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Thermal conductivity and subsurface temperature data pertaining to the Glasgow Geothermal Energy Research Field Site (GGERFS)

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Summary

This report is a compilation of measured thermal conductivity data from across the Central Belt of Scotland from which a representative thermal conductivity log for the geological strata underlying the Glasgow Geothermal Energy Research Field Site (GGERFS) has been constructed. In addition, all subsurface temperature data from within a 20 km radius of GGERFS have been collated and included as data listings. These represent 'pre-drill' datasets, before the new boreholes are drilled and associated new datasets collected, at the field site.

1 Introduction

This brief report is a compilation of the thermal conductivity and subsurface temperature data that is available for the Glasgow Geothermal Energy Research field Site (GGERFS). Some subsurface temperature data were reviewed in Monaghan et al. (2017), but additional data are included here.

2 Thermal conductivity

Thermal conductivity of the geological strata is required for thermal modelling and for estimations of temperatures at depth. Most measured thermal conductivity values have been undertaken in the laboratory from drill chippings. Such measurements are only representative of the strata at a specific location and only give a matrix value of the sample as opposed to a bulk value that would take into account the layering of different lithologies.

This report generates a thermal conductivity log for the vertical section of the bedrock geology that is expected to underlie the GGERFS. The geological section has been taken from Monaghan et al. (2017) and is shown in Figure 1. Measured thermal conductivities are used as the base for constructing the log, but variations in lithology are taken into account in order to derive the best thermal conductivity estimates for the stratigraphic units.

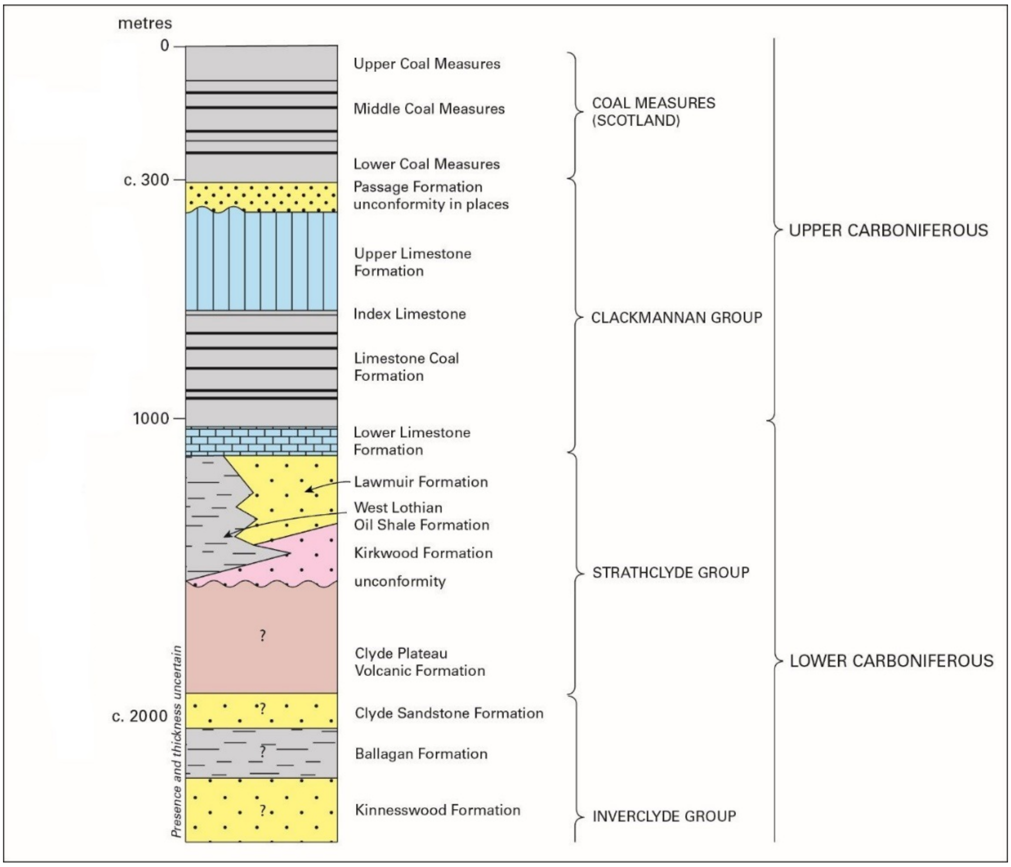

Figure 1. Summary of proved and possible lithology and stratigraphy in the Clyde Gateway area, after Monaghan et al. (2017).

2.1 Measured thermal conductivity data

All of the available laboratory measured thermal conductivity data were taken as part of heat flow studies. Heat flow is obtained from a combination of a temperature gradient and the thermal conductivity along a section of a vertical borehole. There are no heat flow boreholes at the GGERFS, but there are five boreholes within the local vicinity and two, 75 km away in Fife (see Figure 2 and Table 1).

Borehole	BNG co-ordinates (m)	Distance from the GGERFS site (km)	Sampled Formations
Maryhill	257180E, 668560N	7.6	Limestone Coal Lower Limestone
Hurlet House	250100E, 661200N	11.3	Lawmuir Clyde Plateau volcanics
Clachie Bridge	264470E, 683680N	20.8	Clyde Plateau volcanics Ballagan Kinnesswood
Barnhill	242690E, 675710N	23.4	Clyde Plateau volcanics, Clyde Sandstone Ballagan Kinnesswood
Kipperoch	237270E, 677420N	28.9	Ballagan Kinnesswood
Boreholes in Fife			
Boreland	330394E, 694222N	74.9	Upper Limestone Limestone Coal
Glenrothes	325620E, 703140N	75.0	Lower Limestone Pathhead Ballagan

Table 1. Boreholes with relevant thermal conductivity measurements within the Central Belt of Scotland.

As there is a large distance to the boreholes in Fife from the GGERFS, there are likely to be variations in lithology. Hence, where possible, these thermal conductivities are not used in the construction of a representative GGERFS thermal conductivity log.

The measured data comprise a depth to the sample, a measured thermal conductivity and a rock description. In many of the boreholes the sampling is at a regular spacing, which is often 5 m. Irregular spacing does not imply a thickness of the particular rock type. The measured thermal conductivity data from each of these boreholes are presented in Appendix 1.

