49	±	0.05
								B	2.44			
								C	2.54			
GSWA Empress 1A	284.70	284.90			3.5	Whole rock	DIR173	A	1.55	1.57	±	0.02
								B	1.58			
								C	1.58			
GSWA Empress 1A	367.80	368.00			5	Hollow cell, whole rock	DIR174	A	2.21	2.26	±	0.07
								B	2.31			
GSWA Empress 1A	351.80	352.00			5	Hollow cell, whole rock	DIR175	A	3.07	3.05	±	0.05
								B	2.99			
								C	3.09			
GSWA Empress 1A	431.50	431.70			15	Hollow cell, matrix	DIR176	A	1.61	1.55	±	0.21
								B	1.75			
								C	1.34			
GSWA Empress 1A	504.65	504.85			3.5	Whole rock	DIR177	A	4.68	4.61	±	0.23
								B	4.80			
								C	4.36			
GSWA Empress 1A	603.80	604.00			15	Hollow cell, matrix	DIR178	A	1.43	1.43	±	0.16
								B	1.29			
								C	1.60			
GSWA Empress 1A	568.30	568.50			3.5	Whole rock	DIR179	A	3.04	2.96	±	0.12
								B	3.03			
								C	2.83			
GSWA Empress 1A	651.40	651.70			3.5	Whole rock	DIR180	A	3.87	4.02	±	0.25
								B	4.32			
								C	3.90			
GSWA Empress 1A	743.50	743.80			3.5	Whole rock	DIR181	A	2.13	3.02	±	0.99
								B	3.71			
								C	3.95			
GSWA Empress 1A	805.90	806.10			3.5	Whole rock	DIR182	A	2.78	2.41	±	0.34
								B	2.10			
								C	2.44			
GSWA Empress 1A	931.00	931.30			3.5	Whole rock	DIR183	A	3.97	4.18	±	0.19
								B	4.34			
								C	4.25			

GSWA Empress 1A	1122.10	1122.40			3.5	Whole rock	DIR184	A	4.34	4.24	±	0.25
								B	4.44			
								C	3.97			
GSWA Empress 1A	1091.10	1091.30			3.5	Whole rock	DIR185	A	1.78	1.78	±	0.36
								B	2.22			
								C	1.50			
GSWA Empress 1A	1075.90	1076.20			3.5	Whole rock	DIR186	A	5.65	5.54	±	0.11
								B	5.53			
								C	5.43			
GSWA Empress 1A	1223.30	1223.55			3.5	Whole rock	DIR187	A	2.14	2.18	±	0.06
								B	2.16			
								C	2.25			
GSWA Empress 1A	1309.65	1309.80			3.5	Whole rock	DIR188	A	5.65	5.25	±	0.37
								B	5.25			
								C	4.92			
GSWA Empress 1A	1409.40	1409.55			3.5	Whole rock	DIR189	A	2.60	2.68	±	0.12
								B	2.82			
								C	2.63			
GSWA Empress 1A	1403.75	1403.95			5	Hollow cell, whole rock	DIR190	A	2.13	2.09	±	0.06
								C	2.04			
GSWA Empress 1A	1531.70	1531.90			3.5	Whole rock	DIR191	A	1.65	1.61	±	0.04
								B	1.57			
								C	1.62			
GSWA Empress 1A	1603.60	1603.80			3.5	Whole rock	DIR192	A	2.34	2.30	±	0.05
								B	2.25			
								C	2.30			
GSWA Empress 1A	1558.90	1559.20			3.5	Whole rock	DIR193	A	2.09	2.05	±	0.05
								B	2.08			
								C	1.99			
Boondawari 1	302.20	302.40			3.5	Whole rock	DIR194	A	4.37	4.45	±	0.09
								B	4.55			
								C	4.44			
Boondawari 1	613.30	613.50			3.5	Whole rock	DIR195	A	1.47	1.43	±	0.04
								B	1.40			
								C	1.43			
Boondawari 1	612.35	612.60			3.5	Whole rock	DIR196	A	4.80	4.81	±	0.09
								B	4.90			
								C	4.73			
Boondawari 1	1365.40	1365.60			3.5	Whole rock	DIR197	A	2.18	2.25	±	0.07
								B	2.32			
								C	2.26			
Boondawari 1	834.60	834.80			3.5	Whole rock	DIR198	A	4.19	4.45	±	0.30
								B	4.42			
								C	4.79			

