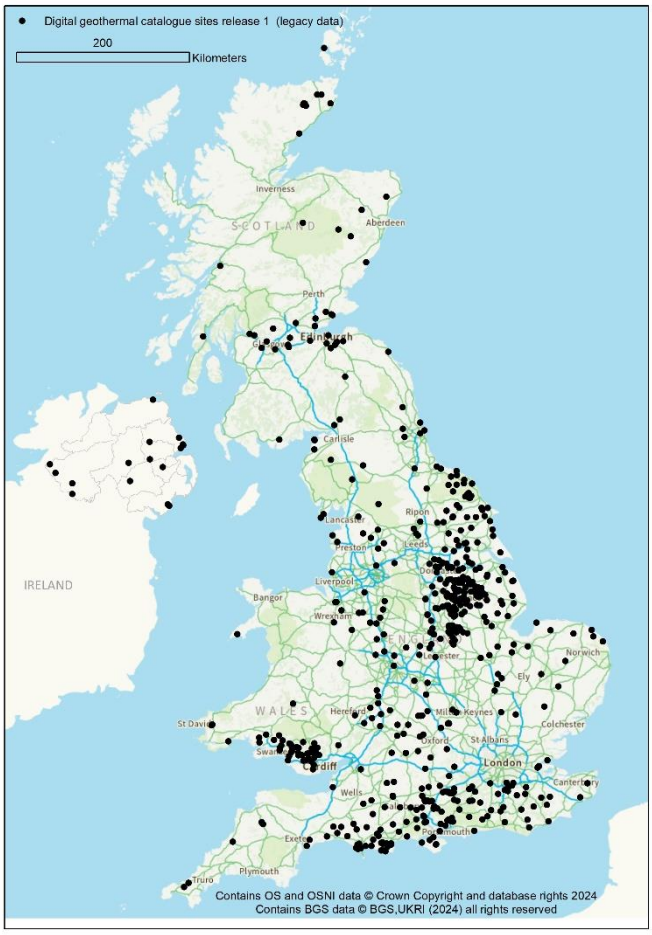

User Guide: BGS UK Geothermal Catalogue first digital release, legacy data

Open report OR/23/060

British Geological Survey

BRITISH GEOLOGICAL SURVEY

OPEN REPORT OR/23/060

User Guide: BGS UK Geothermal Catalogue first digital release, legacy data

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Foreword

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Acknowledgments

This user note accompanies the first digital release of the legacy UK geothermal catalogue. This is derived from a large multi-year programme of work, summarised as 'the 1980s geothermal programme' by numerous BGS, University and other contributors from 1977-1991. Those contributors are sincerely acknowledged for establishing this significant foundation to geothermal energy in the UK. K Rollin, J Busby, S Self and others contributed to digitising the results of the programme.

For this 2024 release, Gerry Wildman at the Coal Authority is thanked in relation to legacy data referenced to British Coal or National Coal Board, Alan Poole at the North Sea Transition Authority and Mark Wilson at the Department for the Economy, Northern Ireland in relation to the legacy hydrocarbon well dataset released under Open Government Licence.

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Summary

This guide accompanies the first digital release from the BGS of the UK legacy geothermal catalogue of temperature measurements, thermal conductivity measurements and heat flow calculations. The geothermal catalogue comprises data contained in numerous historic technical reports (WJ/GE series) from the 1977-1991 Geothermal Energy Programme, delivered by BGS and funded by UK Department of Energy (and both its antecedents and successors), and the European Commission.

Given the UK Government driver to decarbonise the energy system to achieve NetZero by 2050, there is increasing interest in geothermal opportunities within the UK. This has in turn generated an urgent need to make legacy data available in digital form. This release contains 11,821 data points derived from 743 sites – on which a basic set of validation, verification and intellectual property rights (IPR) checks have been undertaken. This comprises around 77% of the legacy geothermal catalogue dataset held by BGS. Alongside this, five of the source reports have also been released onto the NERC Open Research Archive (NORA; see Appendix 1).

This first digital release contains data that has been: spatially located, an identified data source, IPR checked and assessed for release under version 3 of the Open Government Licence (OGL, https://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/). The OGL is equivalent to a CC-BY licence establishing the data release to be suitable for commercial and non-commercial third party use, provided the data source is acknowledged.

The guide describes the background and data sources used in this release, the methods used, limitations on data quality and plans for future releases. The format of the released data is described.

This first release of legacy data focussed on:

- Equilibrated temperature data, heat flow calculations and thermal conductivity data - establishing the data source.
- Collections of temperature datasets e.g. from hydrocarbon and coal boreholes.
- Validation of site / borehole locations.

The main limitations on this dataset are:

- It contains both observation data (temperature and conductivity measurements) alongside interpreted (calculated) heat flow data.
- The data is provided as it was listed in the UK legacy geothermal catalogue. Values have not been validated, so there is a possibility that any errors made in the original reporting have been copied forward.
- Some measures of data quality (e.g. equilibrated temperatures vs bottomhole temperatures) and error were included in the legacy dataset. These have been copied forward but vary by data source and have not been validated here.
- The heat flow calculations and corrections applied are detailed within the original data sources listed and vary between data sources. The heat flow values are reproduced from the legacy geothermal catalogue – subsequent publications (e.g. Busby 2010, Westaway and Younger 2013) document that the magnitude of paleoclimatic and topographic corrections have not been fully recognised, leading to an underestimation of temperatures at depth and heat flows for the UK geothermal resource. As a result, the heat flow dataset in this release should be used with caution and with understanding of these limitations.

Whilst every reasonable check has been made to ensure that these data are appropriate for release, given the challenges in verifying the IPR status of some of the datasets included in the UK geothermal catalogue, a take-down policy is in operation.

Future releases are planned for data for which the IPR is more complex; and for datasets more recent than the 1980s geothermal catalogue. Future developments such as linkages to borehole and well records (through the SOBI, BGS release of hydrocarbon well dataset, NSTA well tops) are under consideration.

1 Introduction

This data represents the first digital release from BGS of the UK legacy geothermal catalogue of temperature measurements, thermal conductivity measurements and heat flow calculations. It has been developed in response to increasing demand for data to support the transition to Net Zero through geothermal energy.

1.1 LEGACY OF THE GEOTHERMAL ENERGY PROGRAMME

Between 1977-1991, the BGS delivered a programme of work referred to as the Geothermal Energy Programme funded by the (then) UK Department of Energy and the European Commission. This resulted in over 70 reports, and the drilling of 7 deep geothermal boreholes across the UK, such as Marchwood 1.

Within that programme, detailed regional studies fed into lower resolution national scale reports, resulting in four released versions of summarised temperature, thermal conductivity and heat flow data. These were compiled in tables and generally referred to as the UK geothermal catalogue (Burley and Edmunds 1978; Gale and Burley 1982, Burley et al. 1984, Rollin 1987; see Appendix 1). This data is recorded from varying depths of boreholes, wells and mines. Each version of the catalogue incorporated some new data, though not all data was listed in subsequent versions. Some data has been republished multiple times. These publications make a significant contribution to geothermal work in the UK, but since then the published geothermal catalogue has not been updated.

During and after the completion of the programme, the data was compiled and eventually uploaded into a BGS Oracle database.

Whilst the published reports of the geothermal catalogue are Crown or BGS/NERC copyright, they contain information derived from a number of data sources. These include:

- Published academic papers
- BGS's own research
- Research undertaken by Oxford University, Imperial College, and the Open University under contract for the BGS-led research programme
- Personal communications
- National Coal Board/British Coal
- Company reports from hydrocarbon exploration wells.

The vintage of the original work and the less rigorous historical attitudes to establishing copyright has resulted in some uncertainties around the IPR for a digital release.

In addition, up until 2023, some of the hydrocarbon well data were not openly accessible; these data could only be accessed via a paywall. As a result, only processed derivatives of these data could be shared by the BGS as maps, products, or within peer-review publications and reports. Recent agreements between the BGS and the North Sea Transition Authority mean that these can now be licenced openly under the Open Government Licence.

Metadata was not originally published alongside this data. Busby et al. (2011) have highlighted the limitations in the quality of the data set. Therefore, before data release, a series of steps were made to validate these data and more fully attribute them with descriptive metadata.

2 Methodology

Data from the UK geothermal catalogue was compiled and then loaded into an Oracle database (tables called 'GTM') in 2003 and 2006. Since that time, the tables had not been updated. Preparing this data for release required checks to be performed on the locations, data sources

and data values, though the size of the database has meant that not all values have been checked.

2.1 OVERVIEW

The UK geothermal catalogue contains data from a wide variety of sources (Appendices 1 and 2) and locations collected over a period of 160 years. The dataset contains observations from Great Britain and Northern Ireland.