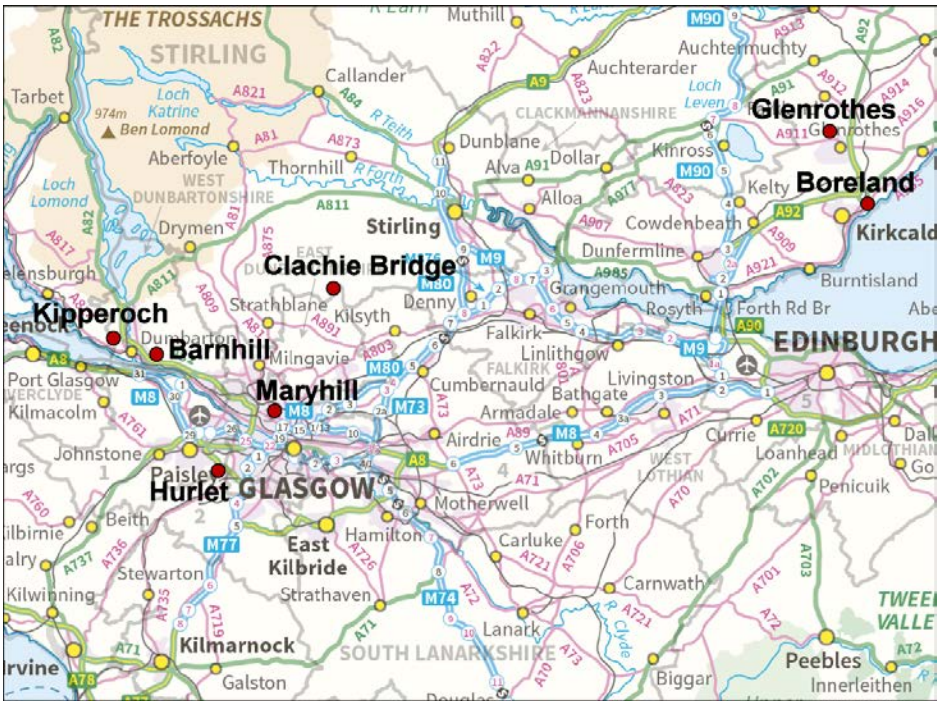

Figure 2. Location diagram for the boreholes with relevant thermal conductivity measurements. Contains Ordnance Survey data © Crown copyright and database rights. All rights reserved [2019] Ordnance Survey [100021290 EUL]

2.2 Presentation of representative thermal conductivity

A geological description has been obtained for each borehole from the literature where the interpreting geologist has subdivided the formations on stratigraphical or lithological criteria. For each of these subdivisions, a thermal conductivity has been derived as the mean of all the measured values that fall within the depth range of the subdivision. Since the thickness of each subdivision is known from the geological interpretation, a thickness weighted thermal conductivity has been derived for each formation from the subdivision thermal conductivities as a harmonic mean, i.e.

$$\frac{1}{\lambda_b} = \sum_{i=1}^{n} \frac{\varphi_i}{\lambda_i}$$

where λ_b is the formation thermal conductivity, λ_i is the thermal conductivity of the ith subdivision and φ_i is the fractional thickness of the ith subdivision. These derived formation thermal conductivities are presented in Table 2.

Formation	**Borehole**						
	Maryhill	Hurlet House	Clachie Bridge	Barnhill	Kipperoch	Boreland	Glenrothes
Upper Limestone						2.25	
Limestone Coal	2.24					1.34	
Lower Limestone	1.88						2.27
Lawmuir		4.36					
Pathhead							2.66
Kirkwood							
Clyde Plateau volcanics		2.12	2.38	2.1			
Clyde Sandstone				4.19			
Ballagan			2.62	3.08	3.71		2.23
Kinnesswood			3.07	4.28	3.64		3.47

Table 2. Harmonic mean thermal conductivities in W m^{-1} K^{-1} for the sampled formations.

2.3 Thermal conductivity of the Coal Measures, Passage Formation and Kirkwood Formation

There are no recorded thermal conductivity measurements on the Scottish Coal Measures, the Passage Formation and the Kirkwood Formation. Thermal conductivities have therefore been estimated from measurements on similar lithologies from outside of the region.

2.3.1 Scottish Coal Measures Group

The Coal Measures are cyclical in their deposition and consist of interbedded sequences of sandstone, siltstone, mudstone and coal and in some cases the coal has been mined to leave a layer of fill (goaf).

There are a large number of site investigation boreholes in the Clyde Gateway area. Borehole Cuningar Loop M7 (BNG 262400E, 662600N; Registration No. NS66SW17585/M7) extends from 34.29 m to 72.54 m depth through the Scottish Middle Coal Measures. The lithological log is shown in Table 3.

Depth (top) m	Depth (base) m	Thickness (m)	Rock type
34.29	35.05	0.76	SANDSTONE, SEAT-EARTH
35.05	37.19	2.14	SILTSTONE, SANDSTONE
37.19	40.23	3.04	SILTSTONE
40.23	41.15	0.92	SANDSTONE
41.15	42.57	1.42	SANDSTONE
42.57	42.72	0.15	COAL
42.72	44.25	1.53	SANDSTONE
44.25	44.37	0.12	COAL
44.37	45.9	1.53	SANDSTONE
45.9	46.13	0.23	COAL
46.13	46.71	0.58	SANDSTONE
46.71	47.07	0.36	COAL
47.07	47.12	0.05	SANDSTONE
47.12	47.24	0.12	COAL
47.24	48.0	0.76	SANDSTONE
48.0	48.06	0.06	COAL
48.06	50.75	2.69	SEAT-EARTH
50.75	55.3	4.55	SILTSTONE, SANDSTONE
55.3	55.88	0.58	SEAT-EARTH
55.88	56.08	0.2	COAL
56.08	59.67	3.59	SILTSTONE
59.67	65.38	5.71	SILTSTONE, CALCAREOUS
65.38	65.74	0.36	IRONSTONE, CARBONACEOUS
65.74	69.34	3.6	MUDSTONE
69.34	71.45	2.11	FILL
71.45	72.54	1.09	SILTSTONE

Table 3. Lithological log through the Scottish Middle Coal Measures for borehole Cuningar Loop M7.

