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Heat Flow Determinations for the Australian Continent: Release 3

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APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

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GEOSCIENCE AUSTRALIA
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by

Weber, R.D., Kirkby, A.L. and Gerner, E.J.

Australian Government
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CONTENTS

Executive Summary

Heat flow data across Australia is sparse, with less than 150 publicly available data-points. The heat flow data is unevenly distributed and most of it comes from studies undertaken by the Bureau of Mineral Resources (BMR) in the late 1970s. Under the federally funded Onshore Energy Security Program (OESP), the Geothermal Energy Project at Geoscience Australia has collected data to add to the heat flow dataset.

This report presents temperature, natural gamma and thermal conductivity data for 25 boreholes across Australia. Temperature logging was performed down hole with temperatures recorded at 20 cm intervals. Drill core samples were taken from each well and measured for thermal conductivity by Geoscience Australia.

One dimensional, conductive heat flow models are presented for 24 of the 25 boreholes presented here. These will add to the 17 heat flow determinations already released under the OESP totalling 41 determinations to add to the Australian continental heat flow dataset.

Introduction

Under the Federal Government funded Onshore Energy Security Program (Geoscience Australia, 2011), Geoscience Australia (GA) has released 17 heat flow determinations (see Kirkby and Gerner, 2010; Jones et al., 2011). This record contains an additional 24 heat flow determinations (Table 1) bringing the total to 41 new heat flow determinations for the Australian continent. This is an increase of approximately 25% in the publically available heat flow points for Australia. The locations of the heat flow determinations produced by GA are shown in Figure 1.

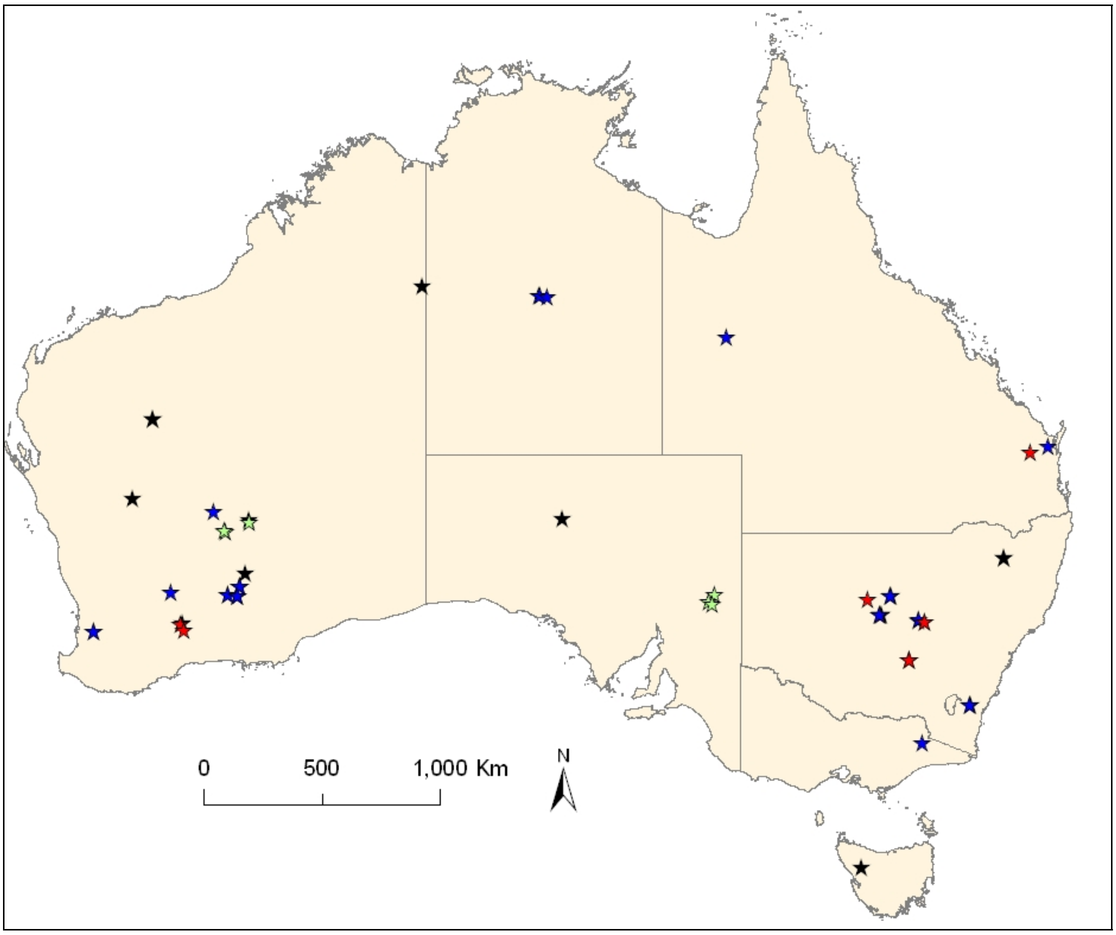

Figure 1: Heat flow determinations made by Geoscience Australia under the Onshore Energy Security Program. Red points are from Release 1 (Kirkby and Gerner, 2010), green points are from Release 2 (Jones et al., 2011), blue points are from Release 3 (this report), and black points are where Geoscience Australia has collected data but the heat flow is yet to be determined.

Table 1: Location, depth, dip and heat flow determinations of the 25 wells discussed in this report. UE means the well is unequilibrated and thus the heat flow is only an estimate and no error could be determined. N/A means no heat flow could be determined due to insufficient data. A spreadsheet version of this table is provided in Appendix 1A.

Well Name	Region	Latitude (GDA94)	Longitude (GDA94)	Depth (m)		Dip (-º)	Heat Flow (mW/m^2)
				Logged Depth	True Vertical		
NR108D010	Tennant Creek, NT	-19.92608	133.32508	441.6	441.6	90.0	98 ± 7
NR142D003	Tennant Creek, NT	-19.96320	133.38755	749.2	679	65.0	94 ± 8
WGR1D011	Tennant Creek, NT	-20.00320	133.65788	536.8	487	65.0	90 ± 11
MEQ1180	Cloncurry, QLD	-21.53913	140.49094	743.8	743.8	90.0	65.5±1
TJVD002	Maryborough, QLD	-25.67452	152.71715	312.8	312.8	90.0	68 + 4/-10
DREX 83	Braidwood, NSW	-35.54780	149.74751	445.7	386	60.0	61.5 ± 4.5
DREX 122	Braidwood, NSW	-35.54459	149.74942	304.8	264	60.0	54 ± 2.5
GW096000	Trangie, NSW	-32.33071	147.77555	136.0	136.0	90.0	N/A
GW800554	Trangie, NSW	-32.27710	147.79339	175.5	175.5	90.0	29 ± 8
TTDD002	Nyngan, NSW	-31.39693	146.73287	1255	1236	80.0	80 ± 9
TTDD003	Nyngan, NSW	-31.39787	146.73294	1280	1250	85.3-76.1	55 - 79 (UE)
TNY046	Cobar, NSW	-32.11187	146.32343	737.6	691	69.5	66.5 ± 3
TD11961T	Kambalda, WA	-31.39991	121.81965	525.9	455	60.0	41 - 45 (UE)
TD11964	Kambalda, WA	-31.39577	121.81995	540.5	568	60.0	29 - 35 (UE)
TD11968TWI	Kambalda, WA	-31.39542	121.81776	690.6	649	75.0	36 - 38(UE)
TD11969TW1	Kambalda, WA	-31.40133	121.81647	638.1	578	65.0	28 (UE)
WRD10990-002	Boddington, WA	-32.42308	119.70619	984.3	806	55.0	45 ± 3
WRD13405-002	Boddington, WA	-32.72147	119.81375	835.8	738	62.0	46 - 52 (UE)
TVDD0013	Southern Cross, WA	-31.27350	119.32596	477.9	432	64.8	27 ± 3
08BKWD0027	Kambalda West, WA	-31.35865	121.49711	500.8	434	60.0	33 ± 1
08BKWD0028	Kambalda West, WA	-31.35687	121.49654	461.7	400	60.0	35 ± 7
08BWDD0013	Kambalda West, WA	-28.16539	120.91759	358.6	327	65.9	26.5 ± 1
10MMDD003	Kalgoorlie, WA	-31.03839	121.94012	355.8	316	62.6	32.5 ± 4.5
10MMRCD060	Kalgoorlie, WA	-31.01492	121.91740	390.8	345	62.1	23 (UE)
09SMDD002	Benambra, VIC	-36.98750	147.91306	278.4	274	80.0	73 +17/-9

Input Data

TEMPERATURE LOGS

Wells were logged by GA using either the Auslog A626 combined temperature/gamma probe or the Auslog A621 temperature probe. Both probes have a temperature precision of 0.007º C and can measure temperatures up to 70º C. The probe is connected to a winch with 1800 m of four-conductor cable, which was sufficient to log all wells reported here to maximum depth or to where blockages occurred.

The Auslog DLS5 digital logging system connects the tool to a laptop computer. Wellvision software was used to record the data. The temperature (and gamma) signal was recorded down the hole at a speed of approximately five metres per minute and the probe is programmed to take measurements every 20 cm, regardless of speed. GA has experimented with sampling intervals and found one sample every 20 cm to be optimum for heat flow determinations.

Wells were logged as long as possible after drilling was completed to increase the chances of equilibrium being reached before logging. In some cases, due to accessibility constraints wells were logged within days of drilling and it is very unlikely that equilibrium had been reached before logging. Where this is the case it has been noted in the results.

The temperature logs were converted from measured depth (length of drill hole) to true vertical depth (perpendicular depth from the surface) using survey information provided by the companies that drilled each well (see Table 1). The temperature data was then smoothed using a three point running average. The raw temperature files can be found in electronic Appendix A.

GAMMA LOGS

Approximately half of the wells were logged using the Auslog A626 probe which collects natural gamma data in addition to the temperature data. The Auslog A621 temperature probe, which measures temperature only, was used when the A626 probe required maintenance. The natural gamma data were collected at 20 cm intervals down the well. The natural gamma logs were converted from measured depth to true vertical depth and smoothed with a 3 point running average. The raw gamma logs can be found in electronic Appendix 2.

THERMAL CONDUCTIVITY MEASUREMENTS

Core specimens were collected from each well in order to undertake thermal conductivity analyses. Specimens approximately 15 cm in length were collected at intervals of 50-100 m down each well. Where available, lithology logs were used to guide sampling. Where possible each lithology was sampled in the well and mineralised zones were avoided.

Core specimens were analysed for thermal conductivity either by Hot Dry Rock Pty Ltd (HDRPL) or by Geoscience Australia (GA). Each core specimen was sub-sampled to create up to three discs. To prepare the discs for measurement they were first flattened to ensure parallel and then polished. The discs were measured using the divided bar apparatus. Where multiple discs were available the harmonic mean and standard deviation of the thermal conductivity were computed. Details of the samples measured for this study are provided in Appendix 3.

At GA the samples were measured first dry and then wet as poorly consolidated rocks may fall apart under water saturation. In these instances the dry thermal conductivity can be used as a back up and an estimate of the porosity used to provide an estimate of the thermal conductivity. HDRPL only measured the samples saturated.

To produce a dry measurement, the discs were placed in an oven at 102 ºC until no more mass changes due to water loss occurred (approximately 48 hours). To produce a saturated measurement, the discs were evacuated under a >95% vacuum for 3-4 hours. Discs were then submerged in water prior to returning to atmospheric pressure. Discs were left in the water at atmospheric pressure for a minimum of twelve hours, and all samples were left in water until just prior to thermal conductivity measurement.

Samples measured at HDRPL were measured for thermal conductivity at a temperature of 30 ± 2º C and samples measured at GA were measured at 25 ± 2º C. However there is very little variability in thermal conductivity at low temperatures and thus it is assumed that the results are comparable (Cull and Beardsmore 2001).

LITHOLOGY LOGS

A number of companies provided lithology logs for their drill holes. Where available, the logs were used in conjunction with the measured thermal conductivities, to assign thermal conductivity values to each unit in the well. These extra thermal conductivity values provided additional constraints on the heat flow determinations.

Heat Flow Calculation Method

Heat flow determinations were calculated using the following method after Kirkby and Gerner (2010).

1. The temperature log was visually inspected in order to select a conductive interval from the temperature log on which to undertake the heat flow determination. This conductive zone:
    a. avoids the near surface which is likely to be affected by seasonal variations in temperature; and
    b. avoids sections of the log which appear to be influenced by significant advective heat flow.
2. Thermal conductivity values were depth corrected and correlated with the depth corrected log to determine which values correspond to the above defined conductive zone.
3. The conductive zone described in point 1 was divided into sub-sections with assigned thermal conductivity values. This was done in one of three ways depending on the data available:
    a. where there was no gamma or lithology logs available the sub-section boundaries were defined by the midpoint between the depth locations of thermal conductivity measurements (thus intervals were around 100 m thick based on thermal conductivity sampling density);
    b. where a gamma log was available, but no lithology log, the sub-section boundaries were defined by variations in the gamma log interpreted to indicate lithology changes. If no gamma variations were present, the above method was used; and
    c. where there was a lithology log available the measured thermal conductivity values were assigned to the rock unit that the depth location correlated with.
4. Thermal conductivity values, their errors and the sub-section boundaries were entered into a 1D conductive heat flow modelling spreadsheet. Modelling commenced at the top of the conductive section using the measured temperature at that point. From this point downward, the measured thermal conductivity values at the sub-section boundaries were used with a constant heat flow value to predict the temperature at the base of each sub-section.
5. The predicted temperatures were then plotted with the temperature log and the heat flow value adjusted until there was good agreement between the predicted temperature and the logged temperature (see Figure 2A and D).
6. Finally, error bounds were calculated to provide an indication of the confidence in each heat flow determination. The errors are due to the uncertainty (standard deviation) of the input thermal conductivity values, as well as uncertainties in the locations of the assigned sub-section boundaries (described in bullet point 3). The following shows how the upper bound and lower bound heat flow values were calculated due to the above uncertainties:
    a. Boundaries were first reassigned to make sections with high thermal conductivity values as thick as possible (resulting in higher heat flow). The heat flow was then determined based on a best fit between the data and the temperature profile predicted from the thermal conductivity values plus one standard deviation. The resulting value is the highest heat flow that could be matched to the data using the method described in points 1-5 (see Figure 2B and D);
    b. Boundaries were then reassigned to make the sections with lower thermal conductivity values as thick as possible (resulting in a lower heat flow). The heat flow was determined based on a best fit to the data using the temperature profile predicted from the thermal conductivity values minus one standard deviation. The resulting value is the lowest heat flow that could be matched to the data using the method described in points 1-5 (see Figure 2C and D);
    c. The error is then the difference between the initial heat flow determined (in point 5) and the highest and lowest heat flow values determined from 6a and 6b; and

d. In cases where there was a lithological log available for the hole, and there was at least one thermal conductivity measurement for each of the dominant lithologies, the boundaries were not shifted as in 6a and 6b. Instead, the error bounds were calculated using only the thermal conductivity data.

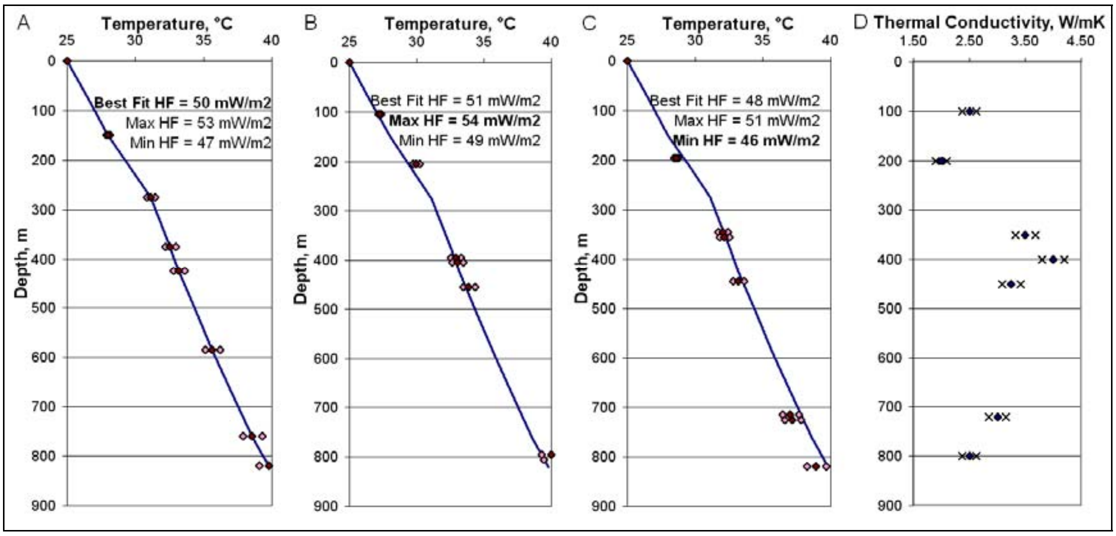

Figure 2: Calculating the error on heat flow determinations to account for boundary and thermal conductivity uncertainties.

Results

NR108D010

NR108D010 is located in central Northern Territory, approximately 97 km south-west of Tennant Creek. The well was drilled by Westgold Resources Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 441.6 m. No lithological logs were provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature profile is shown in Figure 3 and from this the conductive zone has been defined as 300 m to 428 m depth. Above this zone the gradient is disturbed and below this zone the regime is no longer purely conductive. This can be observed as the temperature log starts to invert at approximately 429 m (see Figure 3).

A heat flow of $98.5 \pm 6.5\ mW/m^2$ has been determined for this well. Where possible the gamma log was used to constrain sub-section boundaries; otherwise boundaries were assigned as the midpoint between two thermal conductivity samples (Table 2). Four thermal conductivity samples collected from this well lie in the conductive zone and were used to constrain the heat flow determination.

Table 2: Samples, thermal conductivity values and sub-sections boundaries for well NR108D010. N/A means that the sample was not used for the heat flow modelling.

Sample Number	True vertical depth of sample (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2122368	175.08	Stylotised carbonate rock	6.06	0.02	N/A	N/A
2122369	208.40	Coarse grained meta-volcanic rock	5.60	0.05	N/A	N/A
2122370	230.07	Metamorphic rock, minor schistosity	5.79	0.19	N/A	N/A
2122371	274.93	Metavolcanic rock	3.88	0.07	N/A	N/A
2122372	331.00	Metavolcanic rock	4.39	0.11	300.0-343.8	Midpoint
2122373	356.71	Fine to coarse grained metavolcanic rock	4.38	0.46	343.8-380.9	Midpoint
2122374	405.19	Coarse grained metavolcanic rock, clay and chlorite alteration	4.21	0.13	380.9-415.0	Gamma log
2122375	424.08	Fine to medium grained chloritic rock	6.41	0.02	415.0-428.0	Bottom of conductive zone
2122376	435.05	Fine to coarse grained metamorphic rock	3.80	0.16	N/A	N/A

The modelled temperature data is plotted along with the measured temperature log in Figure 3. There is a good agreement between the measured and modelled data. The error in the heat flow determination is primarily due to the uncertainty of the assigned sub-section boundaries. It is expected that the error would be reduced if lithological information was available to constrain the sub-section boundaries.