This first digital data release focussed on:

- Equilibrated temperature, heat flow and thermal conductivity data.
- Temperature observations from hydrocarbon wells.
- Temperature observations from coal boreholes/coal mines.

Initial work on the dataset focused on the validation of the locations of all sites stored on the BGS Oracle database, which total 1,307 records. For equilibrated temperature, heat flow and thermal conductivity, additional efforts were undertaken to establish data source, as these are disproportionately important to geothermal assessments, and more likely to have been republished multiple times.

The data release is split into the following categories and files:

- Temperature and equilibrated temperature measurements (°C).
- Thermal conductivity measurements ($Wm^{-1}K^{-1}$).
- Heat flow (calculated; mW/m^2).
- Data source information.

Table 1 Numerical summary of the first digital release of the legacy geothermal catalogue.

	Number of sites	Number of temperature and equilibrated temperature measurements	Number of conductivity measurements	Number of heat flow calculations
Total	743	7666	4051	104
Northern Ireland	16	459	271	6
Great Britain	727	7207	3780	98

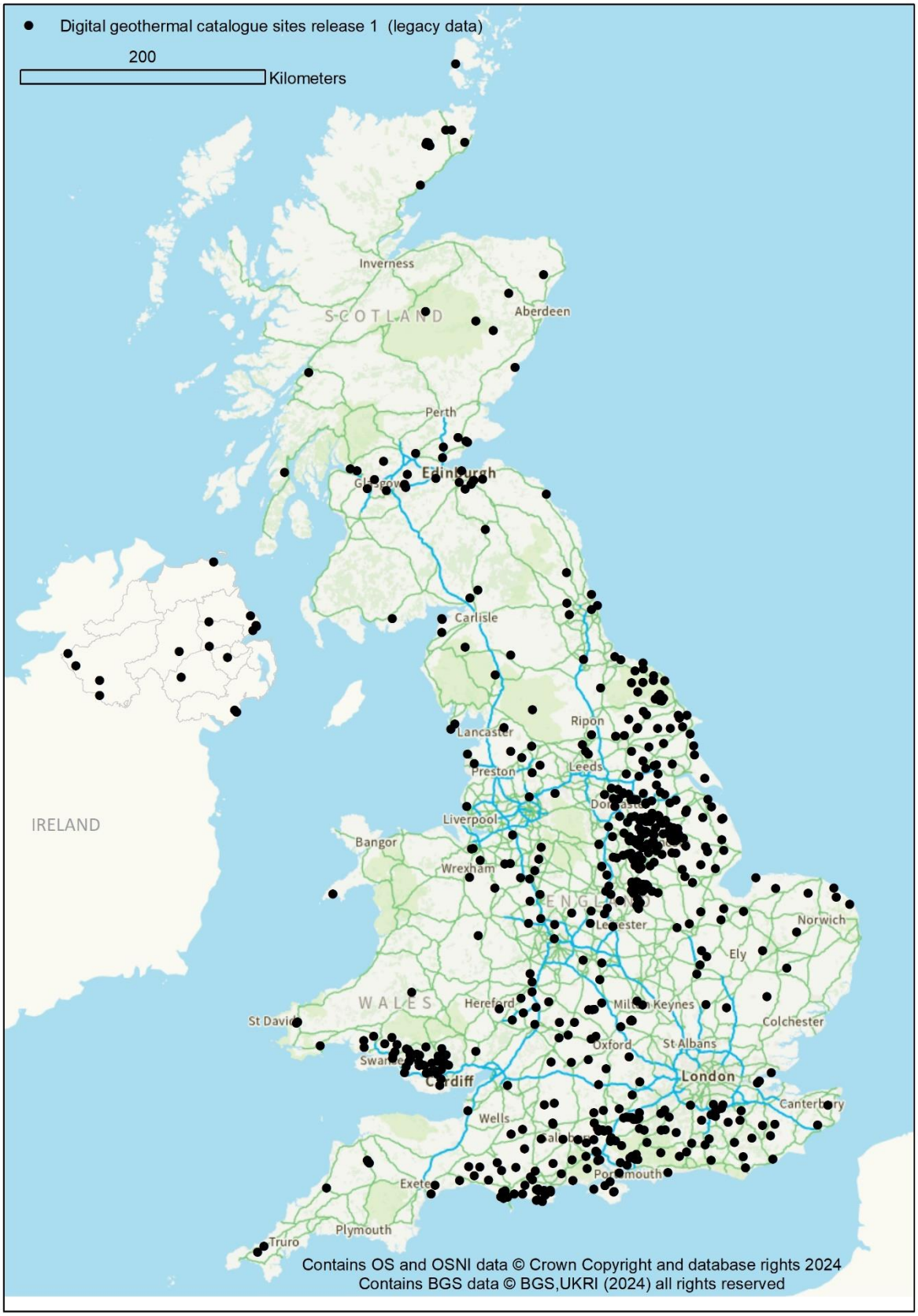

Figure 1 Map showing the distribution of sites in the first digital release of the legacy geothermal catalogue BGS©UKRI.

2.2 VALIDATION OF SITE LOCATIONS

The UK geothermal catalogue contains data from 1,307 locations in Great Britain and Northern Ireland. Many of these locations were specific boreholes, though others are associated with mineral extraction and collieries (coal mines). When work began in May 2023, none of the records had been linked to either the BGS Single Onshore Borehole Index (SOBI) or its Northern Ireland equivalent in the 'GTM' database tables. SOBI is the definitive BGS database of borehole locations and associated metadata in Great Britain. It contains up to date information on borehole metadata including ownership and confidentiality. As the GTM tables were not linked to SOBI, it was possible that information around site confidentiality and location was not up to date.

For Northern Ireland, 16 boreholes were recorded in the UK geothermal catalogue, which were validated in conjunction with the Geological Survey of Northern Ireland (GSNI). For Great Britain 1,291 locations were recorded, all of which required matching to the BGS SOBI to validate their spatial location. To complete this task, a series of steps were undertaken to ensure that sites were mapped and then further validated if the mapping was assessed to be correct.

The coordinates in SOBI did not always match the coordinates for the mapped entries in the GTM tables. In this release, any boreholes matched to SOBI default to the coordinates listed in SOBI. Where there was no match for a location in SOBI, the locations in the release default to those listed in the UK geothermal catalogue. The coordinates for all NI boreholes were individually validated and as such no coordinate mismatch exists.

2.2.1 Sites matched to SOBI

This section details the methods used to match the Great Britain boreholes to SOBI in order to validate their locations. The number of sites across Great Britain (1,291) meant that manual validation would be too time consuming, requiring an automated method.

Matching was done initially using a series of indexed fields including the BGS_ID (SOBI primary key), and the SOBI Ref, against the legacy UK geothermal catalogue. This generated 1,055 matches between the legacy UK geothermal catalogue and SOBI.

The borehole coordinates which were held in both the legacy UK geothermal catalogue and SOBI were then used to validate the match. To do this, the legacy UK geothermal catalogue easting was subtracted from the SOBI easting and the legacy UK geothermal catalogue northing was subtracted from the SOBI northing.

This generated an offset east and an offset north parameter. These were then used to calculate the offset distance in metres between the location recorded in the legacy UK geothermal catalogue, and the location in SOBI; this parameter was labelled as the resultant (Equation 1).

Equation 1: Method used to calculate the offset between locations in SOBI and the GTM.

$$Resultant = \sqrt{(Offset\ East^2 + Offset\ North^2)}$$

The calculation of the resultant allowed a rapid validation of the initial 1,055 database matches. Of the original 1,055 boreholes, 1,029 had a resultant value of 0 m and were presumed a correct match. Of the remaining 26 boreholes, 11 had a resultant value of less than 13 m and were presumed correct.

A further six boreholes had resultant values of more than 100 m. In these cases, the borehole name, date, and depth of temperature measurements from legacy UK geothermal catalogue were compared against the borehole metadata in SOBI. In all these cases it was decided the database matches were most likely correct, despite the large resultant which was attributed to incorrect values in the GTM (geothermal database) tables (Table 2).

Table 2: Examples of borehole and well matches being confirmed despite large resultant values in distance between SOBI and legacy UK geothermal catalogue locations.

SOBI BORE NAME	GTM BORE NAME	Resultant (m)	BGS_ID	Comments
LOCKERLEY 1	LOCKERLEY 1	617.8235994	406622	Name match good, date and total depth also match.
BORDON 1	BORDON 1	1033.174719	426155	Operator total depths and date consistent between records.
HUMBLY GROVE X3	HUMBLY GROVE X3	773.2994245	426538	Operator and date consistent between records.
EGTON HIGH MOOR 1	EGTON MOOR 1	2369.616003	605458	The data source is listed as BP so assumed match to NSTA well (Egton High Moor)
CROPWELL BISHOP 1	CROPWELL BISHOP	3000	232879	Name match good

A small number of sites were simply mismatched to SOBI and in two cases no coordinates were present in SOBI, and the table was updated.