The thermal conductivity for this representative section of Scottish Middle Coal Measures has been estimated by combining the thermal conductivities of the individual lithological units as a harmonic mean (as described above). The lithological thermal conductivities have been obtained from measurements on samples from five boreholes in northern England that penetrated the Pennine Upper, Middle and Lower Coal Measures. These five boreholes were Rowlands Gill (BNG 416640E, 558150N), Shipton (BNG 454460E, 458579N), North Duffield (BNG 469177E, 435235N), Grove No.3 (BNG 476155E, 381373N) and Kelham Hills No. 1 (BNG 475945E, 357615N). The average thermal conductivity for each lithology is shown in Table 4.

Lithology	No. of measurements (n)	Thermal conductivity (W m^{-1} K^{-1})
Sandstone	34	3.58 ± 0.10
Siltstone	34	2.23 ± 0.10
Siltstone/sandstone	7	2.34 ± 0.32
Mudstone	18	1.85 ± 0.15
Siltstone/mudstone	4	1.58 ± 0.19
Ironstone	3	2.35 ± 0.12

Table 4. Average thermal conductivities for lithologies in the Pennine Coal Measures of northern England. Errors have been calculated with Peter's formula, $\sigma_m \cong \frac{5}{4}\frac{r}{(n-1)^{\frac{1}{2}}}$ where σ_m is the standard error in the mean of n observations and $r = \frac{1}{n}\sum|d_i|$ where d_i is the absolute deviation of each measurement from the mean.

Matrix thermal conductivities are also required for coal and goaf. Herrin and Deming (1996) report on the matrix thermal conductivity of coals from the United States and report an arithmetic mean of 0.33 W m^{-1} K^{-1} from 55 samples collected across the United States. Fracturing within the coal (the cleat), which will be most likely partially water filled, will raise the bulk thermal conductivity and so a value of 0.4 W m^{-1} K^{-1} has been estimated for coal. The goaf comprises unconsolidated material and so an estimated thermal conductivity of 1.7 W m^{-1} K^{-1} has been made.

These thermal conductivities and thicknesses from Table 3 have been combined with the harmonic mean to derive an estimated thermal conductivity for the Scottish Middle Coal Measures at the GGERFS of 2.02 W m^{-1} K^{-1}.

2.3.2 Passage Formation

The Passage Formation is described by Monaghan et al. (2017) as dominated by sandstone, some coarse-grained, with red-purple-green-yellow mudstone, seatclay and fireclay. The adopted thermal conductivity is 2.9 as estimated by the BGS GeoReport service.

2.3.3 Kirkwood Formation

The Kirkwood Formation comprises volcanic detritus and is described as a volcaniclastic mudstone and volcaniclastic sedimentary rock. The adopted thermal conductivity is 2.1 as estimated by the BGS GeoReport service.

2.4 Thermal conductivity log

The thermal conductivity log for the vertical section of the bedrock geology that is expected beneath the GGERFS is shown in Figure 3. As mentioned, thermal conductivities from the Boreland and Glenrothes boreholes have only been used in construction of the log when no other data were available. Hence, from Table 2, the only value used is that for the Upper Limestone Formation from the Boreland borehole. Where there is more than one formation value from the Maryhill, Hurlet House, Clachie Bridge, Barnhill and Kipperoch boreholes the mean of the thermal conductivities has been taken.