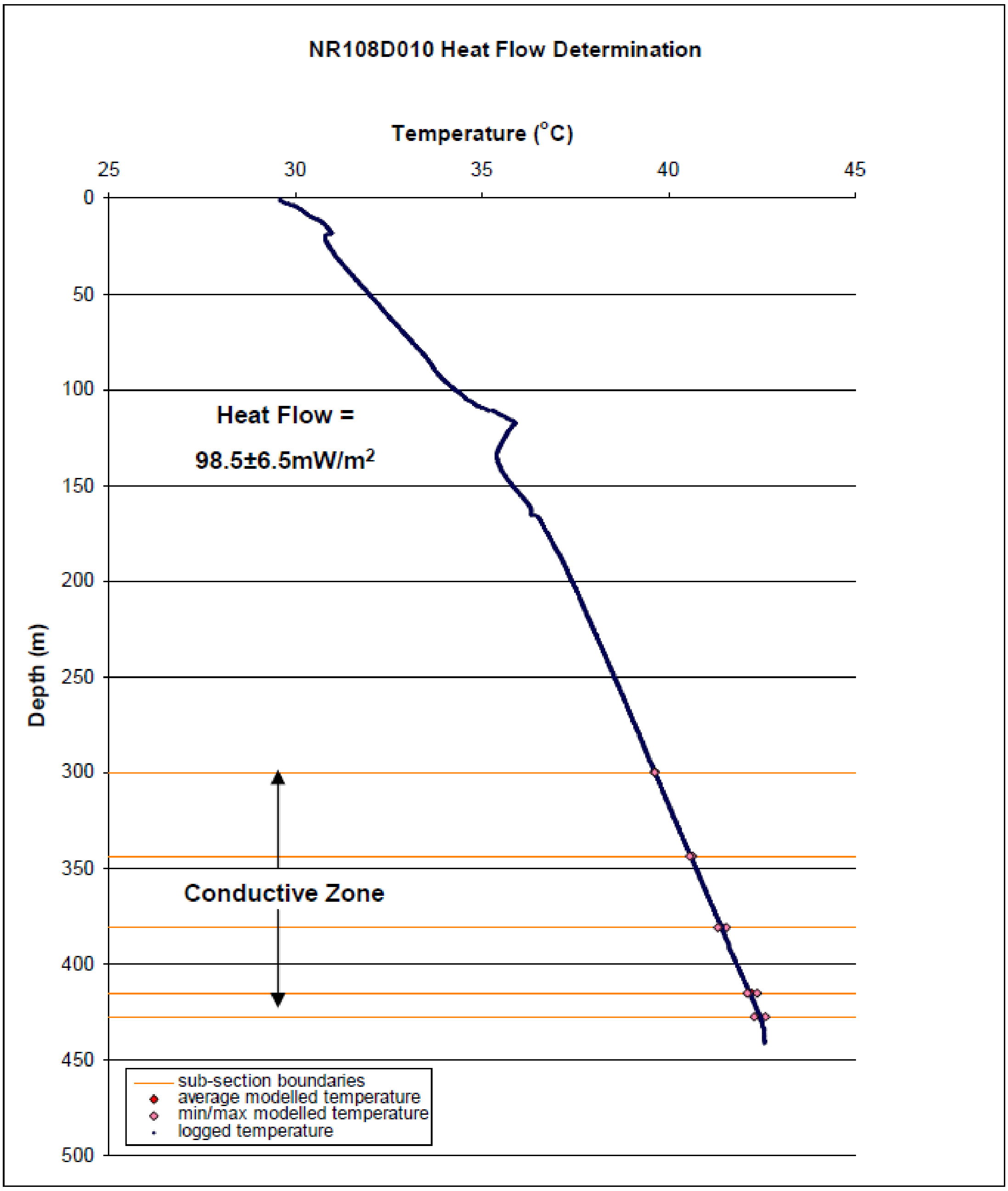

Figure 3: Modelled and measured temperatures versus true vertical depth for NR108D010. The subsection boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

NR142D003

NR142D003 is located in central Northern Territory, approximately 92 km south-west of Tennant Creek. The well was drilled by Westgold Resources Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 679 m. No lithological logs were provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature profile is shown in Figure 4 and from this the conductive zone has been defined as 300 m to 580 m depth. Above this zone the gradient is disturbed and below this zone the thermal conductivity measurements are highly variable. Values decrease from 4.36 W/mK at 540.7 m to 2.57 W/mK at 588.9 m and then increase to 12.49 W/mK at 665.8 m, without any corresponding changes in the gamma log. Furthermore, when these values were assigned to the 1D heat flow model, defining subsection boundaries as the midpoint between sample measurements, it was impossible to fit the model to the data. This could indicate that below 580 m, the heat flow changes abruptly, or, more likely given the smoothness of the temperature profile, these thermal conductivity values do not represent the surrounding rock and are of limited vertical extent. Therefore, it was decided to discard the bottom two thermal conductivity measurements, and perform the heat flow determination using the 6 other sample in the hole. Additional samples and a lithology log would be required to generate a better constrained heat flow determination below 580 m.

A heat flow of $92 \pm 8 mW/m^2$ has been determined for this well. This value has been determined using the gamma log to constrain sub-section boundaries (see Table 3). Six of the thermal conductivity samples collected from this well lie in the conductive zone and were used to constrain the heat flow determination.

Table 3: Samples, thermal conductivity values and sub-sections boundaries for well NR142D003. N/A means that the sample was not used for heat flow modelling.

Sample Number	True vertical depth of sample (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2122377	131.4	Calcareous vuggy siltstone	5.02	0.20	N/A	N/A
2122378	176.0	Grey siltstone	3.25	0.11	N/A	N/A
2122379	190.5	Quartzose fine to medium grained metasediment	5.03	0.12	N/A	N/A
2122380	244.5	Fine to medium grained hematite and clay altered metasediment	4.55	0.05	N/A	N/A
2122381	283.9	Fine to medium grained clay altered metasediment	4.00	0.09	N/A	N/A
2122382	335.3	Fine grained hematite and chlorite altered metasediment	4.27	0.04	300.0-349.0	Gamma log
2122383	381.0	Fine to medium grained metasediment, minor clay alteration	4.28	0.13	349.0-401.0	Gamma log
2122384	424.7	Fine to medium grained metamorphic rock, some chlorite	4.44	0.03	401.0-431.0	Gamma log
2122385	471.6	Slate	3.68	0.13	431.0-514.0	Gamma log
2122386	517.5	Chert, minor alteration	5.76	0.13	514.0-530.0	Gamma log
2122387	540.7	Fine grained	4.36	0.57	530.0-	Bottom

		hematite altered metamorphic rock			580.0	conductive zone
2122388	588.9	Fine grained metasediment, minor pyrite and banded hematite	2.57	0.24	N/A	N/A
2122389	665.8	Banded iron formation	12.49	0.79	N/A	N/A

The modelled temperature data is plotted along with the measured temperature log in Figure 4. There is good agreement between the measured and modelled data. Again, the error in the heat flow determination lies primarily in the uncertainty of the assigned sub-section boundaries. It is expected that the error would be reduced if lithological information was available to constrain the boundaries. The heat flow determined for this well lies in the error range of that determined for NR108D010, which is located 7.8 km to the north-east of this well.

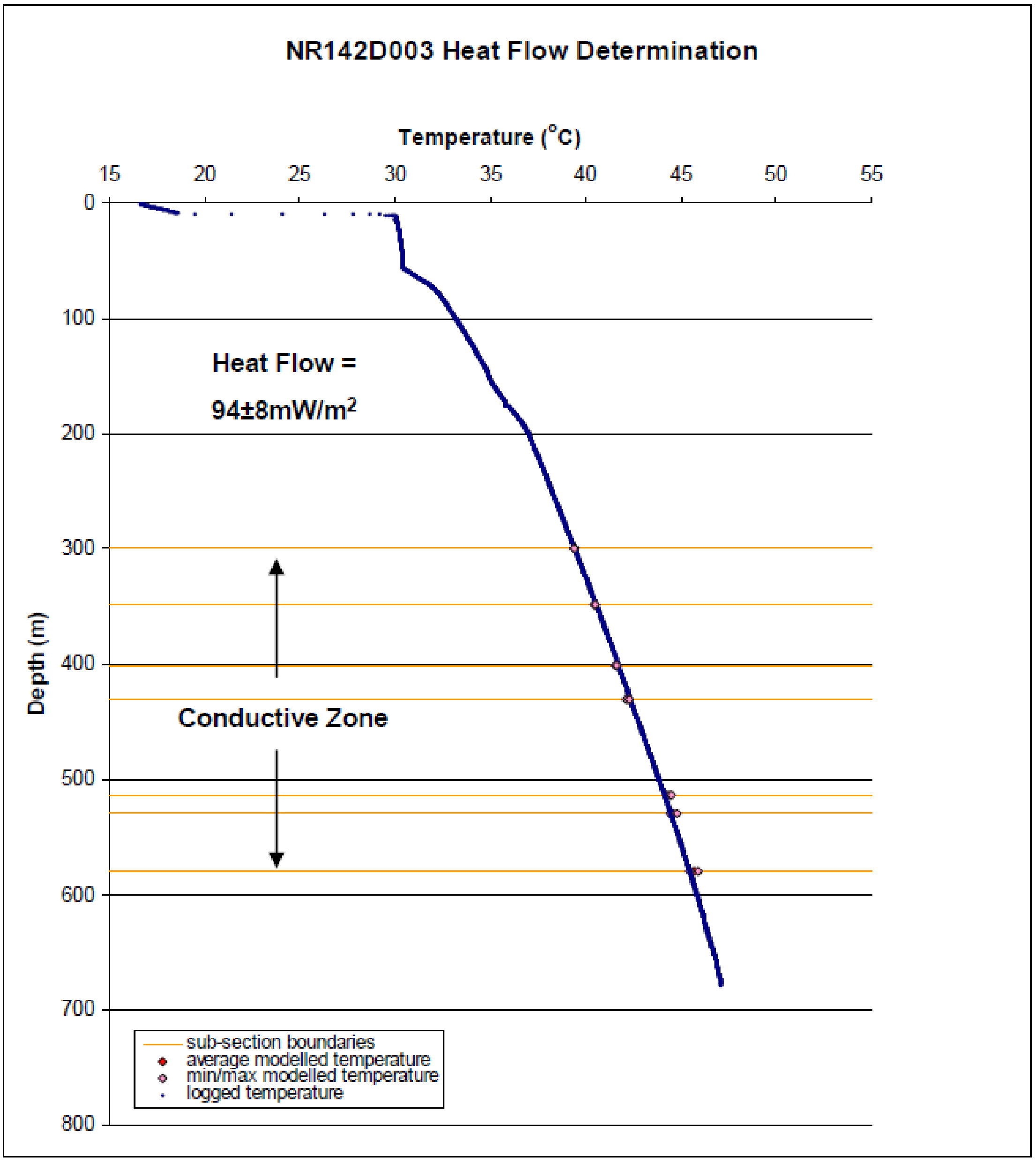

Figure 4: Modelled and measured temperatures versus true vertical depth for NR142D003. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

WGR1D011

WGRD011 is located in central Northern Territory, approximately 68 km south-west of Tennant Creek. The well was drilled by Westgold Resources Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 487 m. No lithological logs were provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature profile is shown in Figure 5 and from this the conductive zone has been defined as 290 m to 424 m depth. Above this zone the gradient is disturbed and below this zone the regime is no longer purely conductive. This can be observed as the gradient is no longer smooth and starts to invert below 424 m (see Figure 5).

A heat flow of 90 ± 11 mW/m^2 has been determined for this well. This value has been determined using the gamma log to constrain sub-section boundaries. Three of the thermal conductivity samples collected from this well lie within the conductive zone of the well and were used to constrain the heat flow determination (see Table 4).

Table 4: Samples, thermal conductivity values and sub-sections boundaries for well WGR1D011. N/A means that the sample was not used for heat flow modelling.

Sample Number	True vertical depth of sample (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2122357	63.3	Calcareous fine grained sandstone	3.81	0.16	N/A	N/A
2122358	108.6	Coarse grained sandstone, pebbly bands	5.09	0.13	N/A	N/A
2122359	159.9	Chert	4.88	0.22	N/A	N/A
2122360	204.6	Chert	5.12	0.13	N/A	N/A
2122361	244.9	Red siltstone, slightly altered	3.70	0.16	N/A	N/A
2122362	294.7	Red chert, slightly altered	5.03	0.06	290.0-339.0	Gamma log
2122363	340.2	Fine to medium grained meta-sediment	3.46	0.05	339.0-367.0	Gamma log
2122364	385.0	Chert, minor clay veining	4.80	0.14	367.0-424.0	Bottom conductive zone
2122365	334.6	Pyritic shale,	12.94	1.27	N/A	N/A
2122366	453.9	haematite, pyrite, sulfide rich rock	10.41	1.17	N/A	N/A
2122367	474.5	Very fine grained, dark, iron rich metasediment	4.75	0.18	N/A	N/A

The modelled temperature data is plotted along with the measured temperature log in Figure 5. There is good agreement between the measured and modelled data. Again, the error in the heat flow determination lies primarily in the uncertainty of the assigned sub-section boundaries. It is expected that the error would be reduced if lithological information was available to constrain the boundaries and if more samples had been collected from the conductive zone. This heat flow value is slightly lower than that of NR142D003 (though still within error bounds), which is situated approximately 27.8 km to the north-west of this well.

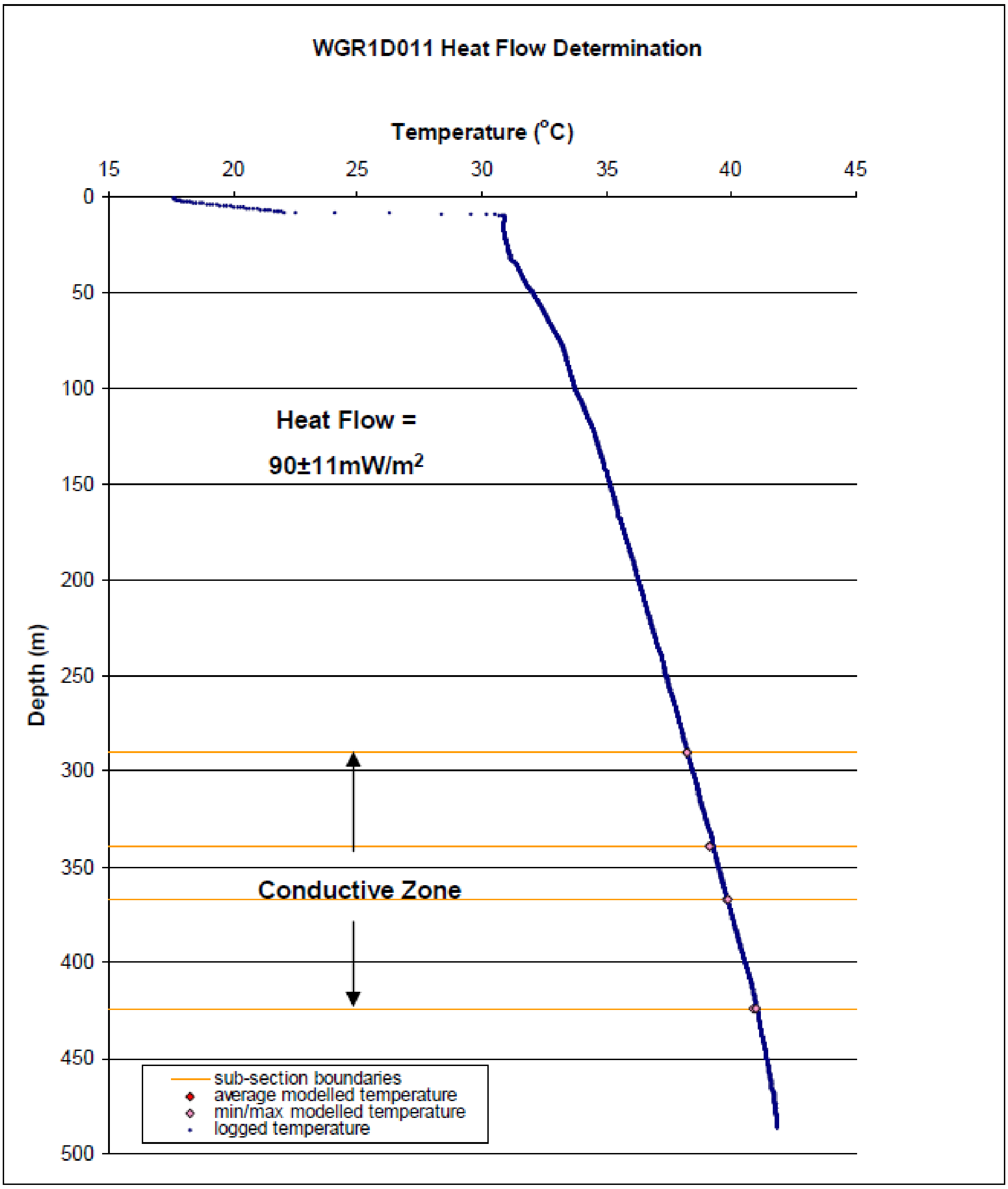

Figure 5: Modelled and measured temperatures versus true vertical depth for WGR1D011. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

MEQ1180

MEQ1180 is located in located in central-western Queensland, approximately 93 km south of Cloncurry. The well was drilled by Ivanhoe Australia Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 743.8 m. No lithological logs were provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature profile is shown in Figure 6 and from this the conductive zone has been defined as 300 m to 574 m depth. Above this zone the gradient is disturbed. Below this zone there is a sharp increase and then inversion in temperature (see Figure 6) which corresponds to a spike in the gamma log. This suggests that there is a heat source at this part of the well, potentially a localised region of elevated concentration of uranium, potassium and/or thorium.

A heat flow value of *65.5 ± 1 mW/m^2* has been determined for the upper section of this well. Where possible the gamma log has been used to constrain sub-section boundaries; otherwise these have been assigned as the midpoint between two thermal conductivity samples. Seven of the thermal conductivity samples collected from this well lie within the conductive zone and were used to constrain the heat flow determination (see Table 5).

Unfortunately there is only one thermal conductivity measurement below the unstable section at about 574 m depth, making it difficult to get a reliable heat flow determination below this point. However, an estimate can be obtained by multiplying the temperature gradient over the flat section between 684 and 725 m depth in the hole, by the thermal conductivity, yielding a value of 62 mW/m^2. This indicates that while the heat flow is slightly subdued below 574 m depth, it is very similar to the value of *65.5 ± 1 mW/m^2* obtained for the rest of the well.

Table 5: Samples, thermal conductivity values and sub-sections boundaries for well MEQ1180. N/A means that the sample was not used for heat flow modelling.

Sample Number	True vertical depth of sample (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2122346	212.2	Banded, brecciated, metamorphic rock, clay, haematite and chlorite alteration,	3.34	0.33	N/A	N/A
2122347	242.0	Hematite altered slate	3.21	0.15	N/A	N/A
2122348	300.8	Clay alteration, hematite, chlorite, slate	2.60	0.06	300.0-318.3	mid point
2122349	335.8	Brecciated altered meta-chert	2.58	0.07	318.3-365.0	Gamma log
2122350	382.0	Fine grained black hematite altered metasediment with granite veins.	2.45	0.06	365.0-421.9	Gamma log
2122351	426.2	Hematite altered granite	2.50	0.04	421.9-445.0	Gamma log
2122352	465.2	Hematite altered, brecciated, loosely banded metasediment, banding parallel to core axis	2.59	0.06	445.0-478.1	Mid point
2122353	491.0	Brecciated, banded altered metasediment	2.68	0.02	478.1-511.0	Gamma log
2122354	528.2	Hematite altered granite	2.96	0.01	511.0-574.0	Bottom conductive zone

2122355	597.0	Hematite altered granite	2.80	0.06	N/A	N/A
2122356	696.8	Quartz vein, hematite altered	3.28	0.12	N/A	N/A

The modelled temperature data is plotted along with the measured temperature log in Figure 6. There is reasonably good agreement between the measured and modelled data. The error on this heat flow determination is quite small, which is probably due to the high density of samples in the conductive zone. Also the thermal conductivity values do not vary greatly, suggesting that the lithology is quite homogeneous. However, the error could potentially still be reduced if lithological information was available to constrain the sub-section boundaries.

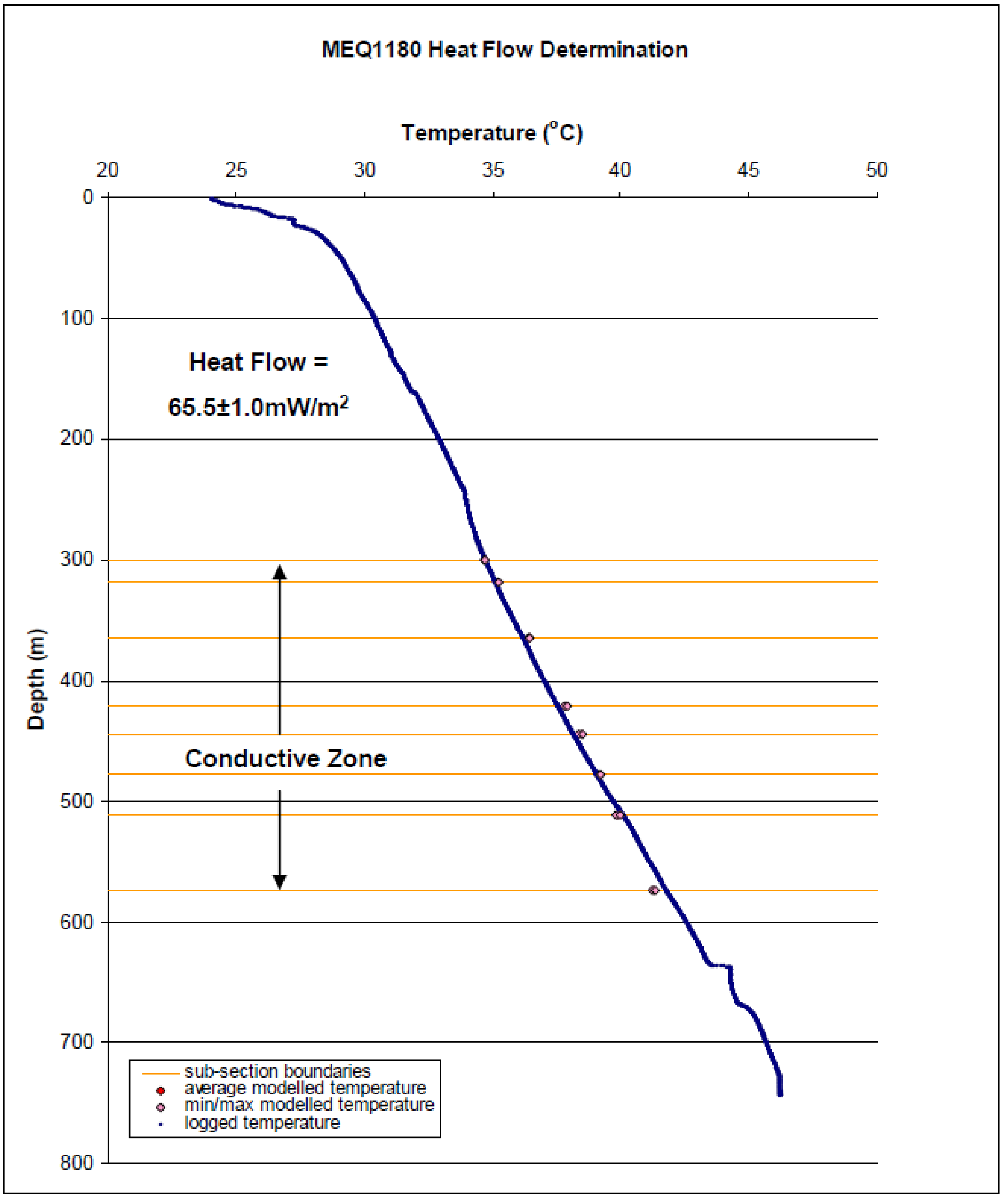

Figure 6: Modelled and measured temperatures versus true vertical depth for MEQ1180. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

TJVD002

TJVD002 is located in south-eastern Queensland, approximately 15 km south of Maryborough. The well was drilled by Tiaro Coal Ltd and was logged by GA using the combined temperature/gamma probe to a vertical depth of 312.8 m. A detailed lithological log was supplied to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature profile is shown in Figure 7 and from this the conductive zone has been defined as 204 m to 310.7 m depth. Above this zone the gradient is disturbed and below this zone the regime is no longer purely conductive. This can be observed as the gradient becomes unstable towards the bottom of the well.