After the initial matching step there were over 200 sites which could not be matched to SOBI. For each of these sites, further matching was attempted, initially using the similarity in borehole name and then manual validation. In total, 48 sites were matched to SOBI which was reduced to 37 after a comparison of coordinate offsets with any site with a resultant offset > 4 km removed (Table 3).

Table 3: Examples of name matching between SOBI and the legacy UK geothermal catalogue.

SOBI BORE NAME	GTM BORE NAME	Easting offset	Northing offset	Resultant (m)	BGS_ID	Correct match
ALBION COLLIERY	ALBION COLLIERY	0	-600	600	377462	Y
FRYSTON COLLIERY NEW FRYSTON	FRYSTON COLLIERY-BEESTON SEAM	-4086	637	4135.355	107555	N
PECKFIELD COLLIERY NO.1 U.G.B.H.	PECKFIELD COLLIERY - BESSTON SEAM	-655	-489	817.402	118293	Y
THORNE COLLIERY	THORNE COLLIERY	-100	300	316.2278	124742	Y
PARSONAGE COLLY. U.G.B.H. 1/76	PARSONAGE COLLIERY - WHITE AND BLACK W14S RETURN	-30	-513	513.8764	792790	Y
PARKSIDE COLLIERY2	PARKSIDE COLLIERY - LOWER FLORIDA L43S RETURN HEADING	-1790	140	1795.467	943682	Y
CWM COLLIERY	CWM COLLIERY	-2000	4400	4833.218	375535	N

2.2.2 Sites not matched to SOBI

In total there were 200 sites which could not be matched to any existing SOBI record, including 110 collieries. Colliery sites often contain tens of similarly named boreholes, some of which may have been drilled underground from within the mine itself. These issues, combined with often incomplete borehole records, makes it very difficult to validate these locations against SOBI. As such for those sites not matched to SOBI, their locations in the GTM tables are presumed correct. As a result, the coordinates supplied in this first release for such sites are taken from the legacy UK geothermal catalogue.

2.3 ESTABLISHING DATA SOURCE

Once locations had been established, the next task was to identify the original data source for the legacy UK geothermal catalogue. Data source had been recorded when the data was compiled to be uploaded into the database in the early 2000s (example in Table 4). In some cases, this was a generic reference to the operator which owned the borehole or well e.g. British Petroleum (BP) or the National Coal Board (NCB). In other cases, it was a book or conference publication reference.

Table 4: Example of thermal conductivity data from the geothermal catalogue showing a National Coal Board (NCB) data source, as prepared in the early 2000s

SOBI Ref.	Borehole	Easting (m)	Northing (m)	Drill Floor Elevation (m)	Ground Level Elevation (m)	Year	Data Source
SE63NW/023	Riccall 1	460620	436420	8	8	1975	NCB
Top depth (m)	**Bottom depth (m)**	**Thermal Cond ($W\ m^{-1}\ K^{-1}$)**	**std dev**	**No. of measurements**	**Type of measurement**	**Rock type**	
370		2.61	0			LMST	
370		2.84	0			LMST	
384		2.23	0			SLST	

However, some code descriptions provided in the legacy UK geothermal catalogue were not sufficient to easily ascribe data source. As a result, additional work was undertaken to better attribute the data source (Table 5). In this case, the reference to historic academic papers were validated and then attributed with a Digital Object Indicator (DOI) as a unique identifier. A full listing of the updated codes is given in Appendix 2.

Table 5: Example of additional attributes added to data sources to legacy UK geothermal catalogue dictionary to better describe data sources.

Original Attributes		Updated Attributes	
Code	**Description**	**Full title**	**Link**
BEN	Benfield	Terrestrial heat flow in Britain	https://doi.org/10.1098/rspa.1939.0157
BN	Bullard and Niblett	Terrestrial heat flow in England	https://doi.org/10.1111/j.1365-246X.1951.tb03007.x
BOT	Bott and others	Terrestrial Heat Flow in North-east England	https://doi.org/10.1111/j.1365-246X.1972.tb06093.x
CHA	Chadwick	Heat-Flow from the Earth at Cambridge	https://doi.org/10.1038/178105a0
IC1	Tammemagi and Wheildon	Terrestrial Heat Flow and Heat Generation in South-west England	https://doi.org/10.1111/j.1365-246X.1974.tb04110.x

2.3.1 Data sources for key sites

This work focused on establishing data source sites with at least one of the following data types:

- Heat flow calculations
- Thermal conductivity measurements
- Equilibrated temperature measurements

It was assumed that this data was most likely to have been published and/or republished in academic journals and there may be restrictions on its reuse.

In total, this encompassed 231 sites of the legacy UK geothermal catalogue. Most of these sites had at least two ascribed data sources. For example, sites with temperature and heat flow observations may be published in separate source locations; as a result not all data sources/republished locations for all data types may be currently listed in the metadata table released for each site.

In some cases, data from boreholes was found to have been republished up to four times. Establishing the timeline of publication was important. Initially information was taken from existing data in the legacy UK geothermal catalogue. For sites where only a generic data source (e.g. 'NCB') or the data source was not published (e.g. Personal Communication) the third/fourth versions of the geothermal catalogue (Burley et al. 1984; Rollin 1987) were checked to establish where the data was republished by the BGS.

2.4 IPR CHECKS AND ASSESSMENT FOR DATA RELEASE

Given the likely commercial use of the digital UK geothermal catalogue, copyright and text / data mining exemptions that apply for personal and non-commercial use do not apply to this release. Therefore, various IPR checks were completed on the dataset.

Once the geothermal catalogue data source had been established and grouped, the IPR and contractual arrangements for the original Geothermal Energy Programme were investigated. This was achieved by examination of acknowledgements within the reports, historical letters and with former BGS staff involved. Whilst copyright of the reports resides with Crown or BGS/NERC, these compilations were made from a range of data sources as detailed in section 1.1, funded by UK Department of Energy and the European Commission. As a result, different IPR checks and processes have been applied to the release dependent on the data source:

- BGS work, university work subcontracted by BGS, and personal communications related to university work subcontracted by BGS – release of this data is subject to risk assessment, with the mitigation that a take-down policy is in place should data be found to have been incorrectly released.
- Data source from published papers which are available under an open licence or where copyright has expired.
- Data source from NCB/British Coal, these data have been shared and their release has been acknowledged by Coal Authority
- Data source from hydrocarbon wells and well reports, the source data is now openly accessible, and the data has been shared and their release has been acknowledged by NSTA.

This digital geothermal catalogue data is approved for release at site level. This means that if a site has a temperature measurement and a heat flow calculation associated: unless the heat flow calculation is released, the temperature will not be released.

A site record owned by an organisation does not mean it retains the rights to all data collected at that location. For example, if a series of thermal conductivity data was collected from a colliery and published in a mining journal, and that conductivity data was used to calculate heat flow, the data associated with the site may rest with more than one publishing company. This complexity has resulted in some sites being excluded from the digital release seemingly at random as data ownership does not align with age, location, or geologic setting. As a result, data from the geothermal catalogue with other sources or unclear sources has not currently been released and will be addressed in future.

Furthermore, some of the data not included in this digital release may be available in the newly released reports on NORA (Appendix 1). This is because of the different IPR, copyright and licensing conditions between the digital dataset release and a legacy PDF report on NORA. The digital dataset is available under OGL, (the equivalent of a CC-BY licence) so it can be used for commercial work with appropriate acknowledgement. Whereas the reports that have been uploaded to NORA are not available for commercial use, see https://nora.nerc.ac.uk/policies.html.

Following the IPR checks, data from 743 of the original 1,307 sites was deemed suitable for release in the first digital catalogue, covering approximately 77% of the measurements/calculated values in the legacy dataset held by the BGS.

2.5 NEW FIELDS ADDED TO THE BGS ORACLE DATABASE

Following the completion of these tasks, updates were made to the BGS Oracle database, derived from the legacy UK geothermal catalogue (GTM). This created a new version of a digital geothermal catalogue which is then used as the source of the current data release.

The new fields added include:

- IPR status
- Site metadata from SOBI, including site confidentiality
- Providing the Northern Ireland borehole and well coordinates in Irish National Grid
- Addition of flags covering quality (section 5).

These changes also provide a baseline metadata standard to incorporate new data for assessing geothermal potential.

3 Technical Information

The data release contains seven comma separated variable (csv) files. The data from the catalogue is split into: thermal conductivity, heat flow and temperature data. These are provided separately for Northern Ireland and Great Britain as the data is in different coordinate systems. A value of -9999 is used to denote a null for numerical fields and 'Not Entered' denotes a null for text fields.

