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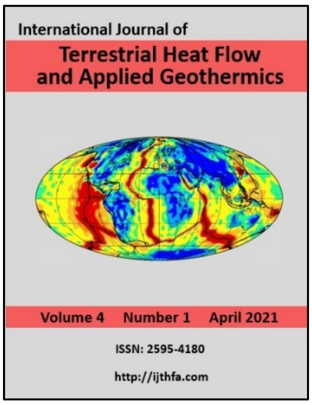

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A new database structure for the IHFC Global Heat Flow Database

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Abstract

Periodic revisions of the Global Heat Flow Database (GHFD) take place under the auspices of the International Heat Flow Commission (IHFC) of the International Association of Seismology and Physics of the Earth's Interior (IASPEI). A growing number of heat-flow values, advances in scientific methods, digitization, and improvements in database technologies all warrant a revision of the structure of the GHFD that was last amended in 1976. We present a new structure for the GHFD, which will provide a basis for a reassessment and revision of the existing global heat-flow data set. The database fields within the new structure are described in detail to ensure a common understanding of the respective database entries. The new structure of the database takes advantage of today's possibilities for data management. It supports FAIR and open data principles, including interoperability with external data services, and links to DOI and IGSN numbers and other data resources (e.g., world geological map, world stratigraphic system, and International Ocean Drilling Program data). Aligned with this publication, a restructured version of the existing database is published, which provides a starting point for the upcoming collaborative process of data screening, quality control and revision. In parallel, the IHFC will work on criteria for a new quality scheme that will allow future users of the database to evaluate the quality of the collated heat-flow data based on specific criteria.

1. Introduction

Studies of Earth's heat flow cover a wide range of scientific and applied aspects, including the planetary energy balance, the driving mechanism of tectonic processes, and the thermodynamic conditions within the interior. Understanding Earth's heat flow is also fundamental for studies about the evolution of hydrocarbon, mineral and geothermal resources, and for planning their exploitation.

The International Heat Flow Commission (IHFC; www.ihfc-iugg.org) has been fostering the compilation of the Global Heat Flow Database (GHFD) since 1963 to provide objective, unique and unambiguous heat-flow data. Those compilations comprise heat-flow data from different acquisition methods, including the common borehole and shallow deep-sea probe sensing determinations, but also measurements using other novel techniques including those conducted in mines and tunnels. Reflecting the needs and technical capabilities at the time, the IHFC has released several data publications during its lifetime, based on the contemporaneous IHFC database compilation (e.g., Lee and Uyeda, 1965; Simmons and Horai, 1968; Jessop et al., 1976; Global Heat Flow Compilation Group, 2013). Beyond the IHFC frame, Hasterok (2019) and Lucazeau (2019) published more recent heat-flow data compilations.

The GHFD provided by Lee (1963), Lee and Uyeda (1965), Lee and Clark (1966), and Simmons and Horai (1968) represented the first printed compilations of heat-flow determinations. The latter reviewed more than 2000 heat-flow observations that were available at that time. Being restricted to printed tables, metadata for each heat-flow location were summarized in a six-digit number representing a code for the geographical region (first number), the geological setting (second number), the type of temperature measurement (third number), the type of thermal-conductivity measurement (fourth number), the type of corrections applied to the heat-flow datum (fifth number), and a quality indication (sixth number). Names of locations were limited to eight characters. Other listed data included the geographical coordinates and elevation, the determined thermal gradient and thermal conductivity values, and the calculated heat-flow density values. In addition, references were given with the last two digits of the year of publication.

During the 1970s, as computer systems became more versatile and the number of heat-flow determinations increased, the IHFC initiated a modification of the previous database structure resulting in a first digital database. With the publication of Jessop et al. (1976), the heat-flow data compilation was made available, for the first time, in a 'computer-compatible format' from the World Data Centre. The principal philosophy of the database was to provide the user with all the information necessary to allow assessment of the heat-flow data quality. Therefore, Jessop et al. (1976) introduced additional database fields compared to the entries listed in the tables of Simmons and Horai (1968). However, the compilers of the database needed to extract the desired information from the original publications and condense the content for a database entry of a maximum of 80 characters for each determination (caused by the state of information technology at that time). The authors were aware of the fact that this limitation in characters hampered a complete description of each heat-flow measurement: "The compilers' aim has been to standardize the description as much as possible, and at the same time to mislead the user as little as possible." The basic structure of that database has remained in place until today and provided the foundation for the most recent compilations of global heat-flow data (Global Heat Flow Compilation Group, 2013; Lucazeau, 2019).