Boondawari 1	349.60	349.80			3.5	Whole rock	DIR199	A	2.22	2.17	±	0.08
								B	2.08			
								C	2.23			
BMR Browne 1			30' 11"	31' 7"	3.5	Whole rock	DIR200	A	1.34	1.33	±	0.01
								B	1.31			
								C	1.33			
BMR Browne 1			325'	325' 6"	5	Hollow cell, whole rock	DIR201	A	1.32	1.30	±	0.04
								B	1.25			
								C	1.34			
BMR Browne 1			192' 1"	192' 7"	5	Hollow cell, whole rock	DIR202	A	1.27	1.25	±	0.03
								B	1.23			
BMR Neale 1A-1B			369' 11"	369' 11"	3.5	Whole rock	DIR203	A	2.52	2.60	±	0.08
								B	2.68			
								C	2.61			
BMR Neale 1A-1B			327'	327' 7"	3.5	Whole rock	DIR204	B	1.73	2.16	±	0.81
								D	2.87			
BMR Neale 1A-1B			308'	308' 9"	5	Hollow cell, whole rock	DIR205	A	1.59	1.59	±	0.05
								B	1.55			
								C	1.64			
BMR Throssell 1			200'	200' 10"	3.5	Whole rock	DIR206	Specimen not measured				
BMR Glenburgh 9			192'	192' 6"	3.5	Whole rock	DIR207	A	1.50	1.53	±	0.05
								B	1.58			
								C	1.50			

4. Discussion and Conclusions

4.1 Bonaparte Basin

The range of thermal conductivity values from the Bonaparte basin is from 1.24–5.09 W/mK, shown by specimens DIR157 and DIR156 respectively, which is a variability of up to a 79% from mean basin conductivity of 2.84 W/mK. The standard deviation between all 13 samples representing the Bonaparte basin is approximately 1.04σ.

4.2 Browse Basin

The range of thermal conductivity values from the Browse basin is from 2.29–4.51 W/mK, shown by specimens DIR149 and DIR147 respectively, which is a variability of up to a 39% from the mean basin conductivity of 3.24 W/mK. The standard deviation between all four samples representing the Browse basin is approximately 0.82σ.

4.3 Carnarvon Basin

The range of thermal conductivity values for the Carnarvon basin is from 0.64–4.97 W/mK, shown by specimens DIR138 and DIR132 respectively, which is a variability of up to a 97% from the mean basin conductivity of 2.52 W/mK. The standard deviation between all 61 samples representing the Carnarvon basin is approximately 0.89σ.

4.4 Officer Basin

The range of thermal conductivity values for the Officer basin is from 1.25–5.54 W/mK, shown by specimens DIR202 and DIR186 respectively, which is a variability of up to 103% from the mean basin conductivity of 2.73 W/mK. The standard deviation between all 40 samples representing the Officer basin is approximately 1.17σ. Thermal conductivity of specimen DIR206 was not measured due to poor sample quality.

The following additional points must be considered if extrapolating the results in this report to *in situ* formations:

1. The samples upon which the thermal conductivity measurements were made are only several square centimetres in surface area. While the specimens were chosen to represent the geological sections from which they came, there is no guarantee that the sections themselves are typical of the overall geological formations. This is especially true for heterogeneous formations. This introduces an unquantifiable random error into the results.

2. Porosity exerts a primary influence on the thermal conductivity of a rock. Water is substantially less conductive than typical mineral grains[5], and water saturated pores act to reduce the bulk thermal conductivity of the rock. Gas-filled pores reduce the bulk conductivity even more dramatically. Results reported in this document are whole-rock measurements. No adjustments were made for porosity. It is to be expected that the thermal conductivity of a given formation will vary from place to place if the porosity of the formation varies (conductivity decreases with increasing porosity).

3. Thermal conductivity of rocks is sensitive to temperature[2], typically decreasing at a rate of around 0.16% per °C. This should be kept in mind when developing models of in situ thermal conductivity.

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[5] **Beardsmore, G.R. and Cull, J.P.** (2001). *Crustal heat flow: A guide to measurement and modelling*. Cambridge University Press, Cambridge. 324pp.

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GEOTHERMAL ENERGY POTENTIAL IN SELECTED AREAS OF WESTERN AUSTRALIA (CARNARVON BASIN)

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