The GB data is encompassed by the bounding box 161570 E, 036330 N to 646070 E, 100889 N in British National Grid. The NI data is encompassed by the bounding box 194800 E, 322900 N to 346259 E, 443525 N in Irish National Grid. Finally, there is a file which contains the metadata for the sites in the geothermal catalogue, a breakdown of the release is given in Table 6.

Table 6: Overview of the files contained in the version one release of the digital geothermal catalogue.

Filename	Description
DGC_V1_GB_COND_DATA.csv	All thermal conductivity observations for GB included within the data release
DGC_V1_GB_HF_DATA.csv	All heat flow calculations for GB included within the data release
DGC_V1_GB_TEMP_DATA.csv	All equilibrated and non-equilibrated observations for GB included within the data release
DGC_V1_NI_COND_DATA.csv	All thermal conductivity observations for Northern Ireland included within the data release
DGC_V1_NI_HF_DATA.csv	All heat flow calculations for Northern Ireland included within the data release
DGC_V1_NI_TEMP_DATA.csv	All equilibrated and non-equilibrated observations for Northern Ireland included within the data release
DGC_V1_SITE_META_DATA.csv	Metadata for all GB and Northern Ireland sites included within the data release

3.1 SITE METADATA

The site metadata file (DGC_V1_SITE_META_DATA.csv) contains a series of well ID fields of which only one, the GEOTHERM_ID is populated in each case. All sites also have a SITE_NAME, Easting, Northing and an EPSG code. A breakdown of the fields is contained within Table 7.

Only the applicable site metadata is included for the Great Britain and Northern Ireland data. The Great Britain data has 16 site metadata columns with the data starting at column 17. For the Northern Ireland sites there are 14 metadata columns with the data starting at column 15.

Table 7: Site metadata field descriptions.

Column Name	Description
GEOTHERM_ID	Unique site identifier in the BGS geothermal database
SITE_NAME	Name of the site
BGS_ID	Unique identifier for boreholes from Great Britain held in BGS Single Onshore Borehole Database
NI_BOREHOLE_ID	Unique identifier for Northern Ireland boreholes
BORE_REGNO	Reference number for onshore boreholes from Great Britain
WELL_ID	Well registration number for onshore boreholes from Great Britain defined by the North Sea Transition Authority
EASTING	The X geographic Cartesian co-ordinate.
NORTHING	The Y geographic Cartesian co-ordinate.
EPSG_CODE	The EPSG code of the co-ordinate reference system
DATE_KNOWN	The date drilling or boring commenced at the site
DRILLED_LENGTH	The length of the shaft or borehole
DRILLING_PURPOSE	The purpose of the borehole/well taken from the BGS Single Onshore Borehole Database
CONDUCTIVITY_DATA	Does site have conductivity data contained within release one
EQUILIBRATED_TEMPERATURE_LOG	Does site have equilibrated temperature log contained within release one
EQUILIBRATED_TEMPERATURE_MEASURMENT	Does site have equilibrated temperature data contained within release one
TEMPERATURE_MEASURMENT	Does site have temperature data contained within release one
HEAT_FLOW_CALCULATION	Does site have a heat flow calculation contained within release one
RT_ELEVATION	Elevation of the site rotary table in m above Ordnance Datum
GROUND LEVEL	Elevation of ground level at site in m above Ordnance Datum
EST_MEAN_ANNUAL_GROUND_TEMP	Estimated mean annual ground temperature in degrees centigrade
SITE_AND_DATA_SOURCE_VALIDATION	Flag to indicate whether the site location and or data source has been validated in the first release of the catalogue
DATA_AVAILABILITY	Flag to indicate what type of data is associated with each site
DATA_SOURCE_1_CODE	The code of the first data source known to be associated with the site
DATA_SOURCE_1_TITLE	The title of the first data source known to be associated with the site
DATA_SOURCE_1_YEAR	The year the first data source known to be associated with the site was published

DATA_SOURCE_1_LINK	The link to the first data source known to be associated with the site
DATA_SOURCE_2_CODE	The code of the second data source known to be associated with the site
DATA_SOURCE_2_TITLE	The title of the second data source known to be associated with the site
DATA_SOURCE_2_YEAR	The year the second data source known to be associated with the site was published
DATA_SOURCE_2_LINK	The link of the second data source known to be associated with the site
DATA_SOURCE_3_CODE	The code of the third data source known to be associated with the site
DATA_SOURCE_3_TITLE	The title of the third data source known to be associated with the site
DATA_SOURCE_3_YEAR	The year the third data source known to be associated with the site was published
DATA_SOURCE_3_LINK	The link of the third data source known to be associated with the site

3.2 CONDUCTIVITY DATA

The conductivity data is supplied across 11 columns containing information on depth, thermal conductivity, lithology, stratigraphy and chronostratigraphy. The catalogue contains point measurements of thermal conductivity, but also average values over a depth range. As a result, all observations have a top and base depth, though for point measurements the value is the same for each. For version one of the digital geothermal catalogue, all of the data are point measurements. A breakdown of the fields relating to thermal conductivity is given in Table 8.

Table 8: Conductivity field descriptions.

Column Name	Description
COND_TOP	Top drilled depth of thermal conductivity in m
COND_BASE	Base drilled depth of thermal conductivity in m
THERMAL_COND	Thermal conductivity value in Watts per metre-kelvin W/(m*K)
THERMAL_COND_SD	Standard deviation of thermal conductivity.
NO_OF_MEAS_FOR_INTERVAL	Number of measurements for interval.
THERMAL_COND_TYPE	Type of thermal conductivity measurements
COND_GEOL_625K	1:625,000 Geological map chronostratigraphy
LITHOLOGY	Lithology where conductivity measurement was taken.
LITHOSTRAT_UNIT_NAME	Lithostratigraphy
OLDEST_CHRONOSTRAT	Oldest chronostratigraphy from conductivity measurement. May be assigned based on Lithostratigraphy
YOUNGEST_CHRONOSTRAT	Youngest chronostratigraphy from conductivity measurement. May be assigned based on Lithostratigraphy

3.3 HEAT FLOW DATA

The heat flow (HF) data provided in this release has not been altered from the information first input into the catalogue (see 5.2). We are unable to confirm if the calculation was undertaken using some or all the values in the catalogue and we have no information as to the chronology of these measurements. For instance, if a site has an associated conductivity measurement which pre-dates the heat flow calculation, that does not mean that the conductivity measurement was available to the interpreter when the heat flow calculation was undertaken.

For each heat flow calculation, there are up to 16 columns of data associated with it. All the heat flow calculations cover a depth interval for a site. Only 2% of the sites have more than one heat flow calculation listed. A breakdown of the fields relating to heat flow is given in Table 9.

Table 9: Heat flow field descriptions.

Column Name	Description
HF_TOP	Top drilled depth of heat flow calculation in m
HF_BASE	Base drilled depth of heat flow calculation in m
NO_OF_COND_MEAS	Number of thermal conductivity measurements made from the site.
NO_OF_TEMP_MEAS	Number of temperature measurements made from the site.
SAMP_INTERVAL	Presumed to be the interval in metres used in the heat flow calculation as described in Burley et al. (1984), Rollin (1987, 1995), aligned to the spacing of thermal conductivity samples
HF_VALUE	Heat flow in milli Watts per square metre (mWm-2)
STANDARD_DEVIATION	Standard deviation of heat flow (described as ‘error range’ in Burley et al. (1984))
HF_CLASS_CODE	Heat flow data Category, see 5.2 for details
HF_CLASS_DESCRIPTION	Heat flow data Category description, see 5.2 for details.
CLIMATE_CORRECTION	Any palaeoclimate correction included in the heat flow in milli Watts per square metre (mWm-2). The information on the derivation of this correction is not listed in the legacy catalogue, but may be described in the original reports and data sources
TOPOGRAPHIC_CORRECTION	Any topographic correction included in the heat flow in milli Watts per square metre (mWm-2). The information on the derivation of this correction is not listed in the legacy catalogue, but may be described in the original reports and data sources
TEMP_AT_MAX_DEPTH	Measured temperature at the maximum depth in degrees Celsius (deg C)
MEAN_THERMAL_CONDUCTIVITY	Arithmetic mean thermal conductivity for the borehole in mM-1K-1
COMMENTS	Any comments associated with the calculation
HF_GEOL_625K_TOP	Top 1:625,000 Geological map lithostratigraphy based on the BGS 1973 geological map.
HF_GEOL_625K_BASE	Base 1:625,000 Geological map lithostratigraphy based on the BGS 1973 geological map.

3.4 TEMPERATURE DATA

The temperature data contains a mixture of equilibrated and non-equilibrated measurements. There are two types of equilibrated measurements, a single equilibrated temperature value and an equilibrated temperature log. For each temperature value there are up to 7 associated columns of data. A breakdown of the fields relating to heat flow is given in Table 10.

Table 10: Temperature field descriptions.