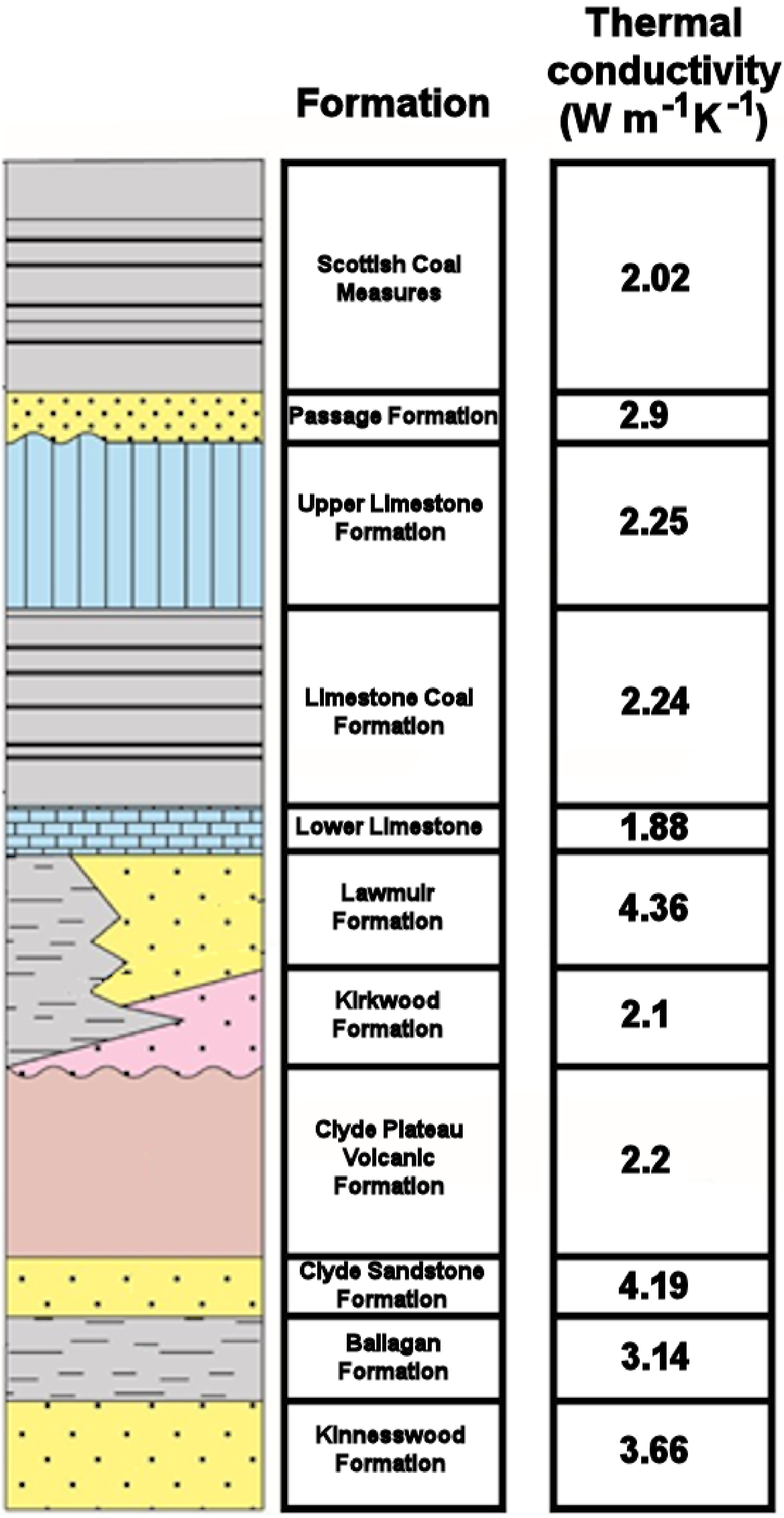

Figure 3. The thermal conductivity log for the vertical section of the bedrock geology that is expected to underlie the GGERFS.

3 Subsurface temperatures

This section of the report lists temperature data within a 20 km radius of the GGERFS. Some of this data has already been presented in Monaghan et al. (2017) where a comprehensive review of heat flow and temperature data was made. However, some extra data has been located since that report was written and is presented here. The locations of the measured data are shown in Figure 4 which is taken from Monaghan et al. (2017).

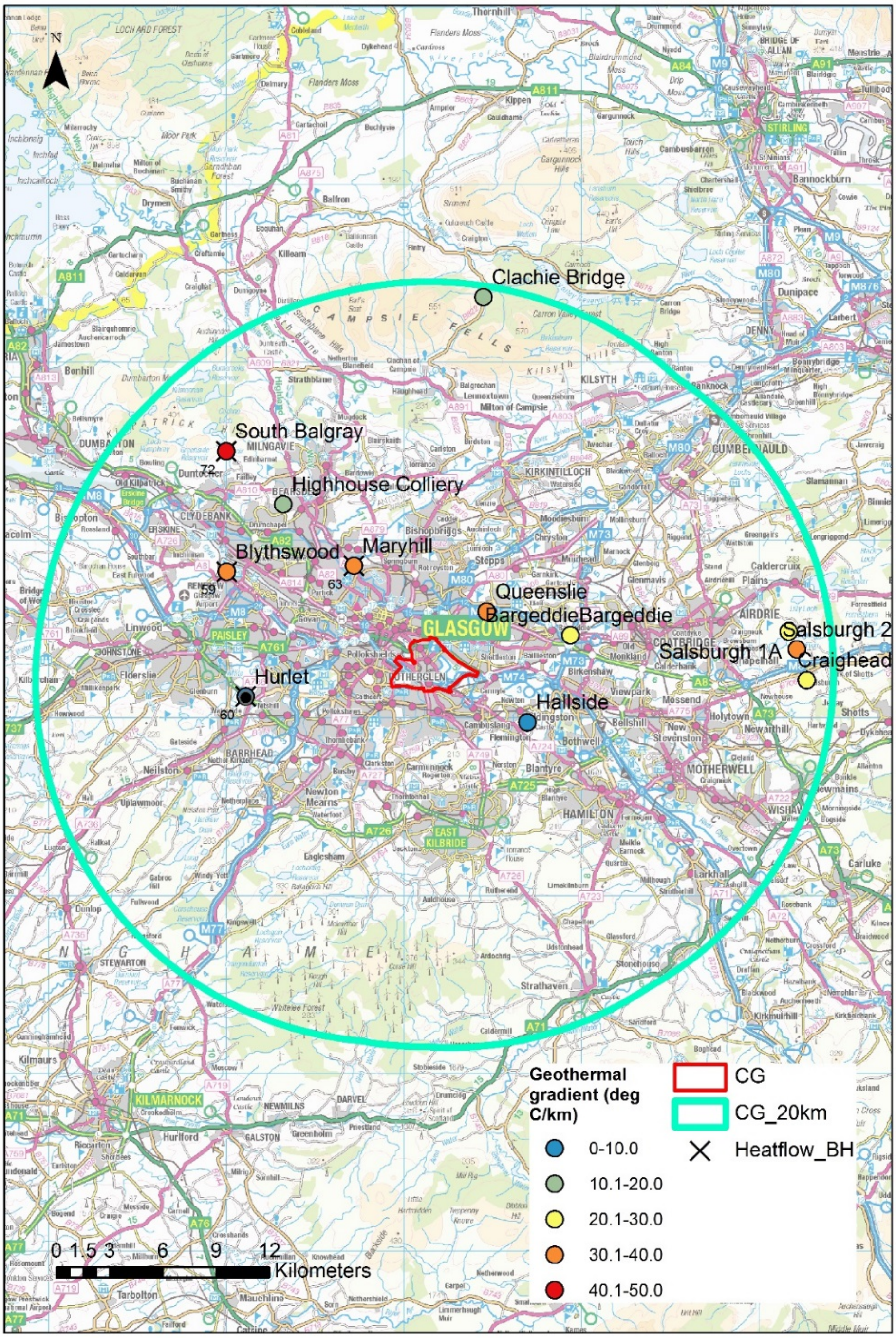

Figure 4. Locations of measured temperature data within a 20 km radius of the Clyde Gateway (CG) area. Contains Ordnance Survey data © Crown copyright and database rights. All rights reserved [2019] Ordnance Survey [100021290 EUL]

Listings of subsurface temperature data are shown in Appendix 2, where the data types are defined as follows;

EQM	Equilibrium temperatures
BHT	Bottom hole temperatures
LOG	Wireline log temperatures
MWT	Mine water temperatures
DST	Drill stem test derived temperatures

The data added here that wasn't included in Monaghan et al. (2017) comprises the following four items.

