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SERVICES
Exploration
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Thermal conductivity of core samples KEN130-KEN145

Prepared for KUTh Energy

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Executive summary

KUTh Energy commissioned Hot Dry Rocks Pty Ltd (HDRPL) to measure the thermal conductivity of 16 core specimens delivered in mid March 2009. Measurements were made on the 16 specimens using a steady state divided bar apparatus calibrated for the range 1.4–9.8 W/mK. 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 25°C. The uncertainty for individual samples is ± 3.5%.

HDRPL 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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1.0 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. This report describes the results of laboratory thermal conductivity measurements on a series of drill core samples from KUTh.

KUTh Energy commissioned Hot Dry Rocks Pty Ltd (HDRPL) to undertake this study. HDRPL took delivery of 16 core specimens[1] from the wells Native Hut, Runnymede, and Cambridge in March 2009 (Table 1). Thermal conductivity measurements were made on all of 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, in general decreasing as temperature increases. The measurements contained in this report were made within ±2°C of 25°C.

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

Table 1. Specimens presented for thermal conductivity measurement.

Well	Formation	Depth From (m)	Depth To (m)	Sample
Native Hut		117.81	117.93	KEN130
Native Hut		125.4	125.51	KEN131
Native Hut		176.11	176.24	KEN132
Native Hut		189.92	190.03	KEN133
Native Hut		221.82	221.97	KEN134
Native Hut		240.6	240.74	KEN135
Runnymede		92.25	92.4	KEN136
Runnymede		119.66	119.81	KEN137
Runnymede		151.98	152.13	KEN138
Runnymede		203.23	203.35	KEN139
Runnymede		235.82	235.96	KEN140
Cambridge		106.91	106.76	KEN141
Cambridge		137.64	137.82	KEN142
Cambridge		178.05	178.08	KEN143
Cambridge		201.68	201.8	KEN144
Cambridge		221.04	221.16	KEN145

2.0 Methodology

Hot Dry Rocks Pty Ltd received 16 specimens of rock from KUTh Energy. HDRPL assumed that the specimens were representative of the average lithological composition of the formation being sampled.

Each specimen was prepared for thermal conductivity measurement in a divided bar apparatus[2]. Three prisms were cut from each consolidated HQ-core, each approximately 1/4 to 1/3 the diameter of the specimen in thickness. These samples were taken to investigate variation in thermal conductivity over short distance scales and to determine mean conductivity and uncertainty. The samples were all of a circular/cylindrical shape. Each sample was ground flat and polished, then evacuated under >95% vacuum for a minimum of three hours. Samples were then submerged in water prior to returning to atmospheric pressure. Water saturation continued at atmospheric pressure for a minimum of three hours, and all samples were left in water until just prior to conductivity measurement.

Values were measured at a standard temperature of 25°C (±2°C). Harmonic mean conductivity (see Figure 1) and one standard deviation uncertainty were calculated for each specimen. Results are presented in the next section.

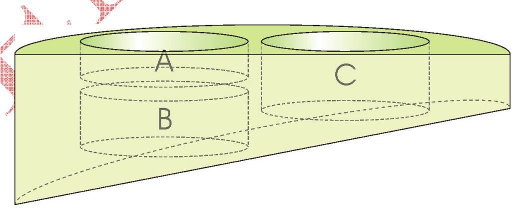

Figure 1. The average conductivity of samples in series (e.g. A and B) is found using the harmonic mean. The average conductivity of samples in parallel (e.g. A and C) is found using the arithmetic mean.

[2] 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.

3.0 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 25°C. The uncertainty for individual samples is approximately ±3.5% for consolidated samples (based on the instrument precision of the divided bar apparatus).

Table 2. Thermal conductivity of samples at 25°C, and harmonic mean and uncertainty[3] for each specimen.

Well	Lith/Fm	Depth From (m)	Depth To (m)	Sample		Conductivity (W/mK)			
					A	4.64			
					B	4.67			
Native Hut	Sst ?Permian	117.81	117.93	KEN130	C	4.17	4.48	±	0.28
					A	4.26			
					B	4.54			
Native Hut	Sst ?Permian	125.4	125.51	KEN131	C	4.32	4.37	±	0.15
					A	3.32			
					B	3.50			
Native Hut	Sst ?Permian	176.11	176.24	KEN132	C	3.63	3.48	±	0.16
					A	2.23			
					B	2.05			
Native Hut	Silty Sst ?Permian	189.92	190.03	KEN133	C	2.30	2.19	±	0.13
					A	2.38			
					B	2.40			
Native Hut	Jurassic Dolerite	221.82	221.97	KEN134	C	2.40	2.40	±	0.01
					A	2.33			
					B	2.36			
Native Hut	Jurassic Dolerite	240.6	240.74	KEN135	C	2.37	2.35	±	0.02
					A	2.61			
					B	2.67			
Runnymede	Jurassic Dolerite	92.25	92.4	KEN136	C	2.61	2.63	±	0.03
					A	2.11			
					B	2.81			
Runnymede	Jurassic Dolerite	119.66	119.81	KEN137	C	2.62	2.48	±	0.36

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

					A	2.47			
					B	2.48			
Runnymede	Jurassic Dolerite	151.98	152.13	KEN138	C	2.49	2.48	±	0.01
					A	2.18			
					B	2.14			
Runnymede	Jurassic Dolerite	203.23	203.35	KEN139	C	2.18	2.17	±	0.02
					A	2.18			
					B	2.17			
Runnymede	Jurassic Dolerite	235.82	235.96	KEN140	C	2.15	2.17	±	0.02
					A	2.23			
					B	2.19			
Cambridge	Cong & coal ?Permian	106.91	106.76	KEN141	C	2.26	2.22	±	0.04
					A	1.87			
					B	1.93			
Cambridge	Cong & coal ?Permian	137.64	137.82	KEN142	C	2.00	1.93	±	0.06
					A	2.10			
					B	1.92			
Cambridge	Cong & coal ?Permian	178.05	178.08	KEN143	C	1.91	1.97	±	0.10
					A	1.91			
					B	2.03			
Cambridge	Cong & coal ?Permian	201.68	201.8	KEN144	C	2.03	1.99	±	0.07
					A	2.00			
					B	1.85			
Cambridge	Cong & coal ?Permian	221.04	221.16	KEN145	C	2.05	1.96	±	0.10

4.0 Discussion and conclusions

For all specimens excepting KEN137, there is less than 10% variation form the mean thermal conductivity; this implies that variation in thermal conductivity appears low over the scale of centimetres for those specimens. The specimen KEN137, however, shows a variation of approximately 16% from the mean (Approximately 2.5 W/mK); this implies that variation in thermal conductivity over the scale of centimetres for that specimen may be significant.

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[4], 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. This should be kept in mind when developing models of *in situ* thermal conductivity.

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