Column Name	Description
DEPTH	Drilled depth of temperature measurement in m
TEMP_OBS_TYPE	Type of temperature observation (see Table 13)
ELAPSED_TIME_HOURS	Elapsed time since circulation finished (hours). Where -1 this is assumed to mean 'during circulation'
TEMP	Temperature in degrees Celsius (degC)
EST_GEOTHERMAL_GRADIENT	Estimated geothermal gradient (degC/km)
CORRECTED_TEMP	Corrected temperature (degC). The information on the derivation of this correction is not listed in the legacy catalogue, but may be described in the original reports and data sources
CORRECTED_TEMP_GRADIENT	Corrected temperature gradient (degC)

4 Licencing the data

To encourage the use and re-use of this data we have made it available under the Open Government Licence www.nationalarchives.gov.uk/doc/open-government-licence/version/3/, with the DOI https://doi.org/10.5285/05569ed5-db0e-4587-807c-58e39ee240fa and subject to the following acknowledgement accompanying the reproduced BGS materials: "Contains British Geological Survey materials © UKRI 2024".

The Open Government Licence is a simple and straightforward licence that allows anyone - businesses, individuals, charities and community groups - to re-use public sector information without having to pay or get permission.
This dataset falls under the BGS' OpenGeoscience portfolio of datasets and services. OpenGeoscience provides a wide range of freely available geoscience information allowing users to view maps, download data, access web services and browse our archive of photos, maps and memoirs. The services available under OpenGeoscience include:

- Map viewers
- Apps
- Map data downloads
- Web services
- Photos and images
- Publications
- Scanned records
- Data collections
- Software

Please refer to OpenGeoscience, see www.bgs.ac.uk/Opengeoscience for more information and a full listing of datasets and services available under this service.

4.1 RATIONALE FOR THE DIGITAL DATA RELEASE UNDER OPEN GOVERNMENT LICENCE (OGL)

The UK and its devolved governments policy emphasis on decarbonisation to meet Net Zero emissions targets, along with drivers for energy security, has generated increased interest in UK geothermal opportunities from a range of stakeholders. This includes the public sector, property developers as well as geotechnical consultants, ground source heat community and deep geothermal companies. Increasing the uptake of geothermal energy technologies requires detailed subsurface information of sufficient quality to make meaningful assessments of geothermal prospectivity.

The legacy UK geothermal catalogue is a significant compilation of data (section 1.1) to inform these assessments. In addition, recent changes in data management practise and responsibilities have resulted in a significant release of previously restricted data, which relate to the geothermal catalogue. For example, the bottom hole temperatures and temperature logs in the geothermal catalogue derived from the UK hydrocarbon industry well data are now available free of charge to all users under an open licence (UK Open Government Licence, a CC-BY by attribution). This is served by the BGS on behalf of the North Sea Transition Authority through the GeoIndex, via the BGS website (https://www.bgs.ac.uk/geological-data/map-viewers/).

Given the drivers and changes, BGS committed funding for a review of the status of these data to enable release of this geothermal dataset. This release follows the first stage of that work, including to improve the metadata available (location; data source) within the digital dataset and to assess risks around IPR of data release. By releasing this data under OGL, the BGS is providing standardised and validated legacy information such that all users can undertake meaningful assessment of data quality for use in geothermal assessments.

4.2 TAKE-DOWN POLICY

If you are a copyright holder and are concerned that you have found material in the data release belonging to you, and have not granted permission for this use, please contact the BGS IPR team at ipr@bgs.ac.uk. Please ensure you include the below information in any communication:

1. Your contact details.
2. The full bibliographic details of the material.
3. The exact and full URL where you found the material.
4. Proof that you are the rights holder and a statement confirming that you are the rights holder or are an authorised representative.

Given proof of valid objection, the BGS will take down the relevant material from the dataset.

4.3 CONTACT INFORMATION

For all data and licensing enquiries please contact:
BGS Data Services
British Geological Survey
Environmental Science Centre
Keyworth
Nottingham
NG12 5GG
Direct Tel: +44(0)115 936 3143
Email: digitaldata@bgs.ac.uk

5 Limitations and data quality

The data quality or uncertainty/error of each data source/data point has not been fully assessed for this release – this would require the measurement method, history for each data point, or an evaluation of the heat flow calculation. The following have been assigned which form a proxy for data availability and potential error in location (Table 11 and Table 12).

Table 11: Description of the data availability flag for each site added to the digital release of the UK geothermal catalogue.

Data Availability Flag	Description
A	Site has one or multiple data types with documented collection methods / calculation methods
B	Site has multiple legacy data types available e.g. equilibrated temperature and conductivity. Collection methods/calculation methods not examined
C	Site has legacy equilibrated temperature or thermal conductivity data. Collection methods/calculation methods not examined
D	Site has only legacy bottomhole temperature data available. Collection methods/calculation methods not examined

Table 12: Description of the location and data source for each site added to the digital release of the UK geothermal catalogue.

Data Source and Location Flag	Description
A	Data source and location are validated
B	Data source is validated but location is unvalidated
C	Location validated but data source yet to be validated
D	Location and data source yet to be validated

Validation of location means that the borehole has been matched to the BGS Single Onshore Borehole Database or validated by the Geological Survey of Northern Ireland. Validation of data source means that the original data source has been specifically identified. In some cases, such as bottom hole temperature from legacy hydrocarbon wells, it is presumed that the data will be contained within the borehole reports, which are now openly available (Section 4.1).

5.1 IMPORTANCE OF EQUILIBRATED TEMPERATURE DATA

During drilling operations fluid/mud is circulated in the well to cool the drill bit, lift rock chippings out of the hole and to balance the formation fluid pressure. This mud is usually cooler than the formation, particularly at significant drilling depths. This results in a cooling effect on the borehole temperature which can take days to equilibrate (e.g. Fryer *et al*. 2018).

Temperatures measured in boreholes during breaks in drilling, or shortly after completion of drilling can be impacted by this cooling effect. This results in an underestimate of temperature. Temperature measurements in the geothermal catalogue were categorised to indicate the method or measurements. This included an assessment of the quality of the equilibrated temperature data.

Table 13 describes the types of temperature measurement included in the geothermal catalogue, from Burley and Edmunds (1978); Burley et al. (1984). It is ordered with most reliable/highest quality data measured in thermal equilibrium at the start of the table.

Table 13: Detailed description of all the types of temperature measurement within the UK geothermal catalogue. Those not included in the first release have been greyed out.

Type of measurement	Code	Explanation
Equilibrium measurements	EQM EQTL EQTLOH	In boreholes in conditions of thermal equilibrium some months or years after drilling, specifically for the purpose of heat flow calculation. **Highest quality/reliability temperature data**
Virgin strata temperatures	VST	This, term is used to describe the measurements more recent than CFM of equilibrium temperatures in coal mines by the Mining Research and Development Establishment of the National Coal Board. Temperatures in specially drilled shot holes. Usually about 2m deep in a freshly exposed coal face, are monitored over periods long enough to ensure that true 'virgin 'strata' (i.e. equilibrium) temperatures are obtained. The techniques used are· described by Harris and Jones (1959) and Verma (1979). Summaries of results are given in Verma (1979 and 1981) and Browning and others (1980). **High quality/reliability temperature data**
Production test measurements	PRO	These are made with thermometers placed in boreholes at the depth of a productive reservoir. They record the temperature continuously during production tests when large volumes of fluid are usually extracted. They are generally unaffected by cooling effects of drilling mud circulation and **give very reliable measurements**.
Coalfield measurements	CFM	These include systematic measurements made by Graham (1922),Jones (1924, 1926) and certain measurements quoted in reports of the British Association (1870, 1871). Temperature measurements were made at the end of horizontal boreholes specially drilled in coal mines. Considerable efforts were made to ensure that the values obtained were unaffected by mine ventilation systems. **Good quality/reliability temperature data**
Drill-stem test measurements	DST	Temperature measurements are usually made during drill-stem tests in hydrocarbon or groundwater exploratory boreholes using maximum thermometers/digital recorders. Should be little affected by the temperature disturbance caused by mud circulation in the borehole if adequate fluid flow occurs. **Generally good quality/reliability temperature data**
Estimated equilibrium temperatures	EST	Estimated equilibrium temperatures based on a series of carefully measured bottomhole temperatures, as recorded for instance in certain boreholes drilled for geothermal exploration purposes. They relate to situations where it was not possible to make equilibrium measurements. **Moderate reliability temperature data**
Mine water temperatures	MWT	Measurements listed in this category were of the temperatures of small flows of water issuing from rock fissures in Cornish mines in the last century, as reported by Henwood and James (1944), and in some coal mines elsewhere. **Moderate reliability temperature data**
Log temperatures	LOG	Bottomhole temperatures extracted from geophysical logs measuring over the length of a borehole rather than a maximum thermometer **Variable reliability temperature data**
Bottomhole temperature measurements	BHT	Taken during routine geophysical logging, not always carefully recorded. Value is usually lower than equilibrium temperature of the rock because of the cooling effect of circulating mud/fluid

		during drilling. (i.e. the minimum temperature) Where known the time between the end of mud circulation and the temperature measurement is quoted in the table. Approximate corrections can be made for time since circulation. **Variable reliability temperature data**

Corrections applied to the temperature data have been discussed by Rollin (1987, 1995). Busby et al. (2011) state in this dataset 'the main correction is that applied to the BHT data (which make up 50% of the catalogue data) to estimate equilibrium temperatures from transient temperatures measured during breaks in drilling. These corrections require the time since circulation of the drilling mud ceased (t_c) and consist of an empirical correction derived from t_c and the magnitude of the temperature or, in later revisions of the catalogue, derived from t_c only. The BHT data where t_c is not known will not have been corrected and are therefore likely to be underestimates of the temperature.'