Although a lithology log was available for this well, many of the lithologies present have not been sampled. Thus the lithology log was of little use for defining sub-section boundaries, though was used to define the extent of the thermal conductivity of sample 2122343. Below this interval the presence of additional mapped lithologies distinct to those sampled (2122344 and 2122345) necessitated a different approach. Accordingly the boundary between samples 2122344 and 2122345 had to be assigned as the midpoint between them, given it was not possible to have small boundaries around each sample and then no thermal conductivity for the various lithologies in between.

A heat flow of *68+4/-10 mW/m*^{2} has been determined for this well. Three of the thermal conductivity samples collected lie within the conductive zone and were used to constrain the heat flow determination (see Table 6). As described above the lithology log and the midpoint technique have been used to assign sub-section boundaries.

Table 6: Samples, thermal conductivity values and sub-sections boundaries for well TJVD002. N/A means that the sample was not used for heat flow modelling.

Sample Number	True vertical depth of sample (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2122336	36.9	Light grey medium grained sandstone	2.68	0.20	N/A	N/A
2122337	38.5	Dark grey siltstone with minor shale	2.03	0.15	N/A	N/A
2122338	68.8	Coaly shale	2.56	0.21	N/A	N/A
2122339	92.0	Fine to medium grained grey sandstone with shale interbeds	1.36	0.46	N/A	N/A
2122340	102.5	Sandstone with clasts of shale 2-60mm in size	3.16	0.15	N/A	N/A
2122341	131.4	Medium grained, grey sandstone, lithic fragments	2.79	0.22	N/A	N/A
2122342	162.5	Siltstone and shale	3.21	0.13	N/A	N/A
2122343	218.4	Black shale	2.18	0.19	204-221	Lithology log
2122344	269.6	Mixed carbonaceous Shale and sandstone	2.51	0.11	221-287.4	Mid point
2122345	305.2	Siltstone and shale	2.48	0.25	287.4-306	Bottom conductive zone

The modelled temperature data is plotted along with the measured temperature log in Figure 7. There is reasonably good agreement between the measured and modelled data. However, the large error for this heat flow determination (and thus only being defined as a range of values) is mainly due to uncertainty in the sub-section boundaries. It is known from the lithology log that the lithology down well is quite heterogeneous and many facies were not sampled. The result would be better constrained if every lithology had been sampled.

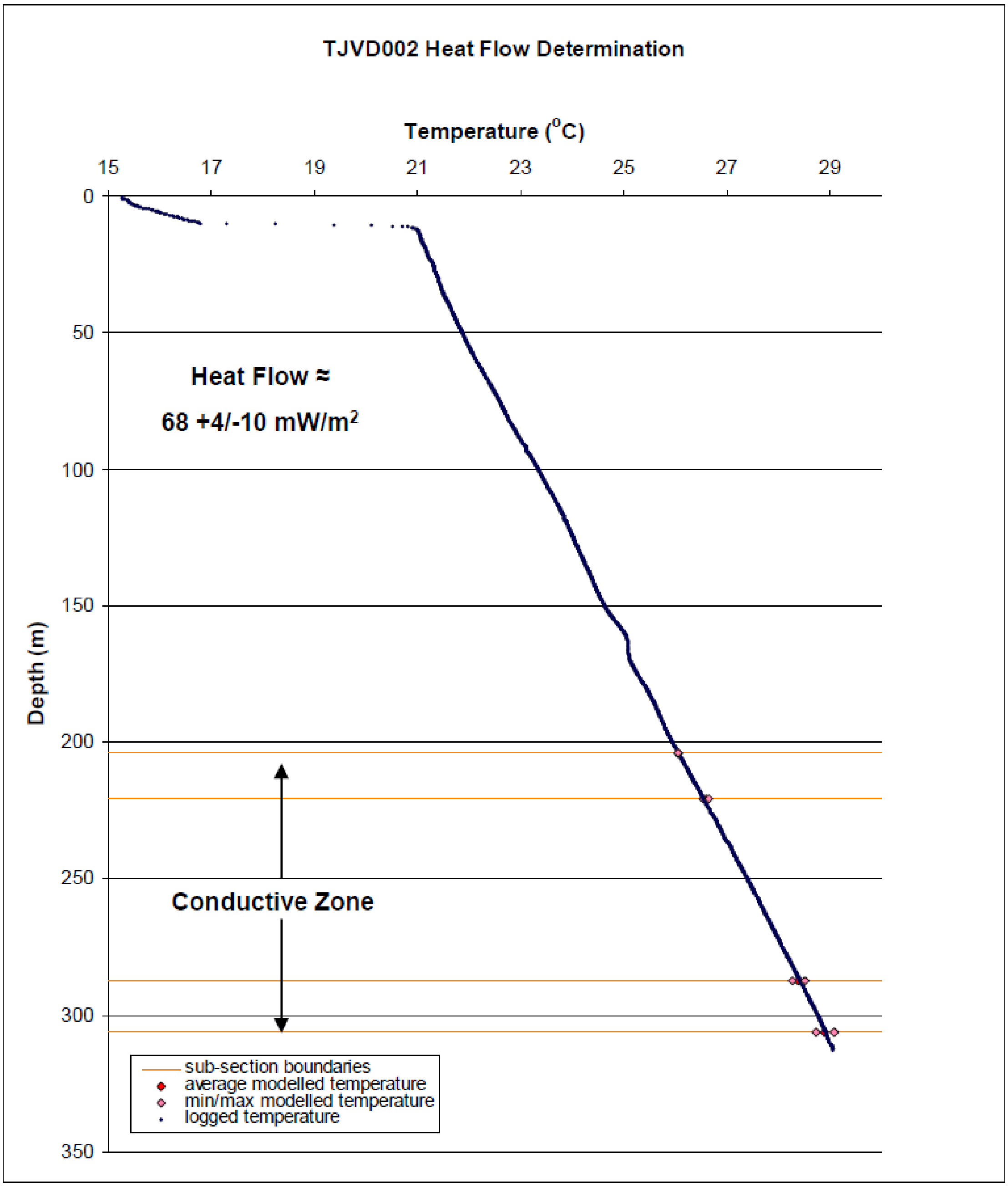

Figure 7: Modelled and measured temperatures versus true vertical depth for TJVD002. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

DREX 83

DREX 83 is located in south eastern NSW, 12 km south-west of Braidwood. It was drilled by Cortona Resources Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 386 m. No lithology log was supplied to GA. Thermal conductivity measurements on samples from this well were undertaken by GA.

The temperature profile is shown in Figure 8 and from this the conductive zone has been defined as from 130 m to 378 m depth. Above this zone the gradient is disturbed and below this zone the regime is no longer purely conductive. This can be observed as the temperature gradient becomes unstable towards the bottom of the well.

The gamma log for this well shows little to no variation around samples and therefore could not be used to assign subsection boundaries. Thus boundaries have been assigned as the midpoint between two thermal conductivity samples. A heat flow of *61.5 ± 4.5* mW/m^2 has been determined for this well. Five thermal conductivity samples were collected and all lie within the conductive zone for this well and were used to constrain the heat flow determination (see Table 7).

Table 7: Samples, thermal conductivity values and sub-sections boundaries for well DREX 83.

Sample Number	True vertical depth of sample (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2109589	126.0	Coarse grained felsic intrusive	2.83	0.09	130-157.9	Midpoint
2109590	189.8	Coarse grained felsic intrusive	2.73	0.11	157.9-253.6	Midpoint
2109591	317.3	Coarse grained felsic intrusive	2.23	0.16	253.6-323.5	Midpoint
2109592	329.7	Coarse grained felsic intrusive	2.71	0.04	323.5-347.9	Midpoint
2109593	366.0	Coarse grained intermediate intrusive	3.13	0.05	347.9-378.0	Bottom conductive zone

The modelled temperature data is plotted along with the measured temperature log in Figure 8. There is reasonable agreement between the measured and modelled data. However, there is a problem with sample density between 150 and 325 m which makes the heat flow determination difficult. If more samples were available from this interval the heat flow determination would be better constrained and have a lower error. It would also be beneficial to have a lithology log to assign the sub-section boundaries, which again would reduce the error.

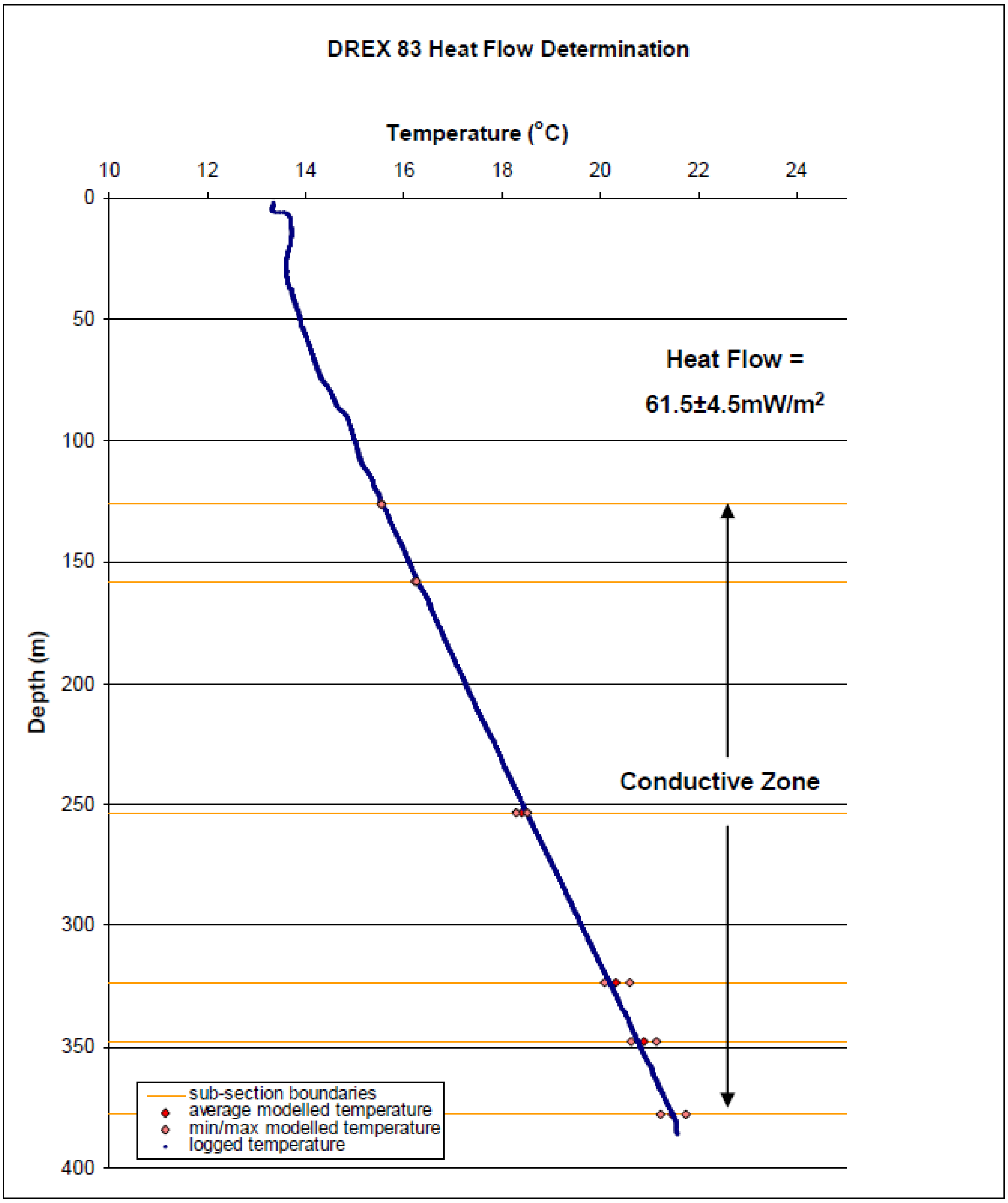

Figure 8: Modelled and measured temperatures versus true vertical depth for DREX 83. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

DREX 122

DREX 122 is located in south eastern NSW, approximately 12 km south-west of Braidwood. It was drilled by Cortona Resources Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 264 m. No lithology log was supplied to GA. Thermal conductivity measurements on samples from this well were undertaken by GA.

The temperature profile is shown in Figure 9 and from this the conductive zone has been defined as 184 m to 264 m depth, which is the bottom of the well. Above this zone the gradient is disturbed.

A heat flow of $54 \pm 2.5\ mW/m^2$ has been determined for this well. Where possible the gamma log has been used to constrain sub-section boundaries; otherwise these have been assigned as the midpoint between two thermal conductivity samples. Seven of the thermal conductivity samples collected lie in the conductive zone and were used to constrain the heat flow determination (see Table 8). The gradient for this well is a bit unsteady in places and suggests that either the well is not completely equilibrated or that it is not a purely conductive regime.

Table 8: Samples, thermal conductivity values and sub-sections boundaries for well DREX 122. N/A means that the sample was not used for heat flow modelling.

Sample Number	True vertical depth of sample (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2109577	130.7	Felsic intrusive	2.64	0.07	N/A	N/A
2109578	143.8	Felsic intrusive	2.55	0.15	N/A	N/A
2109579	151.7	Felsic intrusive	2.48	0.15	N/A	N/A
2109580	160.9	Felsic intrusive	2.55	0.31	N/A	N/A
2109581	174.3	Felsic intrusive	2.56	0.04	N/A	N/A
2109582	184.8	Felsic intrusive	2.85	0.51	184.0-189.2	Midpoint
2109583	193.7	Felsic intrusive	2.30	0.13	189.2-199.8	Midpoint
2109584	206.0	Felsic intrusive	2.57	0.06	199.8-210.9	Midpoint
2109585	215.8	Felsic intrusive	2.65	0.01	210.9-225.0	Midpoint
2109586	228.7	Felsic intrusive	2.55	0.05	225.0-233.0	Gamma log
2109587	237.4	Felsic intrusive	2.63	0.02	233.0-241.0	Gamma log
2109588	247.3	Felsic intrusive	2.53	0.03	241.0-264.0	Bottom conductive zone

The modelled temperature data is plotted along with the measured temperature log in Figure 9. The value obtained for this hole is lower than that for DREX83 which is only 400m south-west of this well. There is a low error on the heat flow value for DREX122. The lithology is fairly homogeneous over the conductive zone and this would account for the low error. The error may potentially be reduced even further if a lithology log were available to assign the sub-section boundaries, instead of relying predominantly on the midpoint technique.

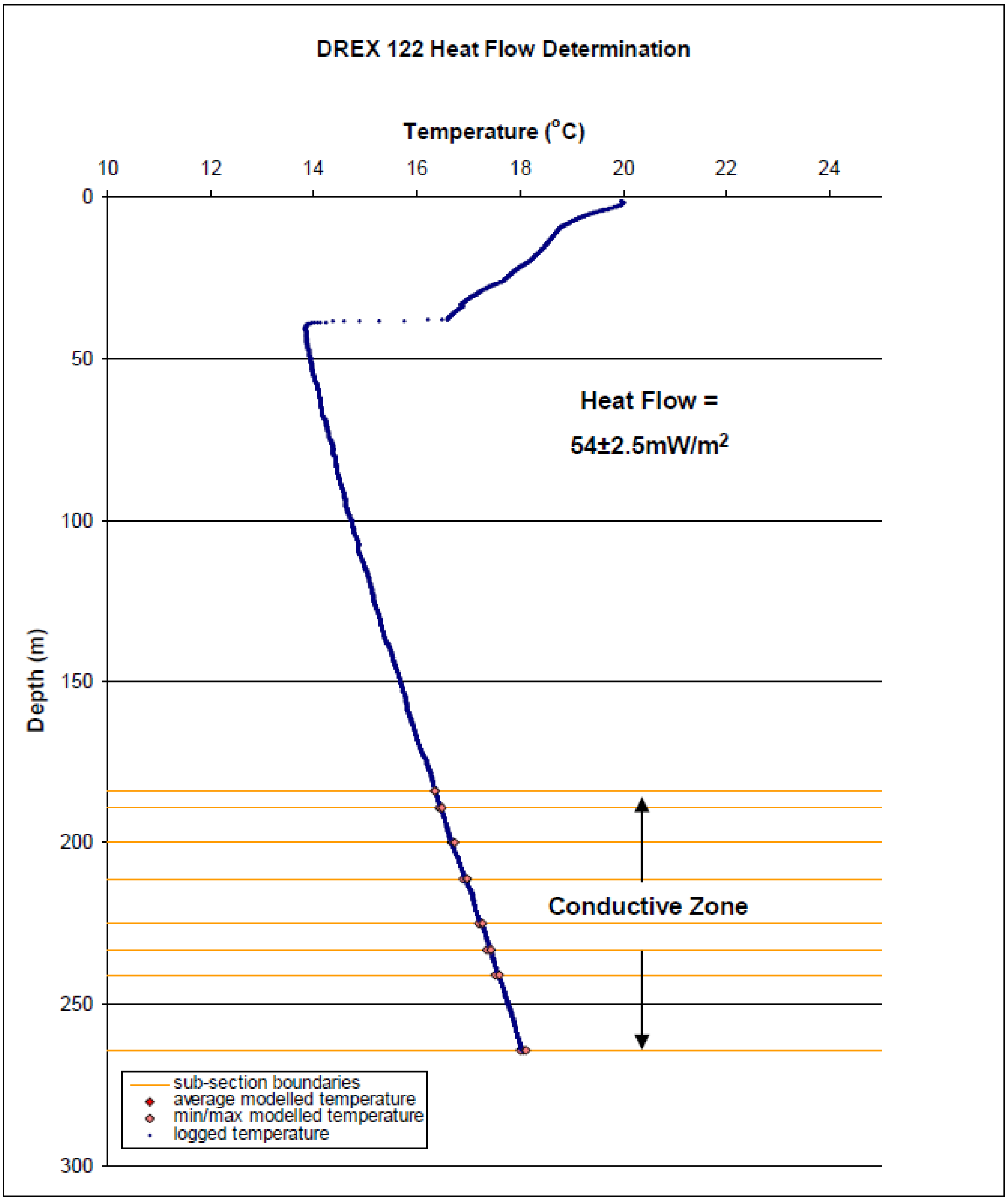

Figure 9: Modelled and measured temperatures versus true vertical depth for DREX 122. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

GW096000

GW096000 is located in central New South Wales, approximately 40 km south-west of Trangie. This well was drilled by the Department of Water and Energy NSW and logged by GA using the combined temperature/gamma probe to a vertical depth of 136 m. Thermal conductivity measurements on samples from this well were undertaken by GA.

This well was blocked at 136 m and all the samples collected were below this point in the well, thus no heat flow could be determined. The thermal conductivity results and the temperature log are shown below in Table 9 and Figure 10 respectively.

Table 9: Samples and thermal conductivity values for well GW096000. N/A means that the sample was not used for heat flow modelling.