1. **Bargeddie No. 1**. Four extra drill stem test temperatures have been obtained from DECC Onshore Wells (M. Quinn pers. comm.) which provides a temperature gradient over a depth interval of 260 m.
2. **Maryhill**. The full equilibrium temperature log from Wheildon et al. (1985) is listed over the depth range 6 – 303m, rather than just the single temperature at 303 m depth.
3. **Clachie Bridge**. Oxburgh (1982) in an unpublished report to J. D. Garnish at ETSU (Energy Technology Support Unit), presents the results of heat flow measurements in which thermal conductivities and temperature gradients are listed. No temperatures are given and so it is not possible to reconstruct the temperature log from the Oxburgh report. However, a single temperature at 300 m depth is given by Burley et al. (1984) from which the temperature log presented here has been derived. Although the temperature type has been listed as LOG, given that this was a heat flow borehole it is very likely that the temperatures were at equilibrium.
4. **Hurlet House**. Temperature gradients are listed by Oxburgh (1982) for the Hurlet House borehole, which was logged in 1979. There are no temperatures, so in order to construct a temperature log the mean annual air temperature, calculated from 1975-1979 has been obtained from the Paisley Mett Office weather station (https://www.metoffice.gov.uk/pub/data/weather/uk/climate/stationdata/paisleydata.txt). This station is located only 3.8 km from the Hurlet House borehole and is at an elevation of +1.69m compared to the borehole site, which equates to a temperature difference of +0.01°C at the borehole site. This mean annual air temperature of 9.2°C has been assumed to be the ground temperature at 15m depth, beneath the zone affected by seasonal fluctuations. As for Clachie Bridge, it is likely that these are equilibrium temperatures.

Temperatures are listed by borehole in Appendix 2.

4 Conclusions

This report has compiled the measured thermal conductivity data from across the Scottish Central Belt to construct a best estimate of the thermal conductivity of the strata underlying GGERFS. A representative thermal conductivity log has been constructed and all of the thermal conductivity data are listed in Appendix 1.

All of the available measured subsurface temperature data from within a 20 km radius of GGERFS are listed in Appendix 2. The two closest temperature logs to GGERFS of equilibrium temperatures in the shallow subsurface are Maryhill and Hurlet House. The temperature gradient at Maryhill is 36.5 ^{0}C/km compared to 22.9 ^{0}C/km at Hurlet House. This can be explained due to the higher thermal conductivity at Hurlet House, where the sequence is the Limestone Coal and Lower Limestone Formations, compared to Maryhill, where the sequence is the Lawmuir and Clyde Plateau Volcanic Formations. The thickness weighted mean thermal conductivity at Hurlet House is 3.61 W m^{-1} K^{-1} compared to 2.04 W m^{-1} K^{-1} at Maryhill.

5 References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: https://envirolib.apps.nerc.ac.uk/olibcgi

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Appendix 1 Measured thermal conductivity data

Maryhill Borehole (257180E, 668560N) Data ref. Wheildon et al. (1985)

Depth top (m)	Thickness (m)	T Cond (W/m.K)	Rock type
7.7	1.1	4.81	SANDSTONE
8.8	6.5	4.11	SANDSTONE
15.3	7.4	1.55	SANDSTONE
22.7	1.3	1.62	MUDSTONE
24	4.1	1.3	MUDSTONE
28.1	1.5	4.78	SANDSTONE
29.6	6.3	1.81	SILTSTONE
35.9	2.9	1.28	MUDSTONE
38.8	3.5	1.52	MUDSTONE
42.3	2	1.71	SILTSTONE
44.3	2	1.15	MUDSTONE
46.3	6.3	1.21	MUDSTONE
52.6	4.5	4.67	SANDSTONE
57.1	3.3	1.69	SILTSTONE
60.4	3.3	1.53	MUDSTONE
63.7	0.7	1.52	SILTSTONE
64.4	3.9	4.3	SANDSTONE
68.3	3.6	4.46	SANDSTONE
71.9	2.3	4.74	SANDSTONE
74.2	3	4.23	SANDSTONE
77.2	4.5	1.71	SILTSTONE
81.7	4.5	3.82	MUDSTONE
86.2	2.6	0.91	SANDSTONE
88.8	3.1	4.79	SANDSTONE
91.9	4.2	4.54	SANDSTONE
96.1	2.3	4.15	SANDSTONE
98.4	2.4	4.56	SANDSTONE
100.8	3.3	1.22	SILTSTONE
104.1	3.3	4.08	SILTSTONE
107.4	9.8	1.02	MUDSTONE
117.2	1.4	1.04	MUDSTONE
118.6	11.5	1.1	MUDSTONE
130.1	3.3	1.25	MUDSTONE
133.4	3.4	1.43	DOLERITE
136.8	1.6	2.28	MUDSTONE
138.4	2.4	2.03	DOLERITE
140.8	6.8	1.59	DOLERITE
147.6	2.9	1.75	DOLERITE
150.5	3.5	2.05	DOLERITE
154	3.3	1.4	DOLERITE
157.3	2.5	1.82	MUDSTONE
159.8	12.8	1.41	MUDSTONE
172.6	2.7	1.81	MUDSTONE
175.3	2.5	1.53	MUDSTONE