5.2 HEAT FLOW CALCULATION

Heat flow calculations in this dataset utilise temperature gradient and thermal conductivity data, taking into account some corrections for surface topography and occasionally climatic corrections. The corrections listed in the legacy geothermal catalogue are included in the data release. Burley et al. (1984), Rollin (1987) provide more information for methods used in the geothermal catalogue and some of the variables affecting reliability of heat flow measurements (groundwater flow, variability in conductivities, Table 14).

For example, in heat flow category B (Table 14), the thermal conductivities used in the calculation may be from representative lithology values, as opposed to measured from samples from the borehole. For a limited number of heat flow calculations, the legacy dataset contains a standard deviation value, which acts as measure of the 'error range' in the calculated values (Burley et al. 1984).

More recent publications (e.g. Busby 2010; Westaway and Younger 2013) document that the magnitude of paleoclimatic and topographic corrections have not been recognised, leading to a underestimation of temperatures at depth and heat flows for the UK geothermal resource. **Users should note that the heat flow values provided in this release are reproduced from the 1980s geothermal catalogue and any usage should be with caution, taking into account more recent work.**

Table 14 Summary of the heat flow category code used in the legacy geothermal catalogue.

Heat flow category	Description (from Burley et al. 1984)
A	Temperatures are measured in conditions of thermal equilibrium using resistance thermometers in boreholes with no evidence of groundwater flow. There are enough temperature measurements to give a good representation of the temperature profile of the zone for which the heat flow is calculated, and they are to a depth of at least 200 metres below the surface. Results from boreholes between 100 and 200 metres deep in uniform granite lithology are included in this category where reliable local empirical corrections for recent climatic effects have been made. Conductivities are measured from cores or chippings where the rock is uniform and impermeable, at intervals to give a good representation of the lithologies in the zone for which the heat flow is calculated.
B	Only one of the sets of conditions in A apply (i.e. those referring to temperature or those referring to conductivity measurements), but results are from measurements to a depth of at least 150 metres, and there is no evidence of groundwater flow in the zone for which the heat flow is calculated.
C	Neither of the sets of conditions in A apply, but the measurements are to a depth of at least 100 metres, and there is no evidence of groundwater flow in the zone for which the heat flow is calculated.
D	Measurements in boreholes or mines not covered by other categories.

5.3 LIMITATIONS ON THE DATA RELEASE

In addition to those limitations described above:

- The data is provided as it was listed in the UK legacy geothermal catalogue. Values have not been routinely validated against original data sources so there is a possibility that any errors made in the original catalogue have been copied forward.
- A limited number of spot checks have been carried out comparing the data in the geothermal catalogue with the original data source. This has not been undertaken for all data points, and it is possible inconsistencies and simplifications could exist, for example for depths in deviated wells.
- The data release contains both observation data (temperature and conductivity measurements) alongside interpreted (calculated) heat flow data.
- The lithology, lithostratigraphy associated with the thermal conductivity data is as assigned at the time of study – subsequently these may have been re-interpreted, subdivided or reclassified lithostratigraphy, compared to what is on the composite logs.
- Different analytical methods were used in different laboratories for thermal conductivity (e.g. divided bar, pillbox, needle probe), these are not listed per data point, and errors will vary between methods but are not quantified.
- For thermal conductivity, the date of the analysis; the length of time the samples were stored before analysis and whether samples were dry or saturated are not recorded per data point.
- For temperature, the age of the measurement compared to if the area was undergoing active pumping or water level recovery (mainly applicable to the coalfields) is not recorded.

Other geospatial limitations include:

- Some discrepancies in the locations of observations. These are discussed in detail in section 2.2. The choice for this first release was to default to locations from borehole databases. In the vast majority of cases, this was a discrepancy of either 0 or < 10 m.
- There are some unquantified uncertainties/errors in start heights of boreholes and wells and/or in topographic corrections (the latter discussed in Westaway and Younger 2013).
- Deviated wells may not have been corrected for true vertical depth.
- There is inevitable spatial clustering of data in some areas and significant data gaps in others (Figure 1).
- There are a small number of sites where the observation depths recorded in the catalogue exceed the recorded depths of the boreholes/wells in the BGS databases. These were checked and updated, however in some cases there are conflicting legacy records that have not or cannot be resolved. See Appendix 3 for details.

5.4 DATA NOT INCLUDED IN THIS RELEASE

Several sites from the legacy UK geothermal catalogue have been excluded from this release due to confidentiality or IPR status. This includes:

- Data which has been published in a journal, or other peer reviewed publication, where reuse policy was not clear.
- Data which has been published in a journal, or other peer reviewed publication, which requires a fee to republish.
- Data from a site which is marked as confidential in the borehole databases.

Users should also note that this first release only covers data from the Geothermal Energy Programme, ending with the fourth release of the geothermal catalogue (Rollin, 1987). It does not contain source data from subsequent BGS work e.g. Busby et al. (2011), Farr et al. (2020) or from published papers and datasets post-1987.

5.5 DISCLAIMER

The use of any information provided by the British Geological Survey ('BGS') is at your own risk. Neither BGS nor the Natural Environment Research Council (NERC) or UK Research and Innovation (UKRI) gives any warranty, condition or representation as to the quality, accuracy or

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6 Future releases

Due to the level of interest in the release of these data, a balance had to be struck between including as much data as possible for which the suitability for release could be assigned, and not unduly delaying the release. Future releases are planned to incorporate more data from the legacy UK geothermal catalogue as well as other BGS projects once their status has been verified.

However, further inclusion of data from the legacy UK geothermal catalogue will be dependent on reaching agreements with publishers and in some cases assessing IPR for work published by organisations which have ceased to exist. Data which is in scope for future release includes newer legacy datasets unavailable to previous versions that may be considered, provided both IPR status and suitability for release can be established.

The current spreadsheet release format is for ease and timeliness of release. Other different future release formats may be considered. This includes developments such as linkages to borehole and well records. Future work could consider the quality assurance of the heat flow data, using the scheme developed by Fuchs et al. (2023).

A wide range of new data collection is also possible, for example from the National Coal Board (NCB) and hydrocarbon well records now openly accessible, newer published data, time-series data from monitoring boreholes, etc. Further releases are dependent on future funding and wider developments with geothermal data.