Sample Number	True vertical depth of sample (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)
2109620	145.2	Massive red mudstone	1.73	0.14
2109621	170.9	Massive purple mudstone	1.67	N/A
2109622	178.5	Red mudstone with quartz veining along and cross cutting bedding planes	2.36	0.27
2109623	186.5	Fine grain, light grey sandstone	2.84	N/A

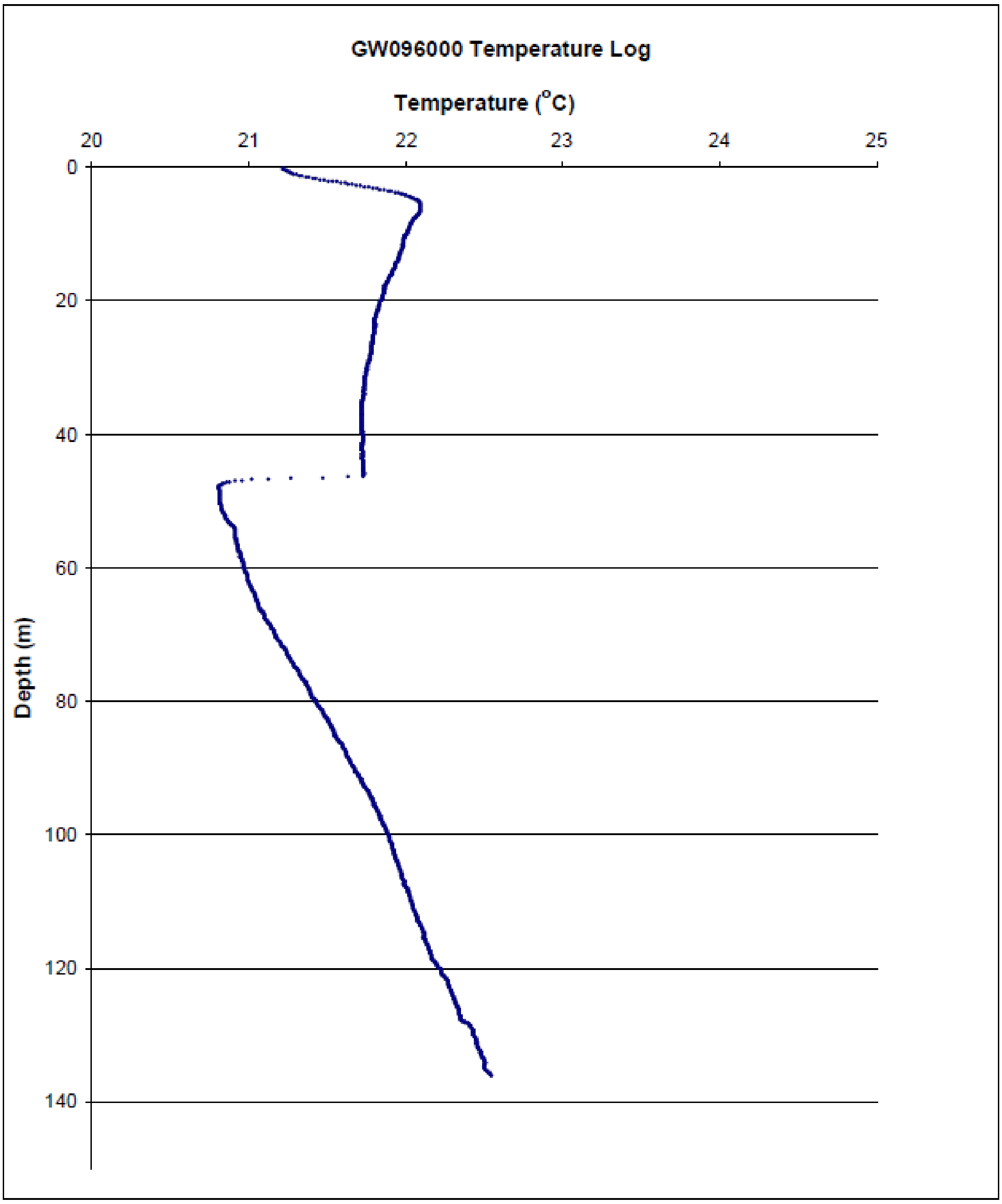

Figure 10: Temperature log for well GW096000. No heat flow was determined as there were no samples over the logged section of the well.

GW800554

GW800554 is located in central New South Wales, approximately 33 km south-west of Trangie. This well was drilled by Department of Water and Energy NSW and logged by GA using the combined temperature/gamma probe to a vertical depth of 175.5 m. Thermal conductivity measurements on samples from this well were undertaken by GA. A lithology log was provided to GA however there were insufficient samples measured from this well to make use of it.

No boundaries could be identified in the gamma log for this well. Thus the sub-section boundaries were assigned to the midpoint between the two thermal conductivity samples used for modelling (see Table 10). There are quite a few issues with this well that make a heat flow determination difficult:

- The well is quite shallow and it is likely that most of the logged depth is being affected by transient temperature variations;
- With the exception of the bottom ~20 m of the log, the temperature profile is quite unstable and appears to be affected by non-conductive processes; and
- There are five samples from this well, two of which disintegrated during sample preparation and no thermal conductivity measurements could be obtained. Sample 2109619 is below the logged depth and, therefore, also could not be used for the heat flow determination. For samples 2109617 and 2109618 only dry thermal conductivity values were obtained. For these samples a saturated thermal conductivity was estimated using a geometric mean mixing law (Beardsmore and Cull, 2001) assuming a porosity of 10 ± 5 %. The porosity value of 10 % was selected based on an actual porosity measurement carried out on sample 2109619. The high error of 5% was applied to account for the fact that no porosity measurements were carried out on the actual samples. The reported standard deviation for the saturated thermal conductivity estimates incorporates the error on the porosity estimate and the standard deviation of the dry thermal conductivity measurements.

A heat flow of *29 ± 8 mW/m*^{2} has been determined for this well (see Figure 11). For the above reasons great care should be taken when using this value for any further work. It is expected that the heat flow determination could be improved if there were more samples, and wet thermal conductivity values were available.

Table 10: Samples, thermal conductivity values and sub-sections boundaries for well GW800554. N/A means that the sample was not used for heat flow modelling.

Sample Number	True vertical depth of sample (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2109617	130.0	Light brown-grey silty mudstone	1.53 (1.11)*	0.30 (0.07)*	152.0-167.4	Midpoint
2109618	172.5	Light grey, fine to medium grained sandstone	2.54 (1.84)*	0.63 (0.30)*	167.4-174.0	Bottom of conductive zone
2109619	177.8	Very fine grained sandstone, light grey with purple lenses.	3.03	0.23	N/A	Below logged section

*Saturated thermal conductivity and standard deviation estimated using method outlined in text. Dry thermal conductivity (and standard deviation) inserted in brackets.

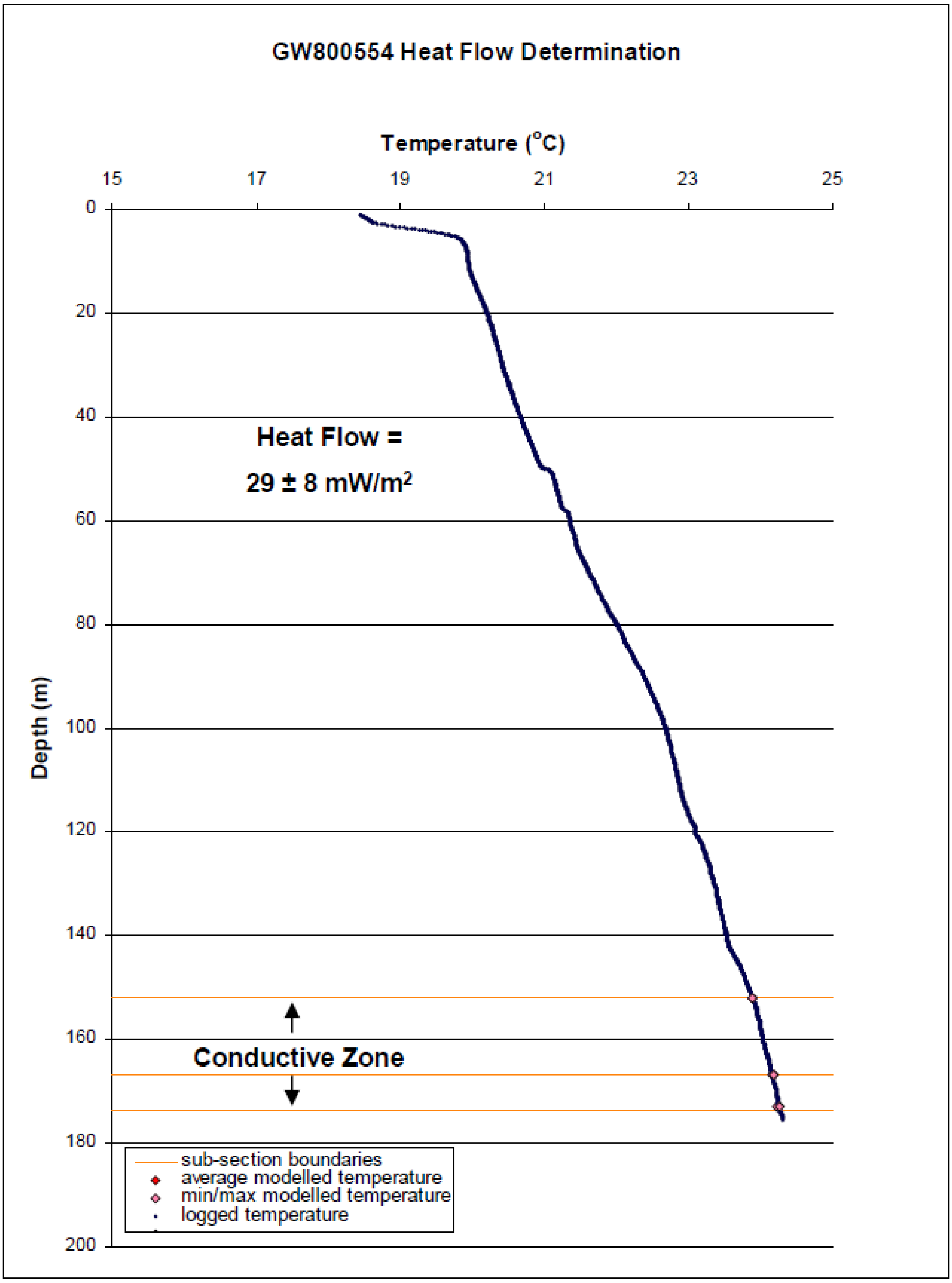

Figure 11: Modelled and measured temperatures versus true vertical depth for GW800554. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

TTDD002

TTDD002 is located in central New South Wales, approximately 47 km north-west of Nyngan. This well was drilled by Tritton Resources Ltd (now Straits) and logged by GA using the temperature only tool to a vertical depth of 1236 m. A detailed lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature profile is shown in Figure 12 and from this the conductive zone has been defined as from 285.0 m to 933.6 m depth. Above this zone the gradient is disturbed, and below this zone mineralisation occurs which is likely to cause strong, small scale fluctuations in thermal conductivity, making it difficult to determine heat flow. Therefore no thermal conductivity samples were collected from below 933.6 m depth.

A heat flow of *80 ± 9 mW/m*^{2} has been determined for this well. Fifty-five sub-section boundaries have been constrained using the lithology log provided by Tritton Resources Ltd. Twelve thermal conductivity samples were collected from this well and used to constrain the heat flow determination (see Table 11). For the sub-sections that were sampled, the measured thermal conductivity value for that subsection was assigned. For the 43 sub-sections that were not sampled an average thermal conductivity for that lithology in the well has been assigned (see Table 12).

Table 11: Samples, thermal conductivity values and sub-sections boundaries for well TTDD002. N/A means that the sample was not used for heat flow modelling.

Sample Number	True vertical depth of sample (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2109626	334.6	Greywacke	5.13	0.07	326.2-366.2	Lithology log
2109627	370.0	Pelite	3.45	0.36	366.2-376.0	Lithology log
2109628	396.5	Greywacke	4.95	0.93	376.0-402.6	Lithology log
2109629	427.8	Greywacke	3.63	0.01	425.2-445.7	Lithology log
2109630	461.1	Greywacke	4.34	0.57	561.1-501.3	Lithology log
2109631	501.3	Greywacke, quartz veins parallel to core axis	7.41	0.12	501.3-518.1	Lithology log
2109632	692.7	Pelite	4.18	0.73	689.4-693.7	Lithology log
2109633	724.2	Psammopelite	4.02	0.05	723.3-735.1	Lithology log
2109634	758.1	Greywacke	3.7	0.11	739.6-762.3	Lithology log
2109635	787.3	Psammopelite	3.72	0.21	780.9-798.6	Lithology log
2109636	818.4	Psammopelite	4.47	0.34	818.2-824.2	Lithology log
2109637	861.9	Greywacke	4.61	0.22	860.3-873.7	Lithology log

Table 12: Average thermal conductivity values for lithologies present in TTDD002 (excluding sample 2109631 which has quartz veins parallel to core axis)

Lithology	Thermal Conductivity (w/Mk)	Error (W/mK)
Greywacke	4.47	0.72
Pelite	3.78	0.67
Psammopelite	4.05	0.39

The modelled and measured temperature data is plotted together in Figure 12. The modelled average temperature fits the measured data quite well. However, the minimum and maximum modelled temperature (based on error in the thermal conductivity values) is in poor agreement with the measured data and the agreement gets worse with depth. This reflects the large errors on the average thermal conductivity values assigned to the sub-sections that were not sampled. For example, greywackes in the well were quite variable, with thermal conductivity values ranging from 3.63 to 5.84 W/mK. Thus the average thermal conductivity value for greywackes has quite a high error, which introduces error to the heat flow determination with each sub-section it is assigned to. This also occurs with the pelites in the well. It is expected that the heat flow value would be better constrained and the error reduced if the sampling density in the well was increased.

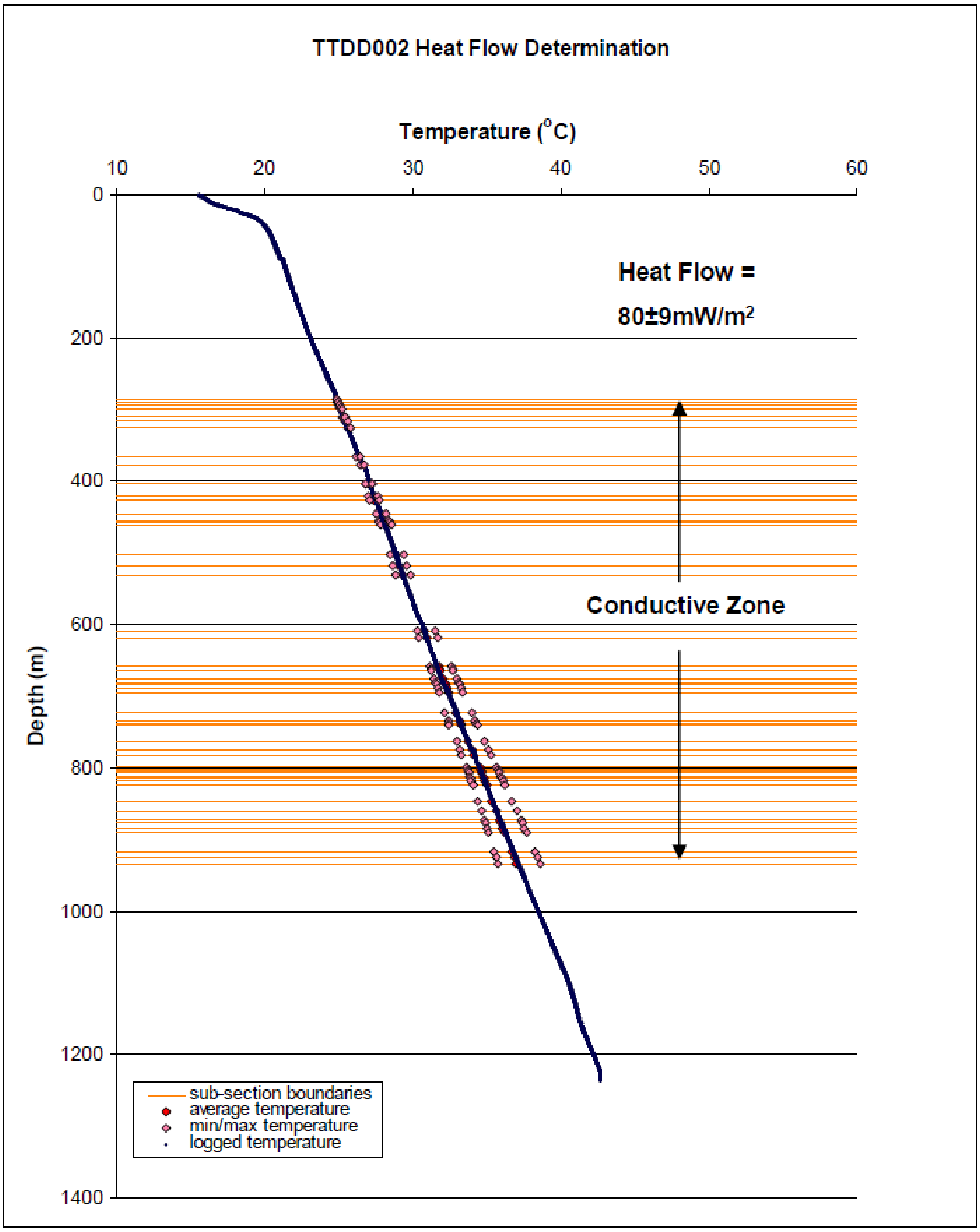

Figure 12: Modelled and measured temperatures versus true vertical depth for TTDD002. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

TTDD003

TTDD003 is located in central New South Wales, approximately 47 km north-west of Nyngan (104 m south of TTDD002). This well was drilled by Tritton Resources Ltd (now Straits) and logged by GA using the temperature only tool to a vertical depth of 1250 m. A detailed lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

It is known that this well was not equilibrated when it was logged. This is also evident from the temperature gradient, where there is a distinct step at 800 m. It was decided to calculate an estimate heat flow from below 800 m as this is the most stable section of the gradient. For the purposes of the estimate the conductive zone has been defined as from 882.9 to 1251 m (Figure 12).

A heat flow range of *55 - 79 mW/m*^{2} has been determined for this well. This is a broad estimate and no error has been given as the well is unequilibrated. Thirty eight sub-section boundaries have been constrained by the lithology log provided by Tritton Resources. Fourteen thermal conductivity samples were collected from this well and used to constrain the heat flow determination. For the sub-sections that were sampled, the measured thermal conductivity value has been assigned (see Table 13). For the sub-sections that were not sampled an average thermal conductivity for that lithology in the well has been assigned (see

Table 14).

Table 13: Samples, thermal conductivity values and sub-sections boundaries for well TTDD003. N/A means that the sample was not used for heat flow modelling.

Sample Number	True vertical depth of sample (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2109638	401.7	psammopelite	2.89	0.21	N/A	N/A
2109639	424.4	greywacke	4.95	0.16	N/A	N/A
2109640	461.8	greywacke	5.75	0.10	N/A	N/A
2109641	492.8	greywacke	4.98	0.08	N/A	N/A
2109642	543.8	greywacke	4.94	0.13	N/A	N/A
2109643	592.2	greywacke	6.44	0.10	N/A	N/A
2109644	637.7	quartz vein	5.92	0.86	N/A	N/A
2109645	687.3	psammopelite	2.12	0.97	N/A	N/A
2109646	883.7	greywacke	4.22	0.57	882.9-888.6	Lithology log
2109647	921.8	greywacke	4.34	0.22	912.2-927.1	Lithology log
2109648	960.5	greywacke	4.39	0.05	946.1-965.4	Lithology log
2109649	1004.4	greywacke	3.97	0.29	997.2-1004.8	Lithology log
2109650	1032.7	pelite	2.78	0.16	1004.8-1059.3	Lithology log
2109651	1075.8	pelite	3.80	0.50	1075.8-1112.8	Lithology log

Table 14: Average thermal conductivity values for lithologies present in TTDD003.

Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)
Greywacke	4.78	0.78
Pelite	2.45	0.69

Psammopelite	3.21	0.67

The modelled and measured temperature data are plotted in Figure 13. The average modelled temperatures agree quite well with the measured values. However, as with TTDD002, the minimum and maximum modelled heat flow values are quite different. Like with TTDD002, this is mainly due to the large standard deviation in the thermal conductivity of pelite, greywacke and psammopelite.

TTDD003 is located only 104 m away from TTDD002 and as such would be expected to have a similar heat flow to TTDD002. The heat flow estimated for TTDD003 is lower, but within error of, that calculated for TTDD003. The small difference could be due to the fact that TTDD003 is unequilibrated. For this reason, the heat flow value presented for TTDD002 is likely to be more representative of the regional heat flow.