In 2020, the IHFC initiated a fundamental revision of the GHFD. The process involved a multi-national collaborating project in order to consider the current and future needs of the database while taking advantage of state-of-the-art information technology. The goals were to create an authenticated database containing information on the type and quality heat-flow data, and to fulfil the requirements of modern research data infrastructure by including detailed metadata descriptions and database interoperability. To reach these goals, self-organized working groups revised and extended the previous database structure provided in Jessop et al. (1976). Working groups, consisting of terrestrial and marine heat-flow experts from all continents, were established for four parameters that affect heat-flow calculation and interpretation: 1) heat-flow determination methods, 2) metadata and flags, 3) temperature measurements, and 4) thermal rock properties. Intermediate and revised results were presented and discussed among all working-group participants. Based on a common understanding of the database entries, the community discussed different information that is necessary to assess heat-flow quality and uncertainty. These efforts have resulted in a new GHFD structure that is presented here. The new structure will form the basis for all new data entries, as well as for the reassessment of existing data.

2. Background on heat flow, temperature and thermal conductivity

Heat flow represents a derivative measure. It depends on the nature, intensity and distribution of subsurface heat sources, thermal rock properties, and the dominant heat transfer mechanism. In general, the sources of heat are related to processes in the Earth's interior, as well as to solar radiation. Heat transfer from higher to lower temperatures occurs through three distinct mechanisms: conduction, convection, and radiation. Convection is often the most relevant mechanism in fluids. In solids, conduction is the dominant heat transport mechanism as long as temperatures do not exceed several hundred degrees Celsius, above which radiation plays an increasingly dominant role. The Earth's lithosphere is solid and exhibits relatively low temperatures in most areas, allowing the general assumption that the heat flow is essentially by conduction. By definition, heat flow q is positive in the direction of decreasing temperature. Where conduction dominates, regional variations in heat flow can be related to changes in the basal heat flux and/or lithological composition of the crust, allowing, e.g., advanced geodynamic interpretations.

The q value stated above represents the best estimate of the mean vertical conductive heat flow through the Earth's surface (often called terrestrial surface heat flow). Quite often, the heat flow determined at a certain location is influenced by near-surface factors and convective heat-transport processes and may therefore include non-steady state, non-vertical, and non-conductive heat transfer components (Figure 1). Possible influences are, e.g., non-vertical heat flow (heat refraction), topographical effects, non-steady state conditions (sedimentation/erosion effects, paleoclimate), additional heat sinks and sources, and convective fluid flow (e.g., Haenel et al., 1988).

Because many factors influence the determination of terrestrial surface heat flow, it is important that the database documents the heat-flow determination method, the estimation methods for temperature and thermal conductivity, and any corrections applied to the terrestrial estimate. For a comprehensive overview of techniques and methods on temperature and conductivity measurements, we refer to Haenel et al. (1988), Beardsmore and Cull (2001), Schön (2015), and Palacios et al. (2019).

In accordance with Fourier's first equation of heat conduction, the heat flow (q in mW/m²) is proportional to the temperature difference across an interval (temperature gradient $\frac{dT}{dz}$ in K/km) and the associated average thermal conductivity (λ in W/[m·K]), where z is positive downwards. For the simplified case of one dimensional flow of heat through the Earth's layers and surface (in z direction), this can be expressed by

$$q = -\lambda_z \frac{dT}{dz} \quad (1)$$

However, if the vertical heat-flow density is somehow distorted or rocks are anisotropic, temperature gradient and conductivity need to be considered as vector and tensor variables, respectively.