Appendix 1 Versions of the geothermal catalogue and report releases

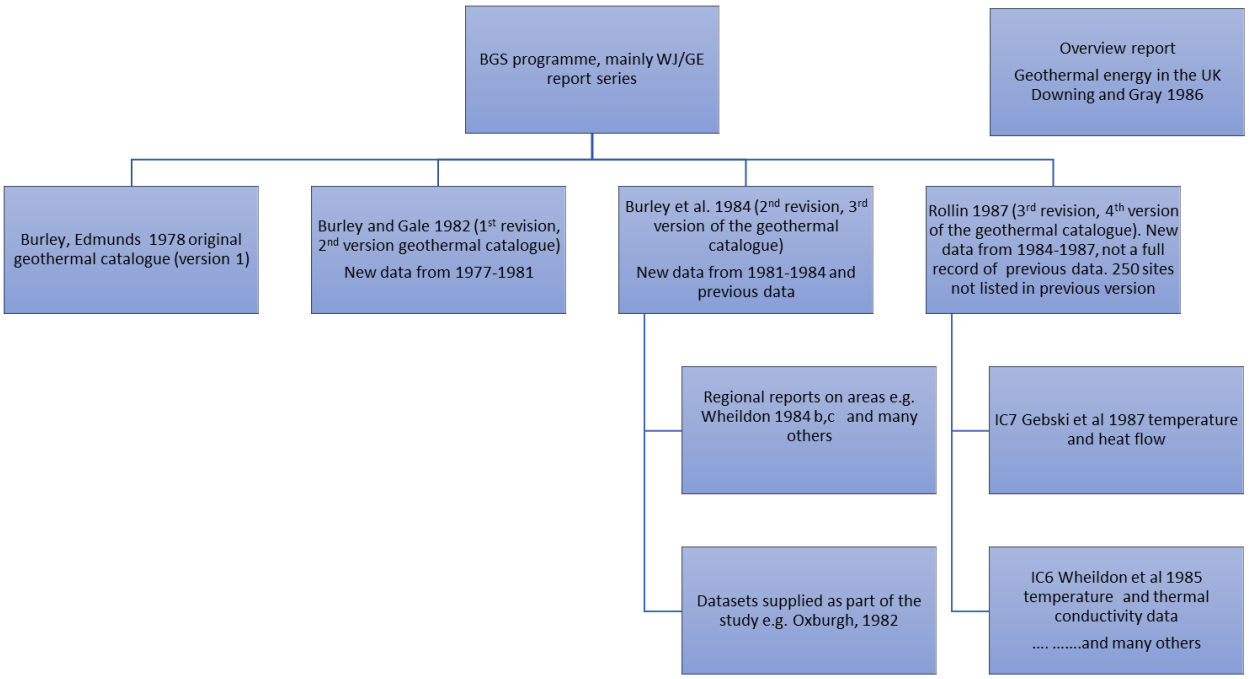

Figure 2 Summary of the relationships between the versions of the geothermal catalogue, together with an indication for the 3rd and 4th version of some of the component data sources feeding into the catalogue.

The following reports have been released to be digitally accessible on the NERC open research archive (NORA, see access/use policy here) in 2024:

BURLEY, A J AND EDMUNDS, W M. 1978. Catalogue of geothermal data for the land area of the United Kingdom. Investigation of the Geothermal Potential of the UK. Department of Energy, London. WJ/GE/78/2 https://nora.nerc.ac.uk/id/eprint/537256 *(this is the first version of the catalogue)*

BURLEY, A J. AND GALE, I N. 1982. Catalogue of geothermal data for the land area of the United Kingdom. First revision: August 1981. Investigation of the Geothermal Potential of the UK. Institute of Geological Sciences, Keyworth. WJ/GE/82/1 https://nora.nerc.ac.uk/id/eprint/537112 *(this is the second version of the catalogue).*

DOWNING, D A. AND GRAY D A. (eds) 1986. Geothermal energy—the potential in the United Kingdom. HMSO, London. WZ/86/3. https://nora.nerc.ac.uk/id/eprint/537257

ROLLIN, K. 1987. Catalogue of geothermal data for the land area of the United Kingdom. Third revision: April 1987. Investigation of the Geothermal Potential of the UK. *British Geological Survey report*. WJ/GE/87/7. https://nora.nerc.ac.uk/id/eprint/537114 *(This is the fourth version of the catalogue)*

GEBSKI J S, WHEILDON, J AND THOMAS-BETTS A. 1987. Investigations of the UK heat flow field (1984-1987). Investigation of the Geothermal Potential of the UK. British Geological Survey. WJ/GE/87/6. https://nora.nerc.ac.uk/id/eprint/537117

The third version (second revision) of the geothermal catalogue was already available on NORA:

BURLEY, A J., EDMUNDS, W M AND GALE, I N. 1984. Catalogue of geothermal data for the land area of the United Kingdom. Second revision: April 1984. Investigation of the Geothermal Potential of the UK. British Geological Survey, Keyworth. WJ/GE/84/20 https://nora.nerc.ac.uk/id/eprint/512272/1/WJGE84020.pdf

The BGS is working through the IPR and copyright assessments towards digital accessibility on NORA of Wheildon et al. (1985a,b; 1985a contains the listings of the datasets), plus the tens of area-specific geothermal energy programme reports (e.g. Wheildon et al. 1984b).

Appendix 2 Updated data source codes

This appendix contains the updated data source codes that were used during the release process (as noted in section 2.3.1, this is not the complete list of data sources).

Table 15 Source codes and links where available

Source Code	Source Code description	Title	Link
AND	Anderson	The loss of heat by conduction from the Earth's crust in Britain	https://doi.org/10.1017/S0370164600020186
BAR	British Association Reports	British Association Committee on Underground Temperatures	
BEN	Benfield	Terrestrial heat flow in Britain	https://doi.org/10.1098/rspa.1939.0157
BN	Bullard and Niblett	Terrestrial heat flow in England	https://doi.org/10.1111/j.1365-246X.1951.tb03007.x
BOT	Bott and others	Terrestrial Heat Flow in North-east England	https://doi.org/10.1111/j.1365-246X.1972.tb06093.x
CHA	Chadwick	Heat-Flow from the Earth at Cambridge	https://doi.org/10.1038/178105a0
IC1	Tammemagi and Wheildon	Terrestrial Heat Flow and Heat Generation in South-west England	https://doi.org/10.1111/j.1365-246X.1974.tb04110.x
IC10	Sams and Thomas-Betts	Heat Flows and temperature predictions in the vicinity of the Carnmenellis pluton. Cambourne School of Mines. Geothermal Energy Project. Int. Rep. 2.	
IC2	Tammemagi and Wheildon	Further data on the South-west England heat flow anomaly	https://doi.org/10.1111/j.1365-246X.1977.tb03721.x
IC3	Wheildon and others	Exploration and Interpretation of the SW England Geothermal Anomaly	https://doi.org/10.1007/978-94-009-9059-3_40
IC4	Wheildon	Heat flow measurement in the Port More Borehole in Wilson, H.E. and Manning, P.I., Geology of the Causeway Coast, Vol 2 Me. Geol. Surv. North. Irel., Sheet 7 pp155-156	https://pubs.bgs.ac.uk/publications.html?pubID=B02142
IC6	Wheildon and others	Further investigations of the UK heat flow field (1981-1984). Investigation of the geothermal potential of the UK	Currently available to view at BGS Library, or PDF from BGS for an admin fee. Working to release on NORA, (1985a,b).
IC7	Gebski. Wheildon and Thomas-Betts	Detailed Investigations of the UK heat flow field (1984-1987). Investigation of the geothermal potential of the UK, WJ/GE/87/006	https://nora.nerc.ac.uk/id/eprint/537117
IC8	Wheildon and others	The Eastern Highlands granites: heat flow production and model studies. Invest. Geotherm. Potent. UK. Brit Geol Survey	Currently available to view at BGS Library, or PDF from BGS for an admin fee. Working to release on NORA.
IC9	Wheildon and others	The Lake District granites: heat flow, heat production and model studies. Invest Geotherm Potent. UK. Brit. Geol. Survey	Currently available to view at BGS Library, or PDF from BGS for an admin fee. Working to release on NORA.
MH	Mullins and Hinsley	Measurement of Geothermal gradients in boreholes. Trans. Inst. Min. Eng. 117, 379–393 (1957).	
OX	Oxford University Heat Flow Group (Department of Geology & Mineralogy)	Compilation of heat flow data measured by the Oxford University Heat Flow Group under contract to the Department of Energy. Unpublished document submitted to J.D. Garnish, ETSU, Harwell.	
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OX3	Bloomer and others	Heat flow in Britain: an assessment of the values and their reliability.	https://doi.org/10.1007/978-3-642-95357-6_31
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OX7	Richardson Cull and others	Heat flow at the Withycombe Farm borehole	https://pubs.bgs.ac.uk/publications.html?pubID=B04525
OX9	Richardson and Jones	Measurements of thermal conductivity of drill cuttings	
PU	Pugh	Geothermal gradients in British lake sediments	https://doi.org/10.4319/lo.1977.22.4.0581
IC11	Burley and Others	Catalogue of geothermal data for the land area of the United Kingdom, WJ/GE/84/020	https://nora.nerc.ac.uk/id/eprint/512272/1/WJGE84020.pdf
BAR1	British Association Committee on Underground Temperatures, 1873.	British Association Committee on Underground Temperatures, 1873. 5th report, Rep. Br. Ass. Advmt. Sci 1872 (Brighton), 128-134	https://archive.org/details/reportofbritisha73brit/page/n237/mode/2up
BAR2	Report of the British association for the advancement of science 39th meeting 1869	Report of the committee for the purpose of investigating the rate of increase of underground temperatures downwards in various localities	https://www.biodiversitylibrary.org/item/93114#page/294/mode/1up
BAR3	British Association Committee on Underground Temperatures, 1871.	British Association Committee on Underground Temperatures, 1871. 3rd report Br. Ass. Advmt. Sci 1872, 29-41	https://archive.org/details/reportofbritisha71brit/page/n127/mode/2up
GSNI1	Geological Survey of Northern Ireland	Geology of the Causeway Coast Volume 2	https://pubs.bgs.ac.uk/publications.html?pubID=B02142
GSNI2	Geological Survey of Northern Ireland	Preliminary report on the Killary Glebe No. I borehole, Coalisland, Co. Tyrone No. 62	

Appendix 3 Discrepancies between geothermal catalogue observation depths and borehole depths

Following the compilation of the data release, an additional data check was performed using the borehole total depth TD and the site observation depths. The well TD was subtracted from the site observation depth and the results filter to identify sites where there was a discrepancy which was ≥ 25 m.