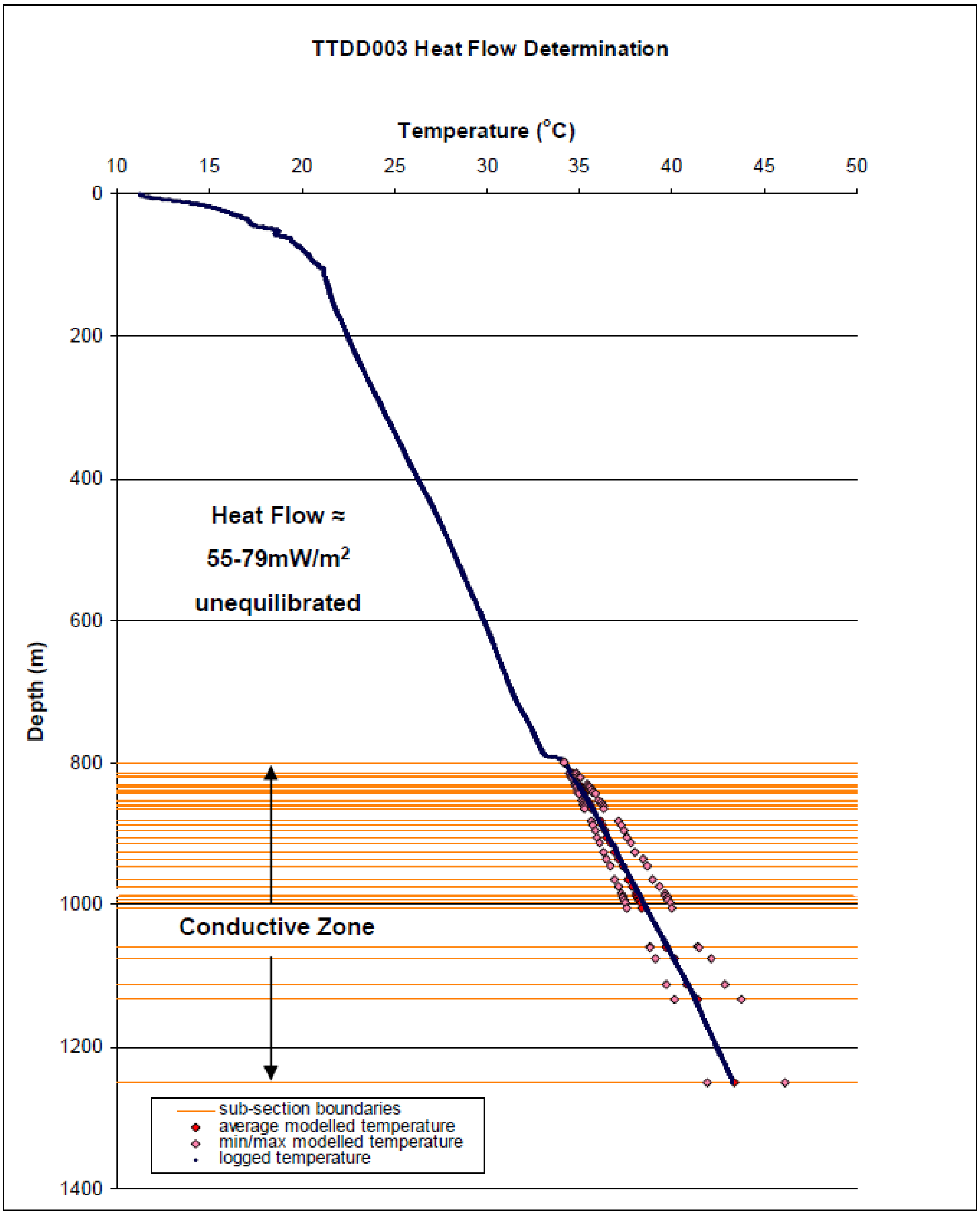

Figure 13: Modelled and measured temperatures versus true vertical depth for TTDD003. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

TNY046

TNY046 is located in central New South Wales, approximately 80 km south-east of Cobar. This well was drilled by YTC Resources Ltd and logged by GA using the temperature only probe to a vertical depth of 691 m. No lithology logs were provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature profile is shown in Figure 14 and from this the conductive zone has been defined as extending from 320 m to 627 m depth. Above this zone the gradient is disturbed and below this zone the regime appears to be no longer purely conductive.

There were no gamma or lithology logs for this well, thus the sub-section boundaries were assigned as the midpoint between two thermal conductivity samples. Four of the thermal conductivity samples collected lie in the conductive zone and were used to constrain the heat flow determination (see Table 15). A heat flow of $66.5 \pm 3 mW/m^2$ has been determined for this well.

Table 15: Samples, thermal conductivity values and sub-sections boundaries for well TNY046. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2115253	140.1	Fine grained, quartz veined, metasediment	5.99	0.22	N/A	N/A
2115254	214.3	Fine grained, quartz veined, metasediment	4.49	0.40	N/A	N/A
2115255	290.7	Slate	4.45	0.31	N/A	N/A
2115256	365.9	Slate	4.61	0.09	320.0-417.2	Midpoint
2115257	468.5	Dark grey, fine grained metasediment	4.74	0.16	417.2-491.8	Midpoint
2115258	515.0	Dark grey, fine grained metasediment	4.12	0.02	491.8-552.1	Midpoint
2115259	589.2	Slate	3.66	0.06	552.1-627.0	Bottom of conductive zone
2115260	664.7	Slate	3.61	0.18	N/A	N/A

The modelled and measured temperature data are plotted together in Figure 14. There is a reasonable match between measured and modelled data and a fairly low error on the heat flow value. However, it is expected that the heat flow determination could be improved with the presence of a gamma or lithology log to help constrain the sub-section boundaries and this would reduce the error. Additionally, if the temperature log is examined closely it can be observed that the gradient is not quite straight and suggesting that the well may not have been completely equilibrated at the time of logging.

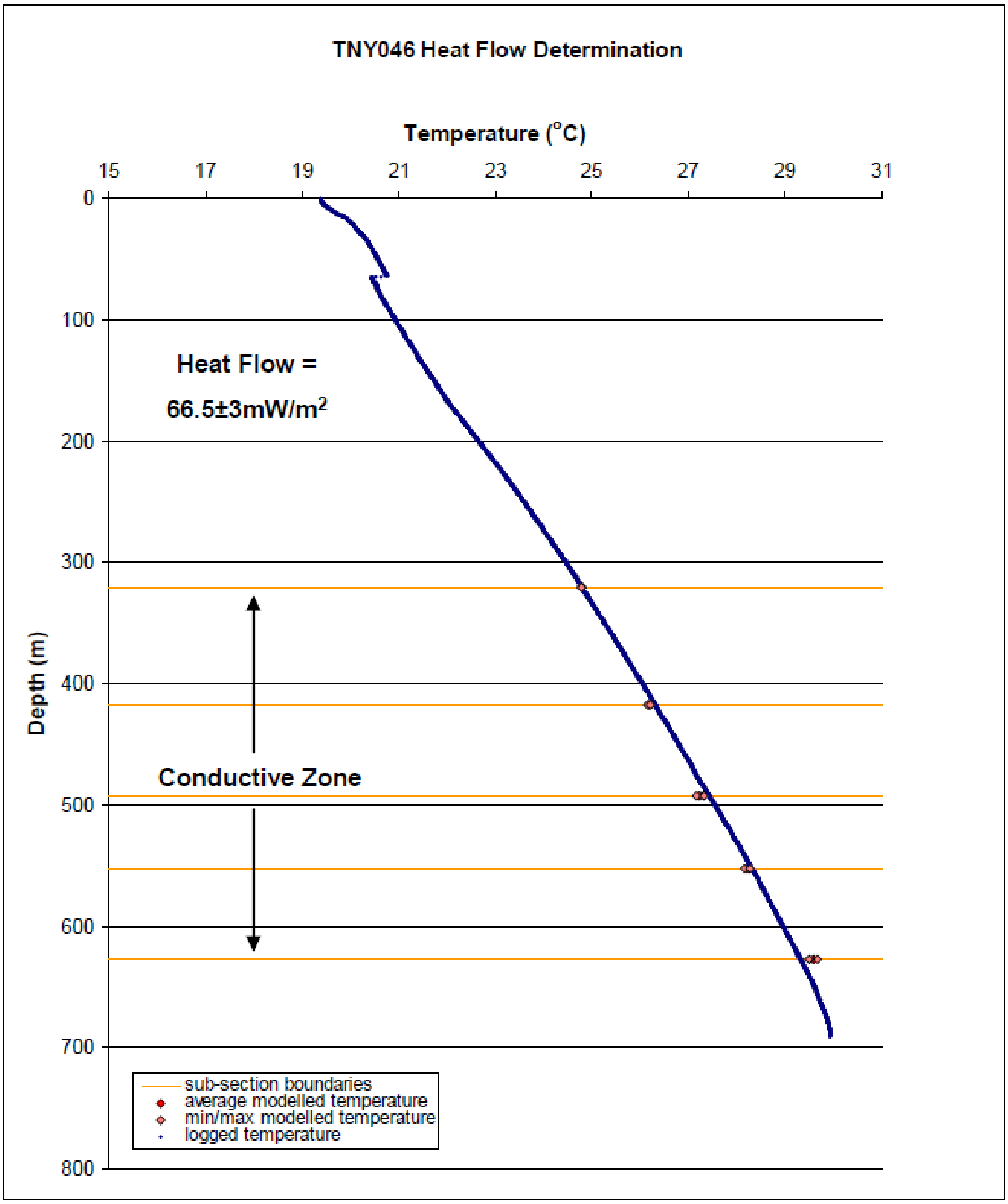

Figure 14: Modelled and measured temperatures versus true vertical depth for TNY046. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

TD11961T

TD11961T is located in central southern Western Australia, approximately 25 km south-east of Kambalda. It was drilled by Gold Fields Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 455 m. Logging was performed within 24 hours of the completion of drilling and therefore it is very unlikely the well was equilibrated when logged. No lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature log is shown in Figure 15. It shows that the log is unsteady with several dips and spikes in the gradient, consistent with the fact that the well is unequilibrated. However, to obtain an estimate of heat flow, the conductive zone has been defined as from 150 m to 416 m depth, as this is the most stable interval in the well (Figure 15).

A heat flow range of *41 - 45* mW/m^2 has been determined for this well. Sub-section boundaries could not be assigned from the gamma log; therefore these were assigned as the midpoint between two thermal conductivity values. Five of the thermal conductivity samples collected from this well lie within the conductive zone and were used to constrain the heat flow (see Table 16).

Table 16: Samples, thermal conductivity values and sub-sections boundaries for well TD11961T. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2115298	137.6	Medium grained schist	5.47	0.24	N/A	N/A
2115299	200.0	Chlorite schist	5.27	0.05	150.0-232.7	Midpoint
2115300	256.3	Schist, chlorite , calcite veining	5.38	0.10	232.7-292.2	Midpoint
2115301	328.1	Light grey/green medium grained metasediment with schistose fabric, mica and chlorite	4.66	0.15	292.2-343.7	Midpoint
2115302	359.3	Meta-igneoous rock with disemminated pyrite	4.72	0.05	343.7-381.4	Midpoint
2115303	403.5	Dark, fine grained metasediment, minor pyrite, some quartz	4.13	0.16	381.4-416.0	Bottom of conductive zone

The modelled and measured temperature data are plotted together in Figure 15. There is good agreement between the measured and modelled data, despite the unstable temperature gradient. This could suggest that the temperature gradient will not change much as it equilibrates and will just become smoother. However, to have certainty in the heat flow determination the well would have to be logged again when equilibrated.

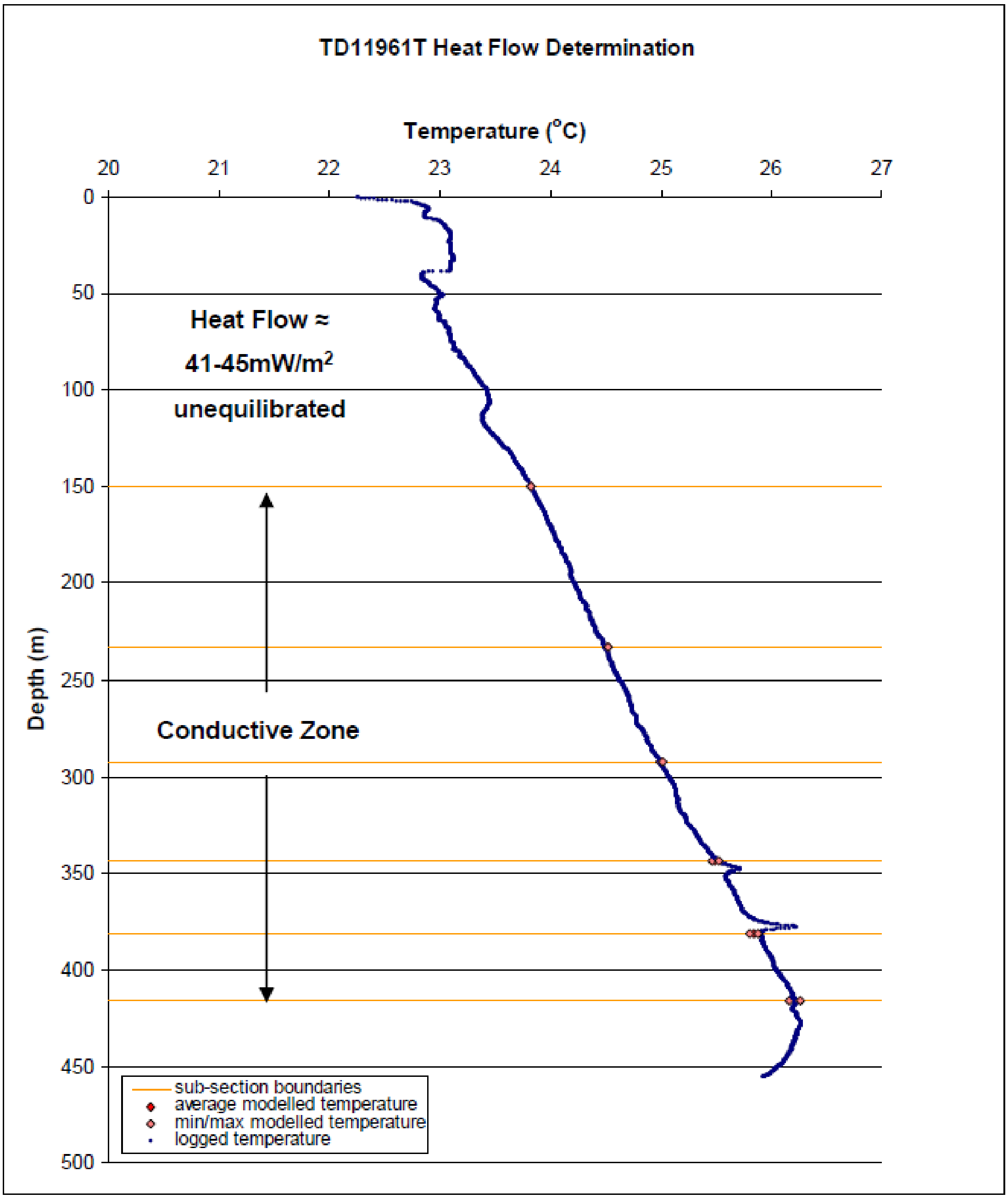

Figure 15: Modelled and measured temperatures versus true vertical depth for TD11961T. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

TD11964

TD11964 is located in the south of Western Australia, approximately 25 km south-east of Kambalda. The well was drilled by Gold Fields Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 568 m. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

Logging was performed five days after drilling ceased and therefore it is unlikely the well was fully equilibrated when logged. This is apparent from the unstable gradient (Figure 16). For the purposes of an estimate of heat flow the conductive zone has been defined as 250 m to 468 m depth as this is the most stable interval of the gradient.

An estimate heat flow of *29-35 mW/m²* has been determined for this well. Four of the thermal conductivity samples collected from this well were used to constrain the heat flow determination. The sub-sections for these thermal conductivity values were defined from the gamma log (see Table 17).

Table 17: Samples, thermal conductivity values and sub-sections boundaries for well TD11964. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2115304	176.4	Medium to fine grained metasedimentary rock, schistose talc, calcite veining, minor pyrite	6.54	0.10	N/A	N/A
2115305	247.8	Medium to fine grained metasedimentary rock, schistose talc, calcite veining, minor pyrite	6.92	0.06	N/A	N/A
2115306	312.7	Dark, fine grained metasedimentary rock, disseminated pyrite, calcite veining	3.31	0.10	250.0-332.0	Gamma log
2115307	355.0	Chlorite schist	5.94	0.08	332.0-357.0	Gamma log
2115308	399.3	Dark, medium grained volcanic rock, calcite veining,	3.73	0.13	347.0-414.0	Gamma log
2115309	441.8	Medium to coarse grained volcanic rock.	3.86	0.24	414.0-468.0	Bottom of well

The modelled and measured temperature data is plotted together in Figure 16. There is reasonable agreement between measured and modelled data. However, as mentioned the well is unequilibrated and thus the heat flow is only an estimate and there is no error value reported. It is expected that the quality of the heat flow determination could be improved by logging the well again when completely equilibrated.

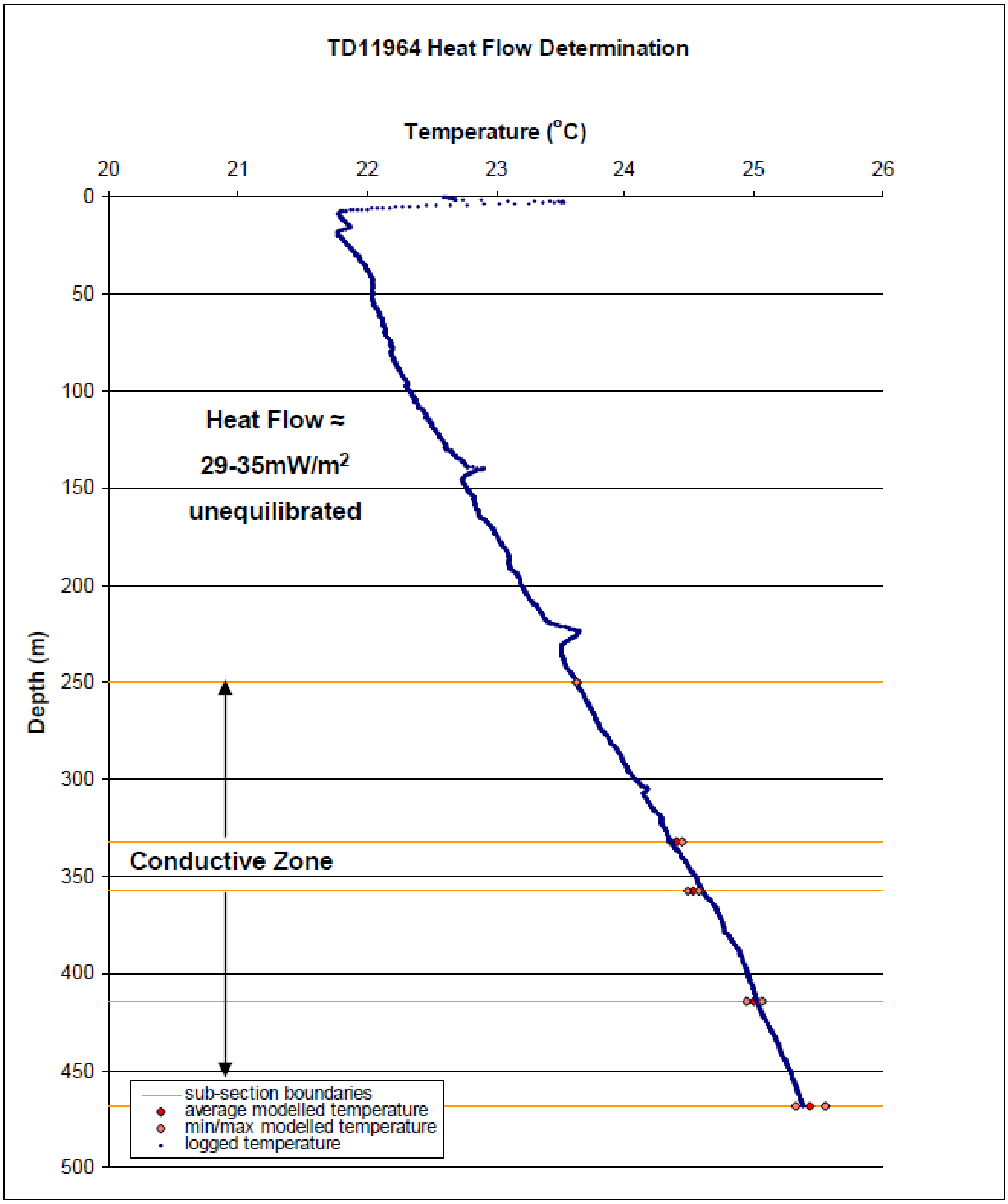

Figure 16: Modelled and measured temperatures versus true vertical depth for TD11964. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

TD11968TW1

TD11968TW1 is located in the south of Western Australia, approximately 25 km south-east of Kambalda. It was drilled by Gold Fields Ltd and logged by GA using the combined gamma/temperature probe to a vertical depth of 659 m. Logging was performed within 24 hours of the completion of drilling and therefore it is unlikely the well was fully equilibrated when logged. Thermal conductivity measurements on samples from this well were undertaken by HDRPL. No lithology log was provided to GA.