For heat-flow calculations, the average thermal conductivity must reflect the in-situ conditions of the embedded rock and the natural flow of heat through the continuous interval. As contactless in-situ measurement is difficult to achieve, representative measurements on reasonable sized rock specimens that reflect the compositional variation of the associated heat-flow interval should also consider the respective subsurface pressure, temperature, and fluid saturation conditions. Techniques used for the determination of thermal conductivity should be selected and applied according to the sample characteristics (rock type, grain size, texture, sample conditions, expected conductivities, etc.) and their ability to be applied under the required pressure, temperature and fluid conditions. In addition, any contact resistance additionally introduced between sample and applied technique needs to be minimized.

Temperature gradients reflecting the background thermal regime should not be affected by transient perturbations like hydraulic flow, drilling or climatic effects, geological (sedimentation/erosion) effects and others. Besides transient effects, structural effects resulting from heat refraction or rapid change in topography can cause local thermal anomalies that need to be considered if the measurements are used for terrestrial heat-flow determinations. In practice, subsurface temperatures are determined in boreholes, mines and tunnels, and in lake or oceanic sediments. A large number of techniques are available to accurately measure rock temperatures for different operational conditions, and/or to correct measurements so that they reflect equilibrium conditions. When free of perturbing effects, the recorded temperatures should allow the computation of interval thermal gradients with an inaccuracy of less than 1%.

3. The new database structure

The revision of the current database descriptions and considerations (Jessop et al., 1976; Lucazeau, 2019) resulted in some fundamental modifications that were partly triggered by the development and possibilities of modern database applications, and partly by methodological developments of heat-flow determination since 1976. The key innovation compared to the former heat-flow database structure is the implementation of a **parent-child system** for heat-flow data determined at each location. Therein, the parent level contains the main location information (e.g., geographical position, and associated metadata). For each location, only one parent entry is possible, containing also the most representative vertical terrestrial **heat-flow value q of the site** (Figure 1).

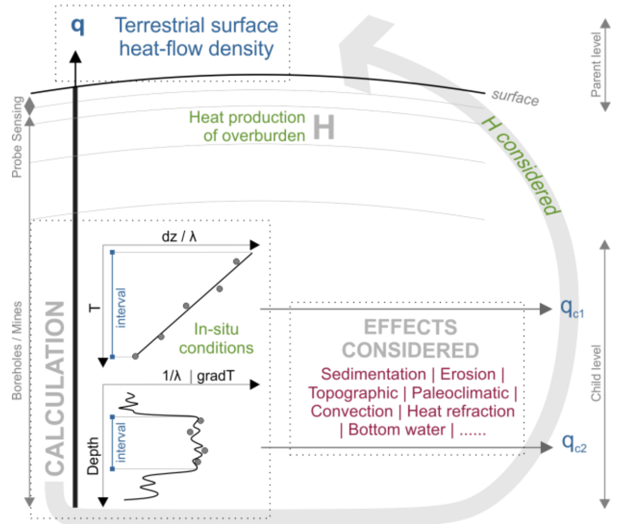

Figure 1 - Concept of terrestrial heat flow q (parent level) and examples of associated heat-flow values q_{ci} (child level). Abbreviations: H: radiogenic heat production, T: temperature, dz/λ: thermal resistance.

Each parent entry is associated with at least one but often multiple child entries (child level). Child entries contain heat-flow values (q_c) with associated conductivity and temperature data, ideally with explicit consideration of conductivity and temperature related perturbations such as diurnal, annual and climatic surface-imposed temperature distortions (including those made below the sea-floor); heat refraction due to conductivity contrasts or anisotropy; convective disturbance or heat redistribution; topographic effects; sedimentation or erosion, and other similar quantifiable disturbances. The consideration and correction of these effects is reported individually for each heat-flow child value using meta-data flags. Multiple **child entries** for a location result from either determinations obtained over different depth intervals and/or determinations of different age, status, methodological approaches and/or by different authors.