Initially this identified 32 sites from the data release, these records were independently checked by staff from the National Geoscience Data Centre to establish if there was either an error in the matching to SOBI or an error within SOBI. This has resolved issues with seven instances. A description of two sites is given below to illustrate issues with the data in the original catalogue and the difficulties in determining well metadata from limited legacy information.

Table 16 Sites with known discrepancy between SOBI total depth and the depth of measurements in the geothermal catalogue including those not been able to be resolved.

SITE_NAME	BGS_ID	GTM base observation depth (m)	Initial SOBI Length (m)	Updated SOBI length (m)	NGDC Comments
CLITHEROE	26487	327.31	301.42		
BENTLEY COLLIERY	115007	624	596.85		
LOCKTON 8	135423	2125	2081.78		
STAPLEFORD 1	219953	164	88.7	164.290	
WILDS BRIDGE	233719	993	935		
BOTHAMSALL 22	235712	1108	1055		
LANGAR 4	238375	962	905.87		
GROVE 1	239948	1423	1573.07		
GAINSBOROUGH 51D	244015	1548	1495.12	1549.6	1549.60 TD, 1494.74 TVD
GLENTWORTH 3	251580	1663	1127.45	1693	
TARENI COLLIERY	256909	477	396.19		
GWAUN-CAE-GURWEN	257508	311	6		
HAMSTEAD COLL.	308192	646	595.88	595.58	595.58 OR 594.67
NORTH LEIGH	320030	1020	99.27		Mismatch - North Leigh BH (NCB), drilled length is 1028.28m
CAERAU COLLIERY	373218	376	324.92	324	
RHONDA MAIN COLL	373683	323	249.02	249.2	
WYNDAM COLLIERY	374887	552	328.24	327.94	
DEEP NAVIGATION	376723	571	58.22		
NANTGARW COLL.	380574	804	763.22	763.45	
LLANBRADACH COLL	382093	573	521.67		
SEABOROUGH 1	385787	6546	1918.41		
HORNDEAN 1A	425930	409	291.08		Mismatch - Horndean 1A is Horndean X1 (1A), drilled length is 2012.9m
HUMBLY GROVE 1	426525	1609	1529.79		
MARTINSTOWN	440146	2416	2269.61	2455	
LANGTON HERRNG 1	440268	426	397.76		
WAREHAM C6	445249	1867	1174.09		
ARRETON 2	455236	3024	2812.38	2812.4	
YARROWS	605848	143.8	99	99.52	
SUTHERLAND 1	606002	736	627	736.09	
STAITHES 1	620314	1173	1146.35	1146.61	
BOLDEN COLLIERY	840698	1365	474.52		

Site: SEABOROUGH 1

The greatest observation depth for this site is given as 6,456 m whereas the base depth of the site is 1,918.41 m. This is an example an error in the legacy geothermal catalogue, here the depth units were incorrectly recorded as 1,918.41 m = 6,456 ft. This data will be removed from the catalogue as there are three other temperature observations closer to well total depth.

Site: CLITHEROE

The base observation from Clitheroe is 327 m whereas the bottom recorded depth in SOBI is 301.2 m. When SOBI is investigated to look at the material held for Clitheroe there are core descriptions down to 301.2 m (see below) however there is no indication that this is the total depth of the well. Without any other information, the database cannot be updated but there is no definitive information to demonstrate the observation depth from the geothermal catalogue is incorrect.

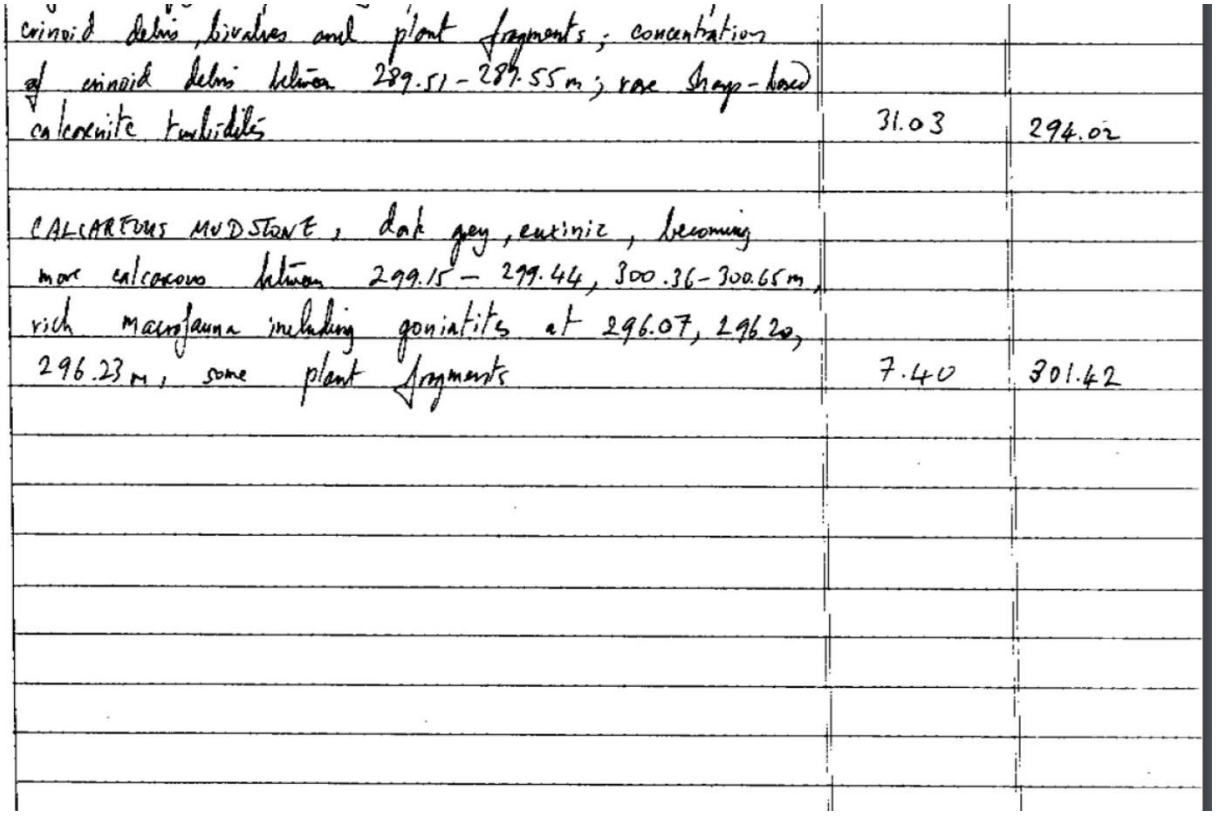

Figure 3 Description from the Clitheroe well example from SOBI, compared to the geothermal sample which was from 327m. Image BGS©UKRI.

Glossary

Term	Explanation
Boreholes	Deep, narrow holes made in the ground, either vertically or inclined, often to locate water or oil.
Conduction	The process by which heat is directly transmitted from one material or substance to another as a result of a difference in temperature.
Convection	The movement within a fluid caused by the tendency of hotter (less dense) material to rise and colder (denser) material to sink under the influence of gravity, which consequently results in circulation and transfer of heat.
Deep geothermal	A term used widely to refer to systems at a depth of more than 500 m below the surface. Systems that produce heat in the 50–200˚C range of medium temperature (steam or water). This may be regarded as medium-high grade heat, suitable for multiple uses including direct use for space heating, industrial and horticulture use or power generation.
Deviated wells	A well which is drilled at an angle from the vertical towards a specific target
Equilibrated temperature	A term used to indicate that the temperature of fluids or rock measured in a borehole or well are the same as the surrounding rock/fluid at that depth (as opposed to being altered by circulation of drilling fluids or pumping)
Geothermal gradient	The increase in temperature with increasing subsurface depth, commonly expressed in degrees Celsius per kilometre (°C/km)
Heat flow	The amount of heat that is transferred per unit of time in the subsurface, measured in this report in milliwatts per square metre (mW/m^2)
Temperature	A measure of hotness or coldness, in this report measured in degrees Celsius (°C)
Thermal conductivity	The rate at which heat passes through the rock or water, expressed as the amount of heat that flows per unit time through a unit area with a temperature gradient of one degree per unit distance, measured in $Wm^{-1}K^{-1}$
Well	Deep, narrow holes made in the ground, either vertically or inclined. Similar to a borehole but that have been used for the testing or production of water, oil, gas or other resources.

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