This well is not yet equilibrated which is apparent from the unstable gradient (Figure 17). For the purposes of an estimate heat flow the conductive zone has been defined as from 150 m to 590 m. A heat flow range of *36-38* mW/m^2 has been determined for this well. All seven thermal conductivity samples collected lie in the conductive zone and were used to constrain the heat flow determination. Where possible the sub-sections boundaries were assigned using the gamma log; otherwise these were assigned as the midpoint between two thermal conductivity samples (see Table 18).

Table 18: Samples, thermal conductivity values and sub-sections boundaries for well TD11968TW1.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2115310	150.4	Volcanic rock	3.74	0.05	150.0-175.7	Gamma log
2115311	202.2	Fine to coarse grained metasedimentary rock, chlorite alteration.	3.78	0.07	175.7-255.2	Gamma log
2115312	297.1	Medium to coarse grained metasedimentary rock, chlorite alteration, some veining	3.83	0.03	255.2-326.2	Midpoint
2115313	355.2	Fine to medium grained grey/green felsic volcanic rock, minor veining, abundant mica	3.46	0.06	326.2-401.3	Midpoint
2115314	447.3	Fine grained, dark, metasedimentary rock, calcite veining	3.97	0.15	401.3-486.4	Midpoint
2115315	525.5	Fine to medium grained metasedimentary rock, chlorite alteration, minor pyrite	3.58	0.05	486.4-549.1	Midpoint
2115316	572.6	Fine grained metasedimentary rock,, quartz and calcite veins, minor mica	3.74	0.17	549.1-590.0	Bottom conductive zone

The modelled and measured temperature data are plotted together in Figure 17. There is reasonable agreement between the measured and modelled data. However as the well is unequilibrated and the reported heat flow is an estimate only no error has been reported. It is expected that the confidence in the heat flow value could be greatly improved if the well was logged when equilibrated.

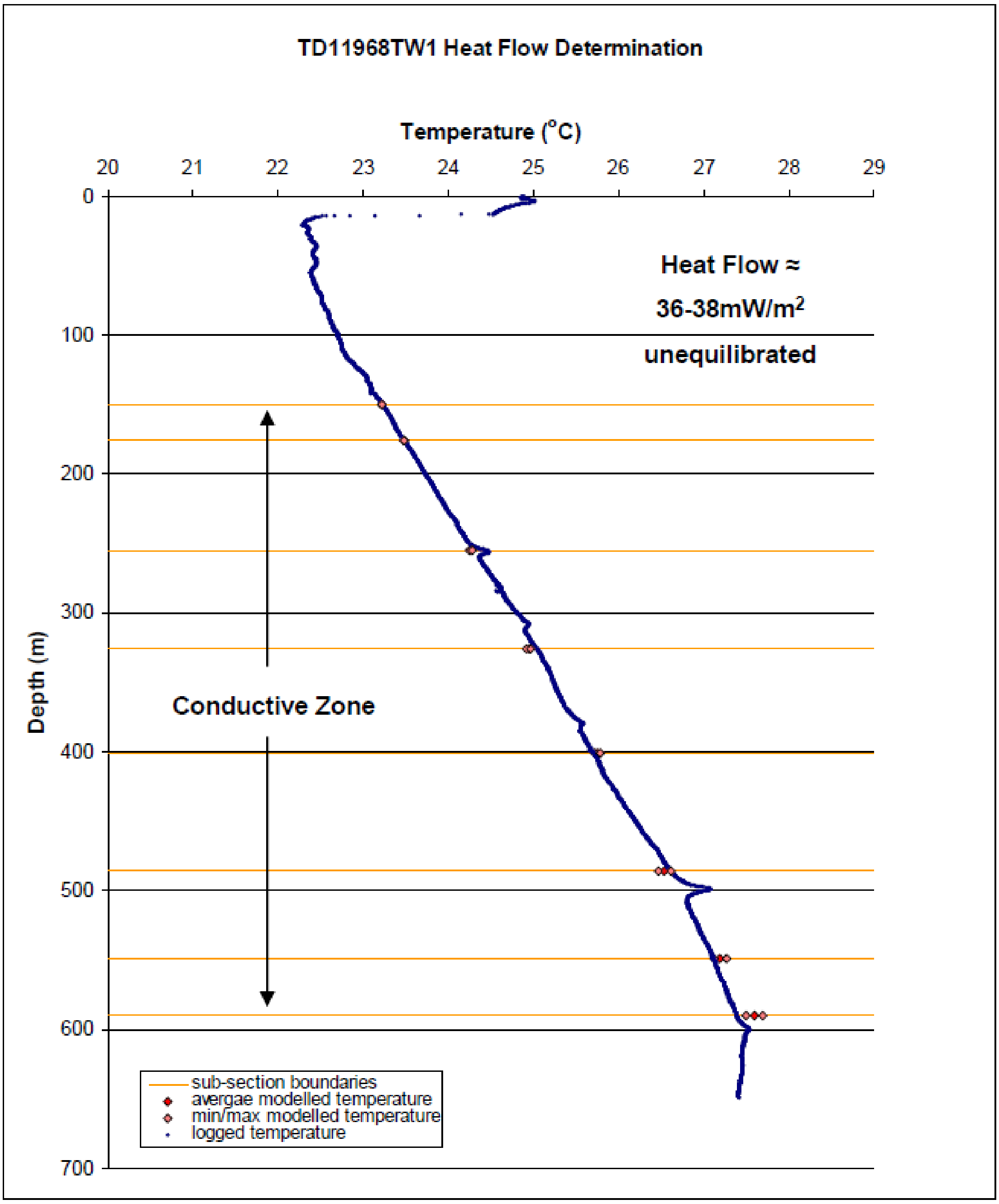

Figure 17: Modelled and measured temperatures versus true vertical depth for TD11968TW1. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

TD11969TW1

TD11969TW1 is located in the south of Western Australia, approximately 26 km south-east of Kambalda. It was drilled by Gold Fields Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 578 m. Logging was performed within 24 hours of the completion of drilling and therefore it is unlikely the well was fully equilibrated when logged. No lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature log is shown in **Error! Reference source not found.**. It shows that the profile is disturbed at several points down the well, consistent with the fact that it was not equilibrated when logged. For the purposes of obtaining an estimate heat flow the conductive zone has been defined as from 315 m to 511 m depth as this is the most stable part of the gradient.

A heat flow of *28 mW/m*^{2} has been estimated for this well. Where possible sub-section boundaries were assigned using the gamma log; otherwise these were assigned as the midpoint between two thermal conductivity samples. Four of the thermal conductivity samples collected lie in the conductive zone and were used to constrain the heat flow determination (see Table 19).

Table 19: Samples, thermal conductivity values and sub-sections boundaries for well TD11969TW1. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2115317	185.9	Very fine grained, dar, metasedimentary rock	3.50	0.10	N/A	N/A
2115318	277.2	Fine grained metasedimentary rock	3.82	0.36	N/A	N/A
2115319	317.3	Fine to medium grained metasedimentary rock, chlorite alteration, minor veining	3.82	0.02	313.0-333.0	Gamma log
2115320	369.7	Fine to medium grained metasedimentary rock, slightly schistose, minor chlorite alteration	3.34	0.08	333.0-387.6	Midpoint
2115321	405.6	Medium grained metasedimentary rock, slightly schistose, altered, calcite veining	3.84	0.03	387.6-493.0	Gamma log
2115322	496.2	Fine grained metasedimentary rock, calcite veining	4.08	0.12	493.0-511.0	Bottom conductive zone
2115323	521.0	Fine to medium grained metasedimentary rock, minor pyrite, minor calcite veining.	4.50	0.06	N/A	N/A

The modelled and measured temperature data is plotted together in **Error! Reference source not found.**. There is good agreement between the measured and modelled data despite the instability in the temperature gradient. This may mean that when equilibrated the heat flow may not change greatly and the gradient may just become smoother. However, since it is not equilibrated the heat flow value is an estimate and no error has been reported. To have confidence in the heat flow value the well would have to be logged again when equilibrated.

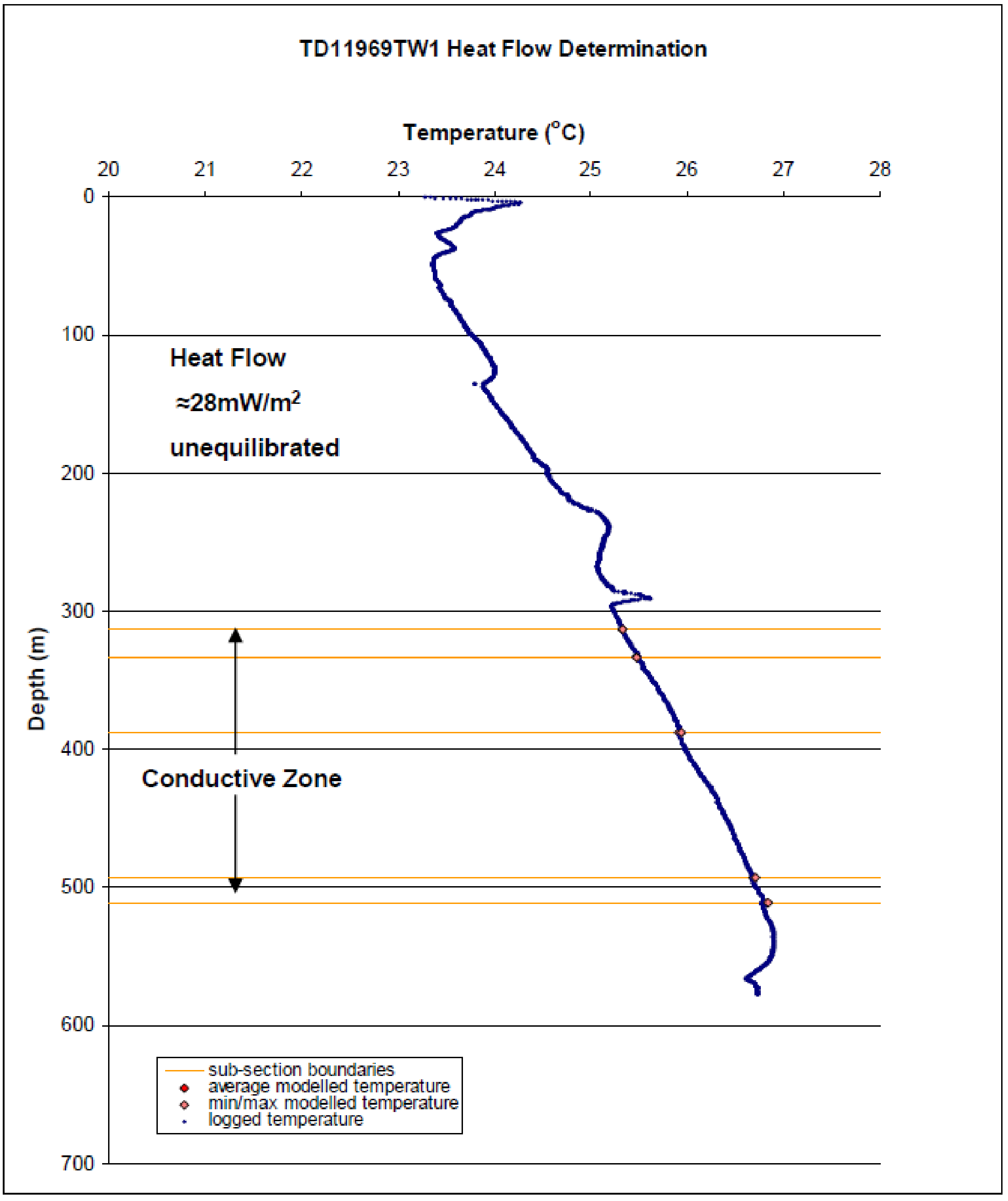

Figure 18: Modelled and measured temperatures versus true vertical depth for TD11969TW1. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

WRD10990-002

WRD109900-002 is located in the south west of Western Australia, approximately 12 km north-west of Boddington. This well was drilled by Newmont Australia Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 806 m. No lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by GA.

The temperature log is shown in Figure 19 and from this the conductive zone has been defined as extending from 423.22 m to 800 m depth. Above and below this zone the gradient is disturbed. Three of the thermal conductivity samples collected lie in the conductive zone and were used to constrain the heat flow. The sub-section boundaries were determined using the gamma log (see Table 20). A heat flow value of *45 ± 3 mW/m*^{2} has been determined for this well.

Table 20: Samples, thermal conductivity values and sub-sections boundaries for well WRD10990-002. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2110660	135.2	Medium grained diorite, quartz veins, iron staining	2.44	0.01	N/A	N/A
2110661	218.6	Medium grained, diorite, quartz veins, iron staining	2.78	0.07	N/A	N/A
2110662	294.3	Medium grained diorite, sulfides present	2.15	0.49	N/A	N/A
2110663	442.2	Medium grained diorite, iron staining	2.38	0.15	423.2-487.8	Gamma log
2110665	626.4	Medium to coarse grained diorite, iron staining	2.36	0.06	487.8-645.9	Gamma log
2110667	790.5	Medium to coarse grained diorite, sulfides present	2.19	0.26	645.9-800.0	Bottom of conductive zone

The modelled and measured temperature data are plotted together in Figure 19. There is good agreement between the model and the measured data. There is little variability in the thermal conductivity values down the well, suggesting that the lithology is quite homogeneous. This contributes to the low error on the heat flow determination. However, this well is located within 100 m of the edge of the main pit at Boddington. This could account for the disturbed gradient above approximately 423 m depth. In addition great care should be taken when using this value, as due to its location it is unlikely to be representative of the heat flow in the region.

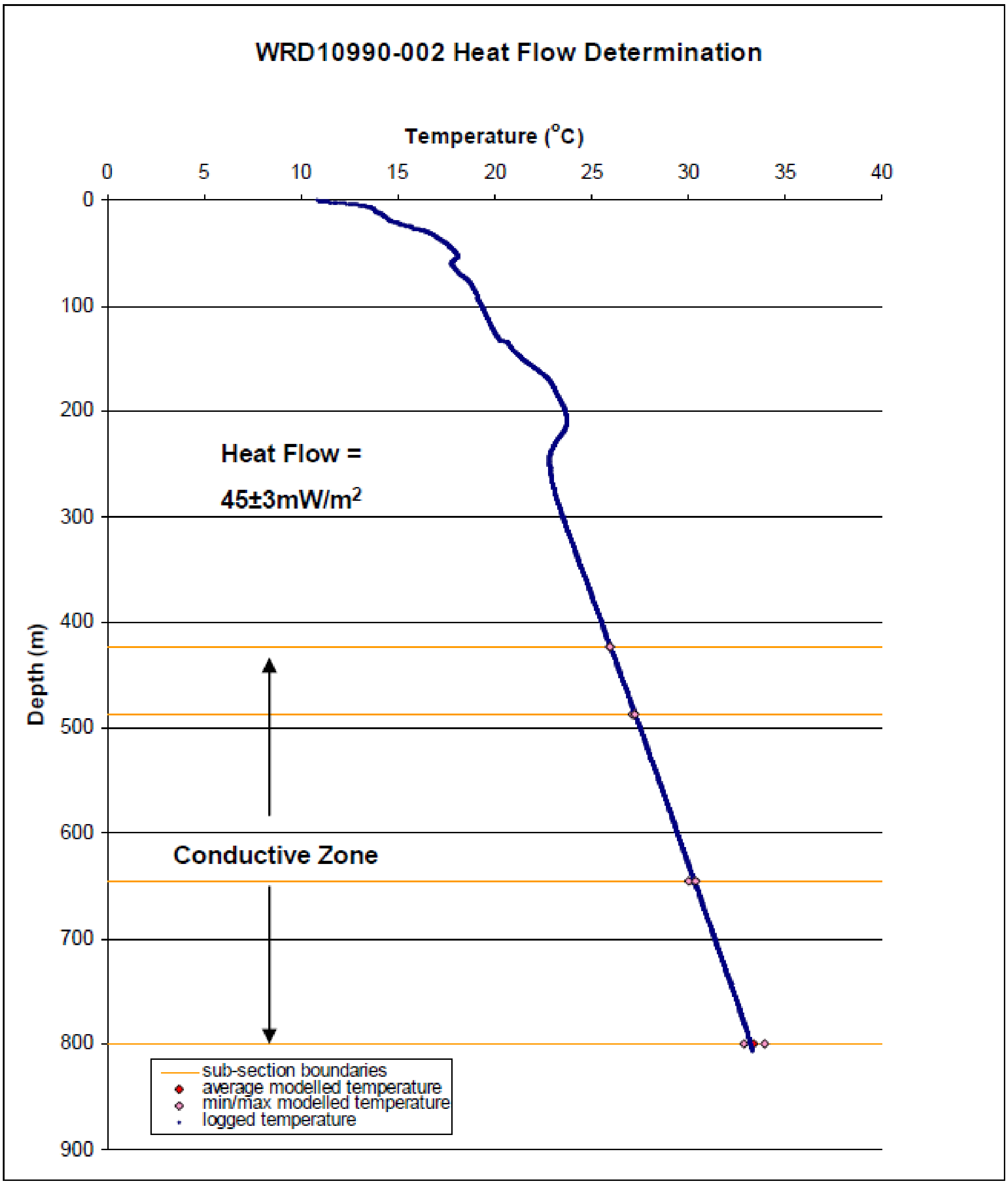

Figure 19: Modelled and measured temperatures versus true vertical depth for WRD10990-002. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

WRD13405-002

WRD13405-002 is located in south-west Western Australia, approximately 14 km north-west of Boddington. This well was drilled by Newmont Australia Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 738 m. No lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by GA.

It is known that this well was logged less than two weeks after drilling was completed and thus it is unlikely to be equilibrated. From the temperature gradient it can be seen the well is not equilibrated, the gradient is quite unsteady (Figure 20). For the purpose of obtaining an estimate of heat flow the conductive zone has been defined as from 200-600 m depth as this is the most stable section of the gradient.

A heat flow range of *46-52 mW/m²* has been determined for this well. Only one of the thermal conductivity samples collected for this well lies in the conductive zone and could be used to constrain the heat flow. Thus, the sub-section boundaries are the top and bottom of the defined conductive zone (see Table 21).

Table 21: Samples, thermal conductivity values and sub-sections boundaries for well WRD13405-002. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2110668	70.8	Medium to coarse grained diorite, pyrite present	3.03	0.31	N/A	N/A
2110669	165.5	Medium to coarse grained diorite, quartz veins present	2.39	0.05	N/A	N/A
2110670	247.8	Medium to coarse grained diorite, quartz veins present	3.12	0.18	200.0-600.0	Conductive zone

The modelled and measured temperature data is plotted together in Figure 20. There is good agreement between the measured and modelled data; however this is to be expected given that the model is only constrained by one thermal conductivity value. As the well is unequilibrated and the heat flow is an estimate no error has been reported. The estimate could be greatly improved if there were more samples collected in the conductive zone. In addition, the confidence in the heat flow would be improved if the well was logged when equilibrated.