177.8	2	1.42	MUDSTONE
179.8	4.1	1.5	MUDSTONE
183.9	2	2.31	TESCHENITE
185.9	3.6	2.34	TESCHENITE
189.5	3.8	2.18	TESCHENITE
193.3	3.1	2.19	MUDSTONE
196.4	3.1	2.27	TESCHENITE
199.5	2.5	2.25	TESCHENITE
202	3.9	2.22	TESCHENITE
205.9	1.8	2.12	TESCHENITE
207.7	4.6	1.18	TESCHENITE
212.3	3.7	2.15	TESCHENITE
216	0.9	1.93	TESCHENITE
216.9	3.9	2.13	TESCHENITE
220.8	4	2.04	TESCHENITE
224.8	8.4	2.06	DOLERITE
233.2	2.9	2.07	TESCHENITE
236.1	1.8	2.11	TESCHENITE
237.9	3.9	1.93	DOLERITE
241.8	3.5	1.95	MUDSTONE
245.3	2.6	4.63	SANDSTONE
247.9	2.7	5.49	SANDSTONE
250.6	3.3	4.6	SANDSTONE
253.9	2.9	4.85	SANDSTONE
256.8	3.1	3.54	SANDSTONE
259.9	2.9	5.47	SILTSTONE
262.8	4	1.67	SANDSTONE
266.8	1.6	1.64	SILTSTONE
268.4	4	1.84	SILTSTONE
272.4	2.9	1.22	MUDSTONE
275.3	3.2	2.77	SANDSTONE
278.5	2.1	2.61	SILTSTONE
280.6	6.7	2.61	SILTSTONE
287.3	5.6	2.03	DOLERITE
292.9	4.6	0.95	MUDSTONE
297.5	2.9	1	MUDSTONE
300.4	3.1	1.02	MUDSTONE
303.5		1.02	MUDSTONE

Hurlet Borehole (250100E, 661200N) Data ref. Oxburgh (1982)

Depth top (m)	Thickness (m)	T Cond (W/m.K)	Rock type
20	10.5	4.6	SANDSTONE
30.5	5.5	4.56	SANDSTONE
36	34	5.68	SANDSTONE
70	5	3.89	SANDSTONE
75	5.3	2.97	SILTSTONE
80.3	6.7	4.84	SANDSTONE
87	5	4.12	SANDSTONE

92	5	4.95	SANDSTONE
97	4.1	4.24	SANDSTONE
101.1	8.9	5.02	SANDSTONE
110	5	4.71	SANDSTONE
115	5	4.59	SANDSTONE
120	10	4.16	SANDSTONE
130	5	4.79	SANDSTONE
135	5	4.68	SANDSTONE
140	15.3	4.78	SANDSTONE
155.3	4.7	3.8	SANDSTONE
160	10.5	5.87	SANDSTONE
170.5	4.5	3.16	SILTSTONE
175	5	3.23	SILTSTONE
180	5	4.92	SANDSTONE
185	5	4.64	SANDSTONE
190	5	4.7	SANDSTONE
195	6	2.73	SILTSTONE
201	4	4.96	SANDSTONE
205	5	3.54	SANDSTONE
210	10	5.09	SANDSTONE
220	5	2.42	SEATEARTH
225	5	4.89	SANDSTONE
230	7	4.94	SANDSTONE
237	6	5.13	SANDSTONE
243	4	5.12	SANDSTONE
247	3	2.42	VOLCANICS
250	15	2.42	VOLCANICS
265	5	2.2	VOLCANICS
270	5	2.47	BASALT
275	5	1.84	BASALT
280	10	1.73	BASALT
290	5	1.67	BASALT
295	5	2.47	BASALT
300		1.84	BASALT

Clachie Bridge Borehole (264470E, 683680N) Data ref. Oxburgh (1982)

Depth top (m)	Thickness (m)	T Cond (W/m.K)	Rock type
32.1	4.5	2.13	BASALT
36.6	13.9	2.13	BASALT
50.5	7.9	2.63	BRECCIA
58.4	30.2	2.13	BASALT
88.6	5.4	2.63	BRECCIA
94	31.3	2.63	BRECCIA
125.3	7.1	2.79	PEGMATITIC GRANITE & APLITIC MICROGRANITE
132.4	6	2.79	PEGMATITIC GRANITE & APLITIC MICROGRANITE
138.4	5.4	2.68	MUDSTONE
143.8	6.6	2.63	BRECCIA
150.4	3.3	2.64	CEMENTSTONE

153.7	21.9	2.63	BRECCIA
175.6	5.4	2.63	BRECCIA
181	11	2.63	BRECCIA
192	11.4	2.68	MUDSTONE
203.4	4.6	2.64	CEMENTSTONE
208	10	2.63	BRECCIA
218	9.3	2.63	BRECCIA
227.3	5.7	2.13	BASALT
233	5.6	2.13	DOLERITE
238.6	6	2.63	BRECCIA
244.6	5.2	2.79	PEGMATITIC GRANITE & APLITIC MICROGRANITE
249.8	23.6	2.79	PEGMATITIC GRANITE & APLITIC MICROGRANITE
273.4	11.6	2.63	BRECCIA
285	9.5	3.51	BRECCIA AND SANDSTONE
294.5		2.63	BRECCIA

Barnhill Borehole (242690E, 675710N) Data ref. Oxburgh (1982)

Depth top (m)	Thickness (m)	T Cond (W/m.K)	Rock type
27	6	2	TUFF
33	5	1.7	TUFF
38	5	2.08	TUFF
43	5	1.93	TUFF
48	5	2.56	TUFF
53	5	2.75	TUFF
58	5	1.89	TUFF
63	5	1.86	TUFF
68	10	1.96	TUFF
78	26.5	2.24	TUFF
104.5	4.5	3.59	SANDSTONE
109	5.5	5.01	SANDSTONE
114.5	4.5	3.8	SANDSTONE
119	5	5.05	SANDSTONE
124	5	5.14	SANDSTONE
129	5.5	4.71	SANDSTONE
134.5	14.5	4.04	SANDSTONE
149	6.6	4.69	SANDSTONE
155.6	4.4	2.58	MUDSTONE
160	14.4	3.89	SANDSTONE
174.4	4.6	3.83	CEMENTSTONE
179	7.5	2.34	MUDSTONE
186.5	12	4.14	SANDSTONE
198.5	92.5	1.85	DYKE
291	4.2	4.9	SANDSTONE
295.2	9.8	3.39	SANDSTONE
305	10	4.69	DOLOMITE
315	10	4.42	SANDSTONE
325	5	4.23	SANDSTONE
330	5	4.8	SANDSTONE

335	5	4.46	SANDSTONE
340	5	3.83	SANDSTONE
345	5	3.79	SANDSTONE
350	5	4.31	SANDSTONE
355		1.66	DYKE

Kipperoch Borehole (237270E, 677420N) Data ref. Oxburgh (1982)