Based on the reported child values, and considering additional radiogenic heat production within the overburden where relevant, the q-value of the parent element represents the best estimate of the mean vertical conductive heat flow through the Earth's surface due to sources in the interior of the Earth (Figure 1, right side). q is almost always a subject of interpretation, which might change over time due to advances in processing and understanding, or as more 'child' data become available. In Figure 1, the determination of heat flow in any one depth interval would yield one child entry (specific to the interval) under the location's parent entry. This system allows for a consistent documentation of all of the available site-specific heat-flow values and supporting data, and provides structure for future estimates to be added. It also simplifies the selection of the relevant representative location values for research incorporating large data sets into continental or global numerical models.

Depending on the applied methodology of heat-flow determination, relevant methodology-dependent database fields are included in the entries for the parent and child level, respectively. For example, heat-flow determinations based on probe-sensing data, such as for lake or marine (oceanic) measurements (as performed by a temperature or a combined temperature and thermal conductivity sensing heat-flow probe), require different database fields to assess data quality than heat-flow determinations based on temperature data collected from greater depth intervals (e.g., from boreholes and mines) and their associated thermal conductivities (Figure 2). Compared to the previous subdivision of the GHFD into continental and oceanic data, which assigned multiple meanings for some database fields (where data came from borehole/mines at the continents and from heat-flow probes in the oceans, respectively), the new database structure is more flexible. It accommodates, for example, the documentation of International Ocean Discovery Program (IODP) borehole-derived heat-flow data in the marine setting as well as the documentation of heat-flow derived from oceanic probe techniques in on-shore lakes (continental setting).

The new database structure includes 56 individual fields that hold information related to the heat-flow determinations. Subsets of these fields were aggregated into single fields in the former database to save storage space, but this constraint is now obsolete. For the same reason of saving storage space, the former database sometimes grouped closely located sites under a single item number for continental data, which is also no longer required. Furthermore, the database is no longer limited by character field length. Therefore, classical codes or short names are not carried forward into the new database. Due to the availability of other digital products (like cartographic services, geological maps, stratigraphic classifications, etc.), some database fields can be automatically filled by a computer using map overlays or database queries. Therefore, some fields in the new database structure refer to such services, e.g., digital object identifier (DOI; www.doi.org) or international geo sample number (IGSN; www.geosamples.org). Fields will be auto-filled when users do not provide the respective data (e.g., elevation). Reference formats, linked to a separate heat-flow literature database, should allow the user to easily access the main publications. As well as each main publication, additional publications may also be stored, as well as supplementary references necessary to understand data collection and processing methods. In contrast to the previous database structure, the new structure does not provide specific fields for recording radiogenic heat production measurements. These data are rarely reported and were scarce in the old database (reported for <2% of entries). However, measurements of radiogenic heat production are now considered in the metadata item for terrestrial heat-flow value corrections (i.e., considering the heat production of the overburden, see also below, sections 3.1 and 3.2).