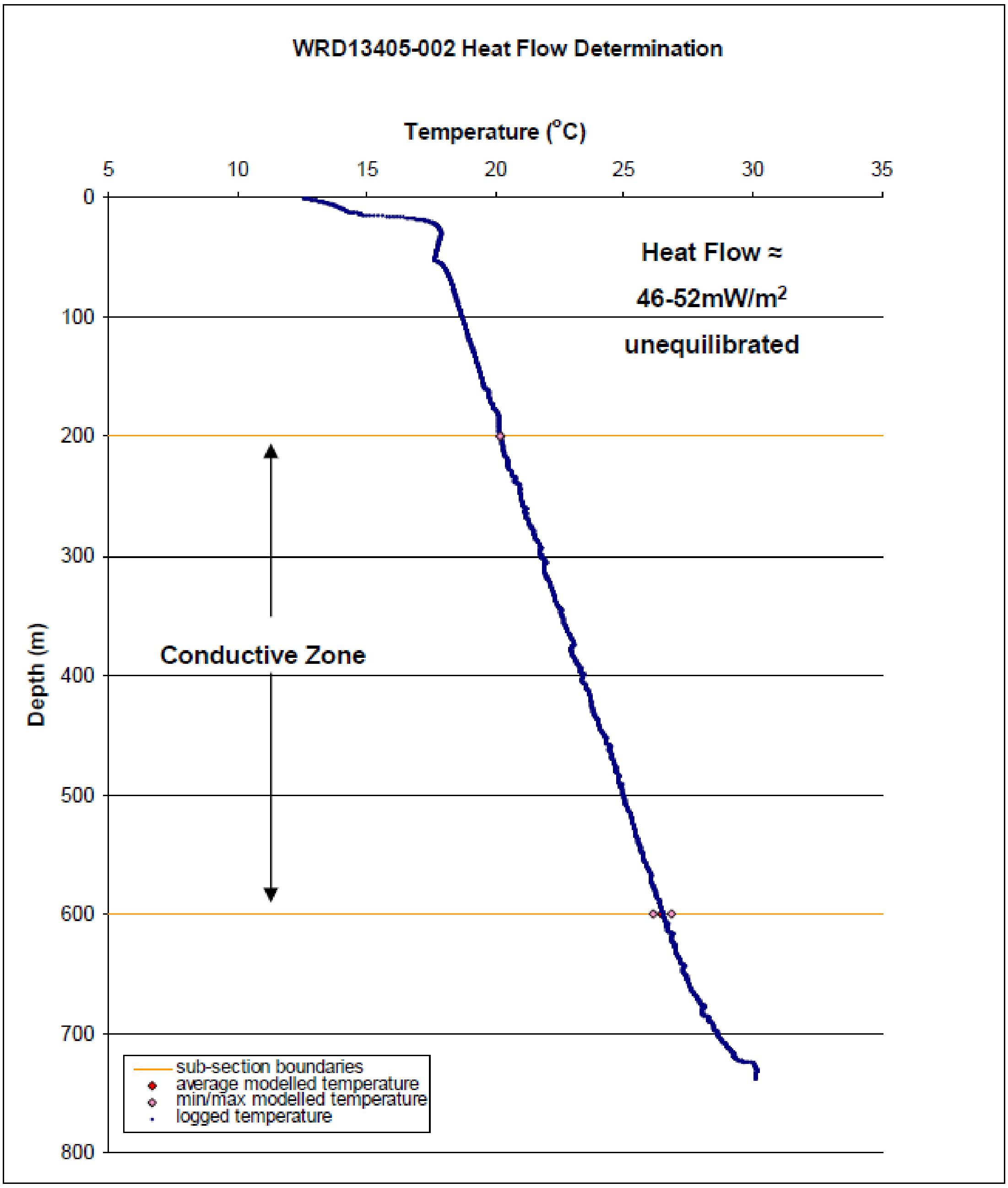

Figure 20: Modelled and measured temperatures versus true vertical depth for WRD13405-002. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

TVDD0013

TVDD0013 is located in the south of Western Australia, approximately 5 km south of Southern Cross. It was drilled by St Barbara Ltd and was logged by GA using the combined temperature/gamma probe to a vertical depth of 432 m. Thermal conductivity measurements on samples from this well were undertaken by HDRPL. No lithology logs were provided to GA.

The temperature log is shown in Figure 21 and from this the conductive zone has been defined as from 200 m to 350 m depth. Above this zone the gradient is disturbed and below this zone the regime is no longer purely conductive. This can be observed from the instability in the temperature gradient below 350 m depth.

A heat flow of *27 ± 3 mW/m*^{2} has been determined for this well. Two of the thermal conductivity samples collected lie in the conductive zone and were used to constrain the heat flow. The sub-section boundaries were determined using the gamma log (see Table 22).

Table 22: Samples, thermal conductivity values and sub-sections boundaries for well TVDD0013. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub Section (m)	Sub-Section Boundary Rationale
2110629	62.7	Altered basalt	2.19	0.07	N/A	N/A
2110630	153.5	Basalt	2.77	0.15	N/A	N/A
2110631	244.7	Medium grained mafic rock	2.70	0.28	200.0-290.0	Gamma log
2110632	425.7	Medium grained mafic rock	2.75	0.12	290.0-350.0	Bottom conductive zone

The modelled and measured temperature data is plotted together in Figure 21. There is good agreement between the modelled and measured data. There is little variability between the thermal conductivity values in the conductive section, consistent with the fact that the lithology is quite homogeneous between the two samples. This is contributing to the low error value. However, this well was located on top of an area of elevated topography, near a shear drop of approximately 200 m. For this reason it is unlikely to be representative of the heat flow in the region. The location of the well may also explain the variations in gradient that are observed above 200 m depth in Figure 21.

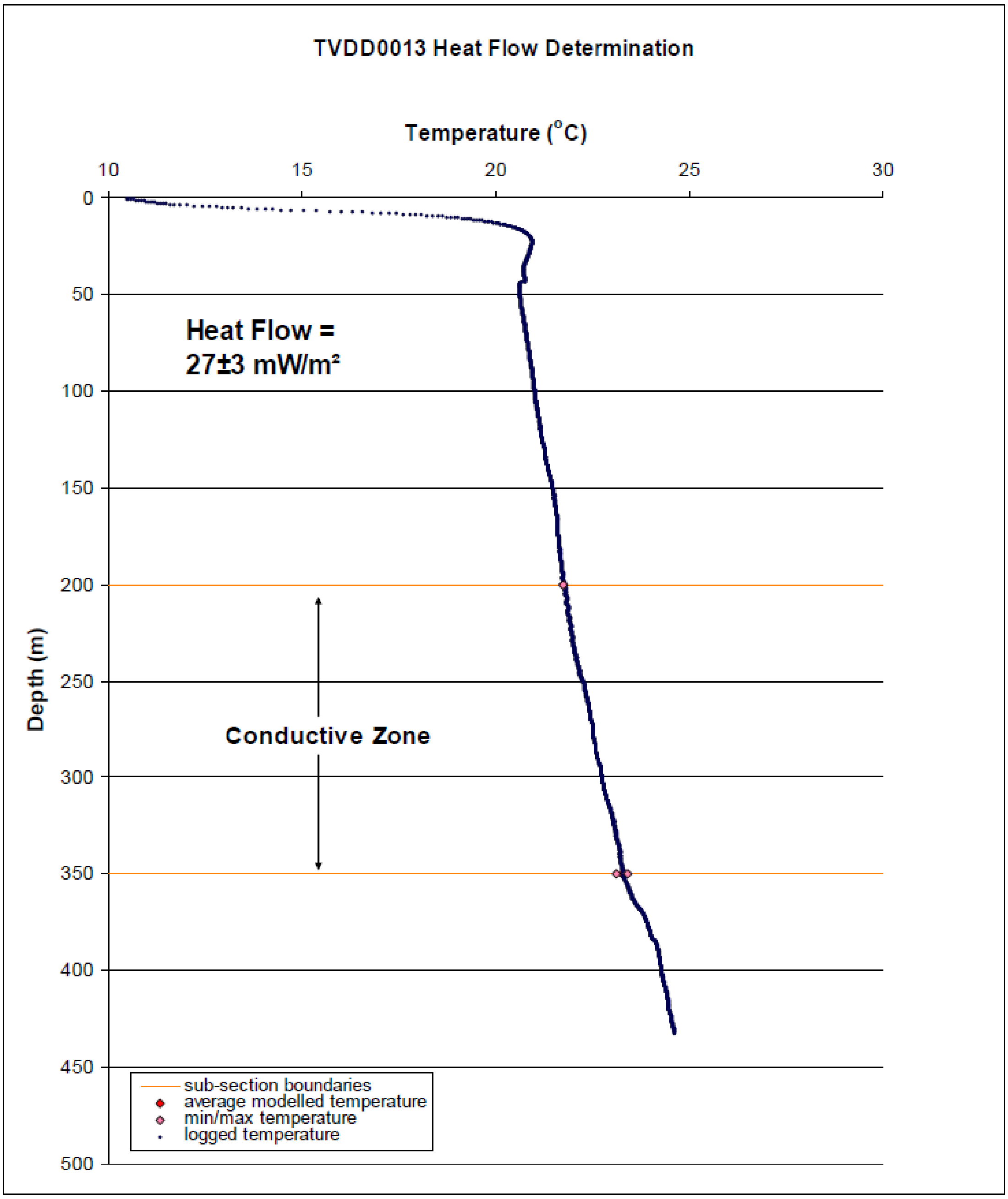

Figure 21: Modelled and measured temperatures versus true vertical depth for TVDD0013. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

08BKWD0027

08BKWD0027 is located in southern Western Australia, approximately 20 km south-west of Kambalda West. This well was drilled by Breakaway Resources Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 434 m. No lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature log is shown in Figure 22 and from this the conductive zone has been defined as extending from 50 m to 433.7 m depth. Above 50 m the gradient is disturbed and 433.7 m is the bottom of the well.

A heat flow of *33 ± 1 mW/m*^{2} has been determined for this well. All six thermal conductivity samples collected lie in the conductive zone and were used to constrain the heat flow determination. Sub-section boundaries were assigned using the gamma log where possible; otherwise the boundaries were assigned as the midpoint between two thermal conductivity samples (see Table 23).

Table 23: Samples, thermal conductivity values and sub-sections boundaries for well 08BKWD0027. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2122321	52.7	Amphibolite	2.83	0.18	50.0-96.1	Midpoint
2122322	139.6	Amphibolite	2.83	0.05	96.1-183.0	Gamma log
2122323	226.4	Amphibolite	2.85	0.04	183.0-260.1	Midpoint
2122324	293.8	Amphibolite	2.33	0.04	260.1-349.4	midpoint
2122325	405.0	Amphibolite	2.78	0.11	349.4-419.3	Midpoint
2122326	433.7	Amphibolite	2.85	0.08	419.3-433.7	Bottom conductive zone

The modelled and measured temperature data are plotted together in Figure 22. There is very good agreement between the modelled and measured data and also very low error value. There is very little variation in the lithology, and therefore (with the exception of sample 2122324), the thermal conductivity values, down the well.

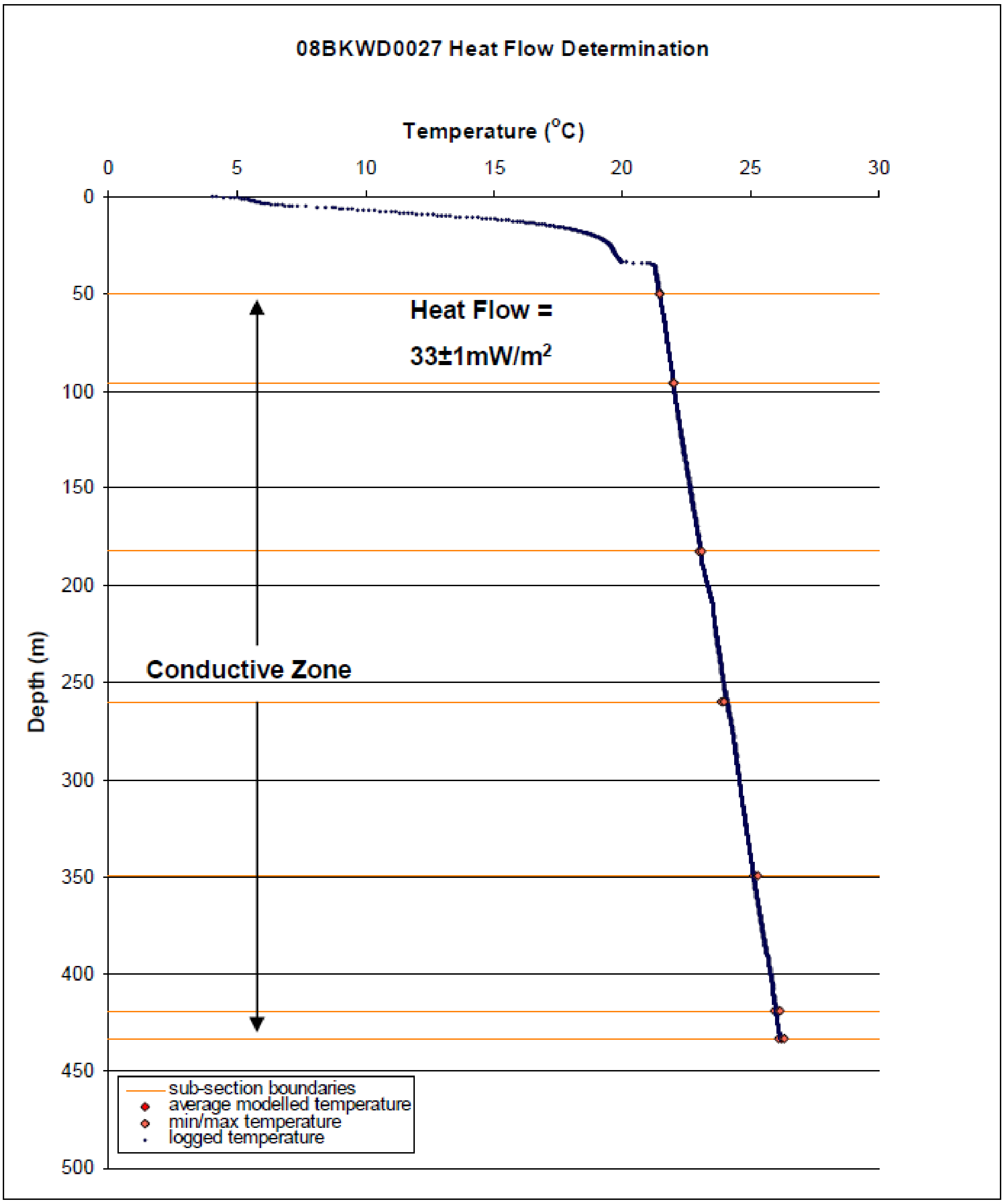

Figure 22: Modelled and measured temperatures versus true vertical depth for 08BKWD0027. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

08BKWD0028

08BKWD0028 is located in southern Western Australia, approximately 20 km south-west of Kambalda West. This well was drilled by Breakaway Resources Ltd and logged by GA using the combined temperature/gamma tool to a vertical depth of 400 m. No lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature log is shown in Figure 23 and from this the conductive zone has been defined as from 100 m to 347 m depth. Above and below this zone the gradient is disturbed.

A heat flow of *35 ± 7 mW/m*^{2} has been determined for this well. Three of the thermal conductivity samples collected lie in the conductive zone and were used to constrain the heat flow. The gamma log could not be used to assign sub-section boundaries and thus boundaries were assigned as the midpoint between two thermal conductivity samples.

Table 24: Samples, thermal conductivity values and sub-sections boundaries for well 08BKWD0028. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2122327	49.8	Gneiss	2.96	0.06	N/A	N/A
2122328	137.3	Gneiss	2.86	0.55	100.0-181.7	Midpoint
2122329	226.1	Metamorphic rock	3.57	0.19	181.7-269.1	Midpoint
2122330	312.1	Metamorphic rock	4.40	0.13	269.1-347.0	Bottom conductive zone
2122331	398.7	Metamorphic rock	2.63	0.10	N/A	N/A

The modelled and measured temperature data is plotted together in Figure 23. There is reasonable agreement between the modelled and measured data. However, there is a large error on the heat flow value for this well. The main source of the error is the uncertainty in the sub-section boundaries. The error would be reduced if there was a lithology log to assign the sub-section boundaries. Although there is significant error the heat flow value determined is very similar (within 2 mW/m^2) to the value determined for 08BKWD0027, which is 200 m to the south-east of this well.

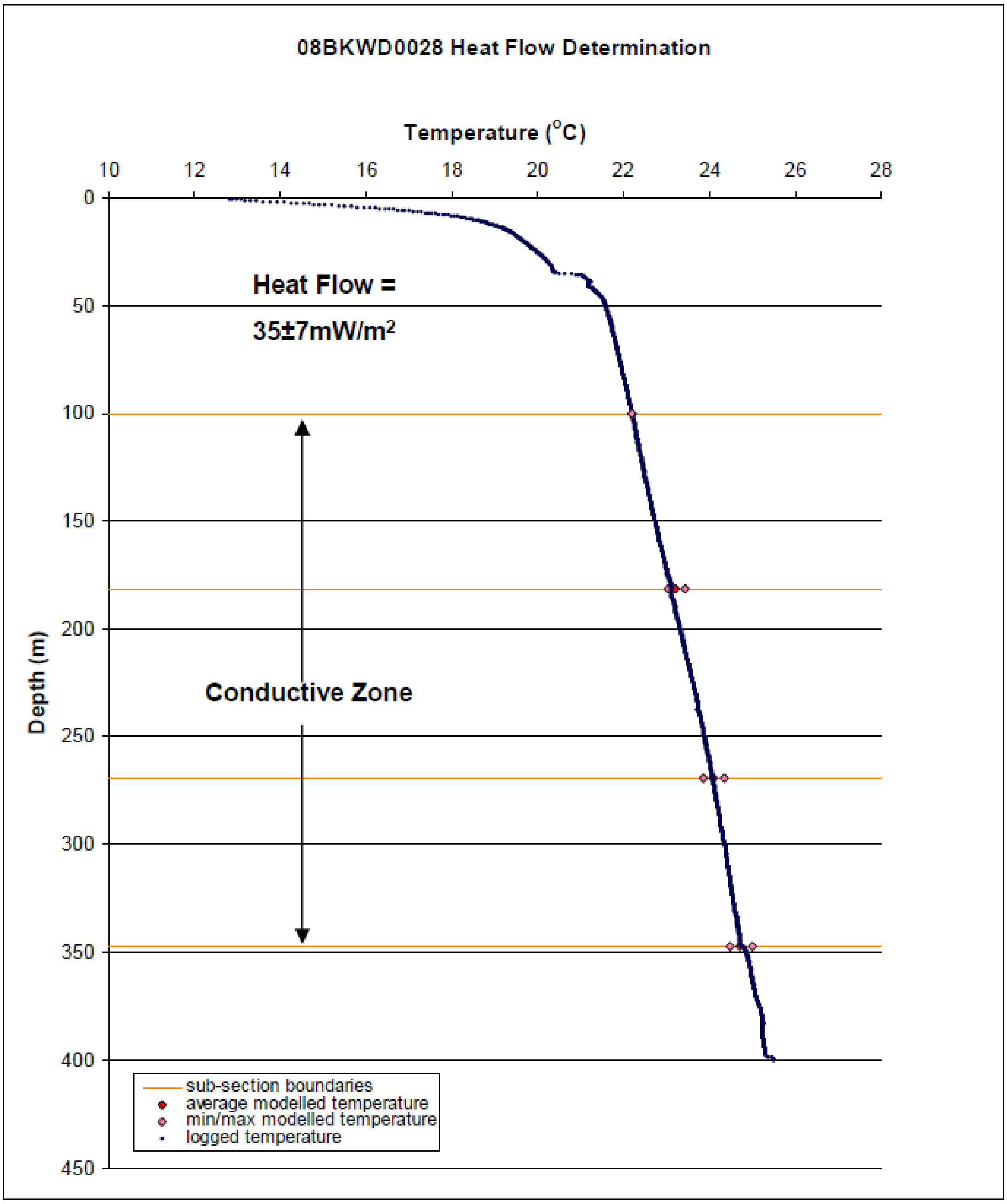

Figure 23: Modelled and measured temperatures versus true vertical depth for BKWD0028. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

08BWDD0013

08BWDD0013 is located in Western Australia, approximately 35 km south-east of Leinster. This well was drilled by Breakaway Resources Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 327 m. No lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature log is shown in Figure 24 and from this the conductive zone has been defined as from 100 m to 327 m depth. Above this zone the gradient is disturbed and 327 m is the bottom of the hole.

A heat flow of $26.5 \pm 1\ mW/m^2$ has been determined for this well. Three of the thermal conductivity samples collected lie in the conductive zone and were used to constrain the heat flow determination. Sub-section boundaries could not be assigned using the gamma log, thus the boundaries were assigned as the midpoint between the thermal conductivity samples (see Table 25).

Table 25: Samples, thermal conductivity values and sub-sections boundaries for well 08BWWD0013. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	LIthology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2122332	45.7	Metamorphic rock	2.48	0.05	N/A	N/A
2122333	137.1	Metamorphic rock	2.27	0.06	100.0-183.2	Midpoint
2122334	229.3	Metamorphic rock	2.56	0.01	183.2-300.0	Midpoint
2122335	326.4	Metamorphic rock	2.40	0.01	300.0-327.0	Bottom of hole

The modelled and measured temperature data is plotted together in Figure 24. There is good agreement between the modelled and measured data. There is little variability in the thermal conductivity values, consistent with the fact that the lithology is quite homogeneous down the well. This would also contribute to the low error value.