Depth top (m)	Thickness (m)	T Cond (W/m.K)	Rock type
30	5	3.81	SANDSTONE
35	5	4.99	SANDSTONE
40	5	2.17	SILTSTONE
45	5	3.71	MUDSTONE
50	5	3.88	SANDSTONE
55	5	4	SANDSTONE
60	5	4.69	SANDSTONE
65	5	3.39	SANDSTONE
70	10	3.82	SANDSTONE
80	5	3.72	SANDSTONE
85	5	4.76	SANDSTONE
90	6	3.05	MUDSTONE
96	14	4.58	DOLOMITE
110	5	5.07	SANDSTONE
115	5	4.16	SANDSTONE
120	10	3.75	SANDSTONE
130	5	4.9	SANDSTONE
135	5	2.82	SANDSTONE
140	5	3.37	SANDSTONE
145	5	3.28	SANDSTONE
150	5	3.49	SANDSTONE
155	5	3.61	SANDSTONE
160	5	3.77	SANDSTONE
165	5	3.61	DOLOMITE
170	6	3	SANDSTONE
176	9	3.45	SANDSTONE
185	5	3.17	SANDSTONE
190	5	2.62	SANDSTONE
195	5	2.61	SANDSTONE
200	5	2.69	SANDSTONE
205	5	3.03	SANDSTONE
210	5	3.4	SANDSTONE
215	5	3.74	SANDSTONE
220	5	3.9	SANDSTONE
225	5	3.83	SANDSTONE
230	5	3.27	SANDSTONE
235	10	3.68	SANDSTONE
245	5	2.85	SANDSTONE
250	5	3.09	SANDSTONE
255	5	3.47	SANDSTONE

260	15	3.4	SANDSTONE
275	5	3.66	SANDSTONE
280	5	3.79	MUDSTONE
285	5	3.65	SANDSTONE
290	5	3.39	SANDSTONE
295		3.05	SANDSTONE

Boreland Borehole (330394E, 694222N) Data ref. Anderson (1940)

Depth top (m)	Thickness (m)	T Cond (W/m.K)	Rock type
516.34	3.63	4.18	SANDSTONE
519.97	89.36	4.18	SANDSTONE
609.33	21.61	1.35	SHALE
630.94	58.86	1.37	SHALE
689.8	0.3	0.59	FIRECLAY
690.1	284.66	1.83	SHALE
974.76	5.49	1.44	SHALE
980.25		1.24	SHALE

Glenrothes Borehole (325620E, 703140N) Data ref. Gebski et al. (1987)

Depth top (m)	Thickness (m)	T Cond (W/m.K)	Rock type
135.13	12.78	2.08	QUARTZ-DOLERITE
147.91	3.98	2.06	QUARTZ-DOLERITE
151.89	2.27	2.16	QUARTZ-DOLERITE
154.16	1.1	2.17	QUARTZ-DOLERITE
155.26	2.26	1.96	QUARTZ-DOLERITE
157.52	2.48	2.38	SANDSTONE
160	3.06	2.52	LIMESTONE
163.06	2.92	3.65	LIMESTONE
165.98	3.02	2.15	MUDSTONE
169	2.47	2.7	SANDSTONE
171.47	2.58	2.08	SILTSTONE
174.05	2.95	2.81	MUDSTONE
177	3.34	2.82	MUDSTONE
180.34	3.23	3.98	SANDSTONE
183.57	2.93	1.01	MUDSTONE
186.5	3	4.16	SANDSTONE
189.5	11.8	1.61	SILTSTONE
201.3	2.7	3.74	SANDSTONE
204	6.15	2.2	SANDSTONE
210.15	2.91	2.95	MUDSTONE
213.06	3.01	2.6	SANDSTONE
216.07	10.35	2.94	SANDSTONE
226.42	2.95	2.02	SILTSTONE
229.37	6.71	1.93	SANDSTONE
236.08	5.97	1.34	SILTSTONE
242.05	6.06	2.41	MUDSTONE
248.11	9.25	3.55	SANDSTONE

257.36	9.89	2.41	MUDSTONE
267.25	3.33	2.11	SANDSTONE
270.58	2.72	1.27	MUDSTONE
273.3	6.08	2.19	SILTSTONE
279.38	5.99	1.24	SILTSTONE
285.37	3.2	1.56	SILTSTONE
288.57	9.49	2.06	MUDSTONE
298.06	3.34	2.09	MUDSTONE
301.4	19.65	2.25	SILTSTONE
321.05	7.18	1.87	MUDSTONE
328.23	6.53	1.69	MUDSTONE
334.76	11.58	2.1	MUDSTONE
346.34	13.31	2.13	MUDSTONE
359.65	10.23	4.29	SANDSTONE
369.88	10.86	3.2	SANDSTONE
380.74	11.36	3.68	CNST
392.1	10.92	3.68	SANDSTONE
403.02	16.75	3.06	SANDSTONE
419.77	15.51	3.46	SANDSTONE
435.28	25.97	3.75	SANDSTONE
461.25	19.94	3.15	SANDSTONE
481.19	20.37	3.59	SANDSTONE
501.56	19.52	2.94	SANDSTONE
521.08	20.05	3.61	SANDSTONE
541.13	23.4	4.27	SANDSTONE
564.53		4.21	SANDSTONE

Appendix 2 Measured subsurface temperature data

Hallside Borehole (266940E, 659750N) Data ref. Burley et al. (1984)

Depth (m)	Temperature (°C)	Type	Comment
350.0	11.8	LOG	60 hr after circulation correction applied

Queenslie No. 4 Borehole (264660E, 665980N) Data ref. Burley et al. (1984)

Depth (m)	Temperature (°C)	Type	Comment
691.0	36.0	BHT	No correction applied

Bargeddie No. 1 Borehole (269378E, 664649N) Data ref. DECC Onshore Wells

Depth (m)	Temperature (°C)	Type	Comment
720.8	30.3	DST	DST 6; tight?
773.9	29.5	DST	DST 2; produced gas
802.8	32.9	DST	DST 4; tight?
884.0	36.1	DST	DST 5; produced water
934.9	38.0	DST	DST 3; produced water
978.9	38.7	DST	DST 1; produced water

Maryhill Borehole (257180E, 668560N) Data ref. Wheildon et al. (1985)