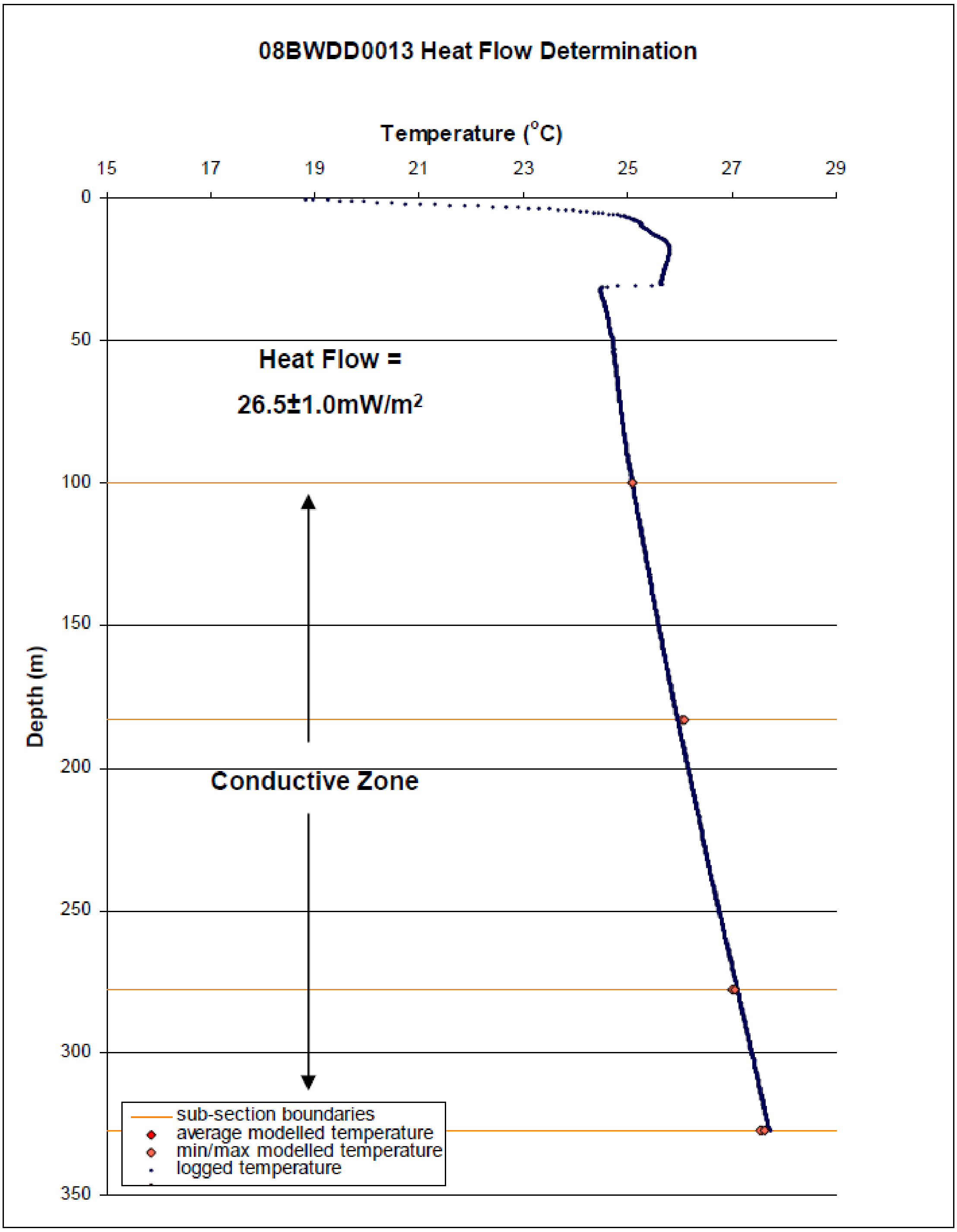

Figure 24: Modelled and measured temperatures versus true vertical depth for BWDD0013. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

10MMDD003

10MMDD003 is located in the central south of Western Australia, approximately 31 km north-east of Kambalda. This well was drilled by Silverlake Resources Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 316 m. No lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by GA.

The temperature log is shown in Figure 25 and from this the conductive zone has been defined as from 200 m to 300 m depth. Above this zone the gradient is disturbed and below this zone the regime is no longer purely conductive. It should be noted that there is some instability in the temperature gradient which could indicate advective flow.

A heat flow value of $32.5 \pm 4.5\ mW/m^2$ has been determined for this well. Three of the thermal conductivity samples collected lie in the conductive zone and were used to constrain the heat flow determination. Sub-section boundaries could not be assigned using the gamma log as there were no discernible signals, thus boundaries have been assigned as the midpoint between two thermal conductivity values (see Table 26).

Table 26: Samples, thermal conductivity values and sub-sections boundaries for well 10MMDD003. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2122060	143.3	Dark grey metasediment	5.19	0.35	N/A	N/A
2122061	165.0	Dark grey schist	4.84	0.46	N/A	Not conductive
2122062	202.1	Chlorite altered medium to coarse grained metasediment	2.88	0.18	200.0-223.1	Midpoint
2122063	244.2	Light grey, medium to coarse grain metasediment, chlorite veins	3.44	0.21	223.1-270.4	Midpoint
2122064	296.7	Light grey, medium to coarse grained metasediment	3.15	0.38	270.4-300.0	Bottom conductive zone

The modelled and measured temperature data are plotted together in Figure 25. There is a reasonably good match between the modelled and measured data. The error on the heat flow could be improved if there were a lithology log to help assign the sub-section boundaries.

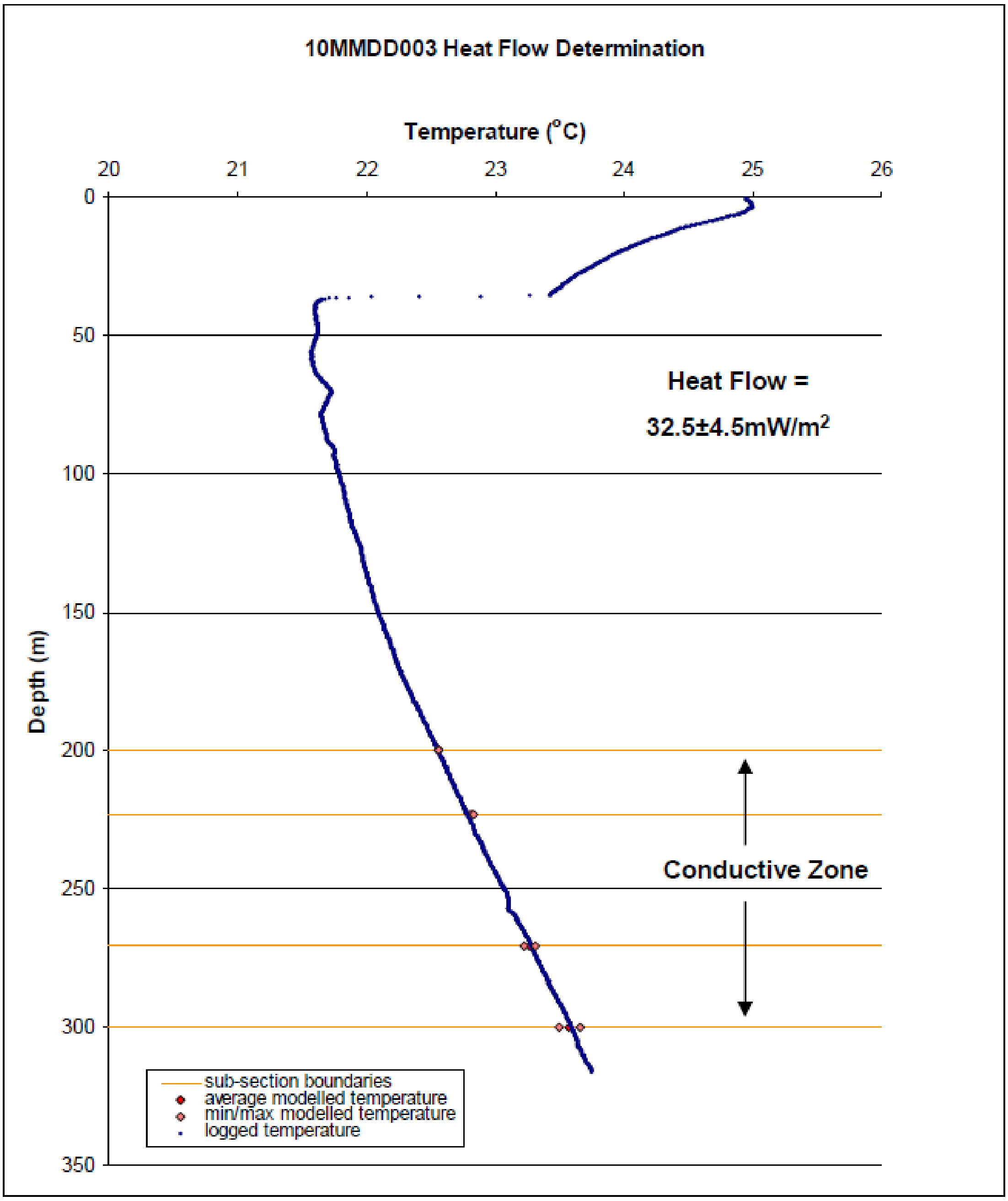

Figure 25: Modelled and measured temperatures versus true vertical depth for 10MMDD003. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

10MMRCD060

10MMRCD060 is located in the central south of Western Australia, approximately 31 km north-east of Kambalda. This well was drilled by Silverlake Resources Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 345 m. No lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by GA.

It can be observed from the Figure 26 that the temperature profile is disturbed. This could be because the well is unequilibrated. However for the purpose of obtaining an estimate heat flow the conductive zone has been defined as from 200 m to 340 m depth as this is the most stable interval of the gradient.

A heat flow range of *21-40 mW/m*^{2} has been estimated for this well. All four thermal conductivity samples collected lie in the conductive zone. However, sample number 2122065 has a much higher thermal conductivity than the remaining samples, possibly because it has a carbonate vein running through it. When this sample is incorporated in the heat flow model, it is not possible to fit the model to the data, however when this sample is excluded from the analysis, a very good fit can be generated. A likely reason for this is that the sample is not representative of the formation. Therefore, we have used only the bottom three samples collected from the hole to constrain the heat flow determination. Sub-section boundaries could not be determined from the gamma log as there were no discernible variations, thus the boundaries were assigned as the midpoint between thermal conductivity samples (see Table 27).

Table 27: Samples, thermal conductivity values and sub-sections boundaries for well 10MMRCD060. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mK)	Standard Deviation (W/mK)	Sub-Section (m)	Sub-Section Boundary Rationale
2122065	226.1	Medium to coarse grained light grey metasedimentary rock with carbonate vein	6.60	0.89	200.0-246.4	N/A
2122066	266.7	Medium to coarse grained metasedimentary rock	2.48	0.15	246.4-278.0	Midpoint
2122067	289.2	Schist, mafic	4.53	0.59	278.0-297.0	Midpoint
2122068	337.6	Dark grey metasedimentary rock	2.67	0.03	297.0-340.0	Bottom of conductive zone

The modelled and measured temperature data are plotted together in Figure 26. There is good agreement between the modelled and measured data, however there is a large range of possible heat flow values. The quality of the heat flow determination for this well could be improved by having a lithology log to assign the sub-section boundaries, by an increase in thermal conductivity sample density, and also by logging this well again when equilibrated.

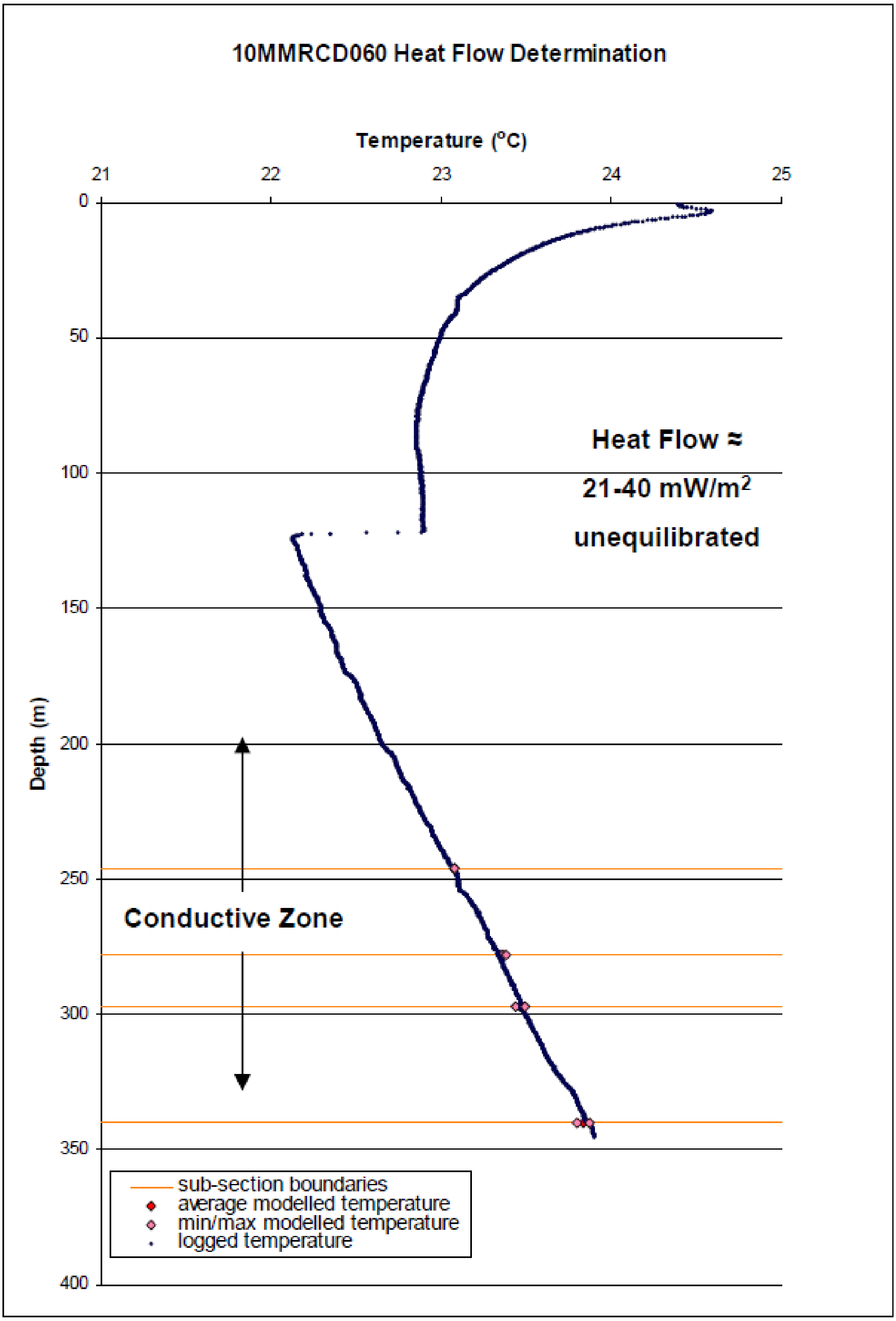

Figure 26: Modelled and measured temperatures versus true vertical depth for 10MMRCD060. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

09SMDD002

09SMDD002 is located in eastern Victoria, approximately 32 km north-east of Omeo. This well was drilled by Jabiru Metals Ltd and logged by GA using the combined temperature/gamma probe to a vertical depth of 274 m. No lithology log was provided to GA. Thermal conductivity measurements on samples from this well were undertaken by HDRPL.

The temperature log is shown in Figure 27 and from this the conductive zone has been defined as from 170 m to 275 m depth.

The sampling strategy for thermal conductivity measurements was slightly different for this well compared to other wells. Instead of collecting one sample every 50-100 m, three samples were collected from two 5 m intervals in the well. This allowed the thermal conductivity of each of these intervals to be characterised very well.

A heat flow of *73 +17/-9 mW/m*^{2} has been determined for this well. Two subsections were modelled, each encompassing one of the five metre intervals (i.e., three samples). The boundary between the two subsections was determined using the gamma log (see Table 28).

Table 28: Samples, thermal conductivity values and sub-sections boundaries for well 09SMDD002. N/A means that the sample was not used for heat flow modelling.

Sample Number	Sample Depth (m)	Lithology	Thermal Conductivity (W/mk)	Standard Deviation (W/mK)	Sub Section (m)	Sub-Section Boundary Rationale
2122266	190.3	Mafic gneiss	3.86	0.18	170.0-208.0	Gamma
2122267	191.9	Mafic gneiss	4.04	0.27		
2122268	195.7	Mafic gneiss	4.47	0.40		
2122269	268.1	Mafic schist	3.17	0.19	208.0-275.0	Bottom of conductive section
2122270	269.6	Mafic schist	3.01	0.10		
2122271	272.4	Mafic schist	2.96	0.11		

The modelled and measured temperature data is plotted together in Figure 27. There is reasonable agreement between the modelled and measured data. However the error on the heat flow value is quite large for this well. This may be because there is a large gap between the two intervals for which thermal conductivity samples were collected. Thus the error could be reduced by collecting more samples distributed evenly across the conductive zone.

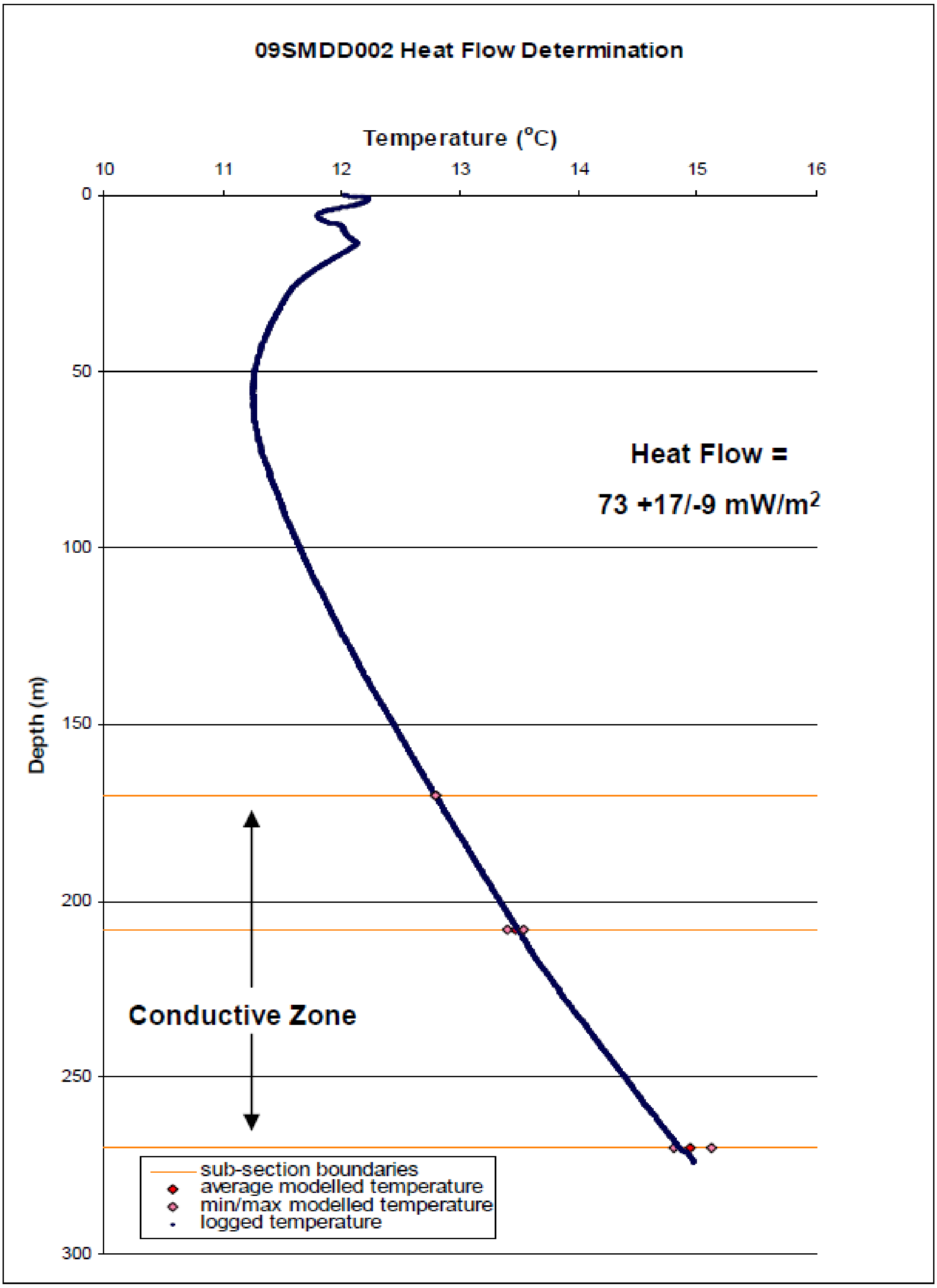

Figure 27: Modelled and measured temperatures versus true vertical depth 09SMDD002. The sub-section boundaries are highlighted in orange. The modelled temperature at the top and bottom of each sub-section is highlighted in red (mean) and pink (error bounds on the modelled temperature).

Conclusions

The heat flow determinations included in this report are the third release of heat flow data from Geoscience Australia's Geothermal Energy Project. The collection of new temperature and thermal conductivity data is ongoing and more heat flow determinations will be released in the future. This data is making a significant contribution to improving the heat flow coverage of Australia. Future field work will be aimed at filling in the gaps in coverage to enhance the spatial distribution across the country. This data will improve the understanding of the thermal structure of the Australian continent and will be used as inputs to geothermal modelling and geothermal energy prospectivity analyses in the future.

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