Depth (m)	Temperature (°C)	Type	Comment
6.12	9.36	EQM	
9.18	9.39	EQM	
12.24	9.39	EQM	
15.30	9.43	EQM	
18.35	9.50	EQM	
21.41	9.64	EQM	
24.47	9.80	EQM	
27.53	10.01	EQM	
30.59	10.17	EQM	
33.65	10.26	EQM	
36.71	10.31	EQM	
39.77	10.39	EQM	
42.83	10.49	EQM	
45.89	10.62	EQM	
48.95	10.77	EQM	
52.00	10.92	EQM	
55.06	11.01	EQM	
58.12	11.09	EQM	
61.18	11.18	EQM	
64.24	11.29	EQM	
67.30	11.36	EQM	
70.36	11.43	EQM	

73.42	11.48	EQM
76.48	11.53	EQM
79.54	11.61	EQM
82.60	11.72	EQM
85.65	11.83	EQM
88.71	11.92	EQM
91.77	12.00	EQM
94.83	12.08	EQM
97.89	12.28	EQM
100.95	12.29	EQM
104.01	12.40	EQM
107.07	12.51	EQM
110.13	12.71	EQM
113.19	12.91	EQM
116.25	13.09	EQM
119.30	13.27	EQM
122.36	13.45	EQM
125.42	13.67	EQM
128.48	13.87	EQM
131.54	14.05	EQM
134.60	14.17	EQM
137.66	14.27	EQM
140.72	14.37	EQM
143.78	14.47	EQM
146.84	14.55	EQM
149.89	14.64	EQM
152.95	14.73	EQM
156.01	14.82	EQM
159.07	14.94	EQM
162.13	15.07	EQM
165.19	15.23	EQM
168.25	15.37	EQM
171.31	15.49	EQM
174.37	15.61	EQM
177.43	15.73	EQM
180.49	15.84	EQM
183.54	15.93	EQM
186.60	16.01	EQM
189.66	16.09	EQM
192.72	16.18	EQM
195.78	16.27	EQM
198.84	16.35	EQM
201.90	16.43	EQM
204.96	16.51	EQM
208.02	16.60	EQM
211.08	16.69	EQM
214.14	16.77	EQM
217.19	16.86	EQM
220.25	16.95	EQM
223.31	17.04	EQM

226.37	17.13	EQM
229.43	17.24	EQM
232.49	17.32	EQM
235.55	17.41	EQM
238.61	17.50	EQM
241.67	17.58	EQM
244.73	17.64	EQM
247.79	17.69	EQM
250.84	17.73	EQM
253.90	17.78	EQM
256.96	17.82	EQM
260.02	17.88	EQM
263.08	17.97	EQM
266.14	18.07	EQM
269.20	18.18	EQM
272.26	18.30	EQM
275.32	18.40	EQM
278.38	18.49	EQM
281.44	18.61	EQM
284.49	18.78	EQM
287.55	18.96	EQM
290.61	19.18	EQM
293.67	19.39	EQM
296.73	19.57	EQM
299.79	19.80	EQM
302.85	20.01	EQM
303.12	20.03	EQM

Hurlet House borehole (250100E, 661200N) Data ref. Oxburgh (1982)

Depth (m)	Temperature (^oC)	Type	Comment
15	9.2	LOG	
21	9.3	LOG	
40	9.8	LOG	
75	10.7	LOG	
85	11.0	LOG	
90	11.2	LOG	
95	11.3	LOG	
105	11.5	LOG	
115	11.6	LOG	
125	11.9	LOG	
135	12.1	LOG	
145	12.3	LOG	
160	12.6	LOG	
175	12.9	LOG	
185	13.1	LOG	
195	13.3	LOG	
205	13.5	LOG	
215	13.6	LOG	

225	13.8	LOG
235	14.0	LOG
240	14.1	LOG
245	14.2	LOG
255	14.4	LOG
260	14.6	LOG
265	14.7	LOG
270	14.8	LOG
275	15.0	LOG
280	15.1	LOG
285	15.3	LOG
290	15.5	LOG
295	15.6	LOG

Blythswood Borehole (250030E, 668230N) Data ref. Burley et al. (1984)

Depth (m)	Temperature (^oC)	Type	Comment
105.0	12.0	EQM	

Highhouse Colliery (253210E, 672020N) Data ref. Burley et al. (1984)

Depth (m)	Temperature (^oC)	Type	Comment
436.0	18.0	MWT	

South Balgray Borehole (250000E, 675000N) Data ref. Burley et al. (1984)

Depth (m)	Temperature (^oC)	Type	Comment
137.0	14.5	EQM	
160.0	15.3	EQM	

Salsburgh 1A Borehole (281660E, 664860N) Data ref. Burley et al. (1984)

Depth (m)	Temperature (^oC)	Type	Comment
874.0	29.0	DST	No correction applied
883.0	30.0	BHT	No correction applied

Salsburgh 2 Borehole (282110E, 663850N) Data ref. Rollin (1987)

Depth (m)	Temperature (^oC)	Type	Comment
1104.0	44.0	BHT	No correction applied

Craighead No. 1 Borehole (282670E, 662120N) Data ref. Burley et al. (1984)

Depth (m)	Temperature (^oC)	Type	Comment
977.0	35.0	BHT	No correction applied

Clachie Bridge Borehole (264470E, 683680N) Data ref. Burley et al. (1984) & Oxburgh (1982)

Depth (m)	Temperature (^oC)	Type	Comment
30	7.0	LOG	
35	7.1	LOG	
45	7.4	LOG	
55	7.6	LOG	
80	8.3	LOG	
90	8.6	LOG	
120	9.3	LOG	
130	9.6	LOG	
135	9.7	LOG	
140	9.8	LOG	
145	9.9	LOG	
170	10.6	LOG	
180	10.8	LOG	
200	11.3	LOG	
205	11.4	LOG	
215	11.6	LOG	
225	11.8	LOG	
230	11.9	LOG	
235	12.0	LOG	
245	12.2	LOG	
265	12.6	LOG	
285	13.0	LOG	
290	13.0	LOG	
300	13.2	LOG	