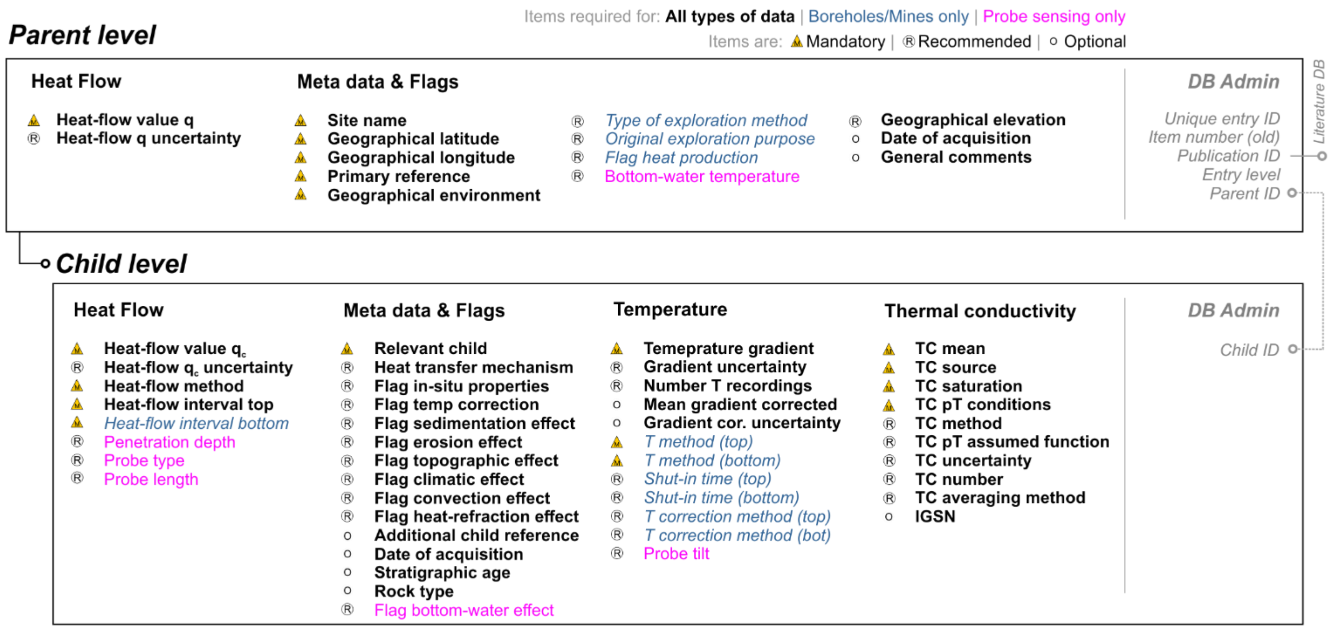

Figure 2 - New database structure showing associated data fields for the parent and child level relevant for all entries (bold black), for classical heat-flow determinations based on deeper temperature recordings from borehole and mines (blue italic), for shallow marine probe sensing data (purple), and for data administration (grey).

Based on the observation that many of the database fields established by Jessop et al. (1976) held no respective data entries, the new structure also assigns a 'desirability' classification to each field according to its relevance for understanding the quality of the reported heat-flow value; 'mandatory', 'recommended', or 'optional'. This desirability classification emphasizes mandatory fields that delineate minimum requirements for heat-flow values to be entered into the database. The number of mandatory fields depends on the measurement type — 18 for data from boreholes and mines, and 15 for data from probe sensing. Recommended fields number 26 for both methods, and greatly assist a full quality assessment of the heat-flow value. Optional fields number nine for both methods. In addition, auto-added fields (e.g., continents or oceans from coordinates) and new database fields for administrative organization were introduced. A comprehensive list of all fields, including field desirability classifications and examples of associated data, is included as an Appendix.

The new database structure aims to provide all of the relevant information for geothermal and heat-flow researchers to enable individual quality control, data exchange and comparison studies. Fields used for the organization and administration of the database are invisible to general users but are necessary to ensure database integrity and to enable internal data queries. Other types are numerical fields (1 to 8 bytes, containing integer, float and double precision format), string fields with up to 255 characters, and date fields (in the POSIX date format, YYYY-MM-DD, and year, YYYY).

Each database field is described in detail in the following subsections. For each database field, six characteristics are listed to describe the field thoroughly: (1) the field name ('name'), (2) the internal field short name ('short name') used for data queries, (3) the field unit ('unit') defining the associated physical S.I. unit of the stored value if applicable, (4) the data type of the data field ('type'), (5) the range of values expected or allowed in the database field ('range'), and (6) a detailed explanation ('description') of the database field. For the sake of clarity, the fields are grouped in four main thematic groups, namely: heat-flow density, metadata and flags, temperature, and thermal conductivity.

3.1 Fields: Heat-flow density

A lot of contextual information is required to understand the status and quality of a reported heat-flow value and its method of computation (see Table 1 and Figs. 1 and 2). The fields reporting the heat-flow value and its uncertainty (entries 1 and 2 in Table 1) are relevant to both parent and child level entries. Other fields are required depending on the associated methodological approach. An informed assessment of the suitability of specific heat-flow data for geothermal and other analyses requires a detailed description of the conditions of data collection and processing. This is further explained in section 3.2 (Metadata and Flags). The Appendix provides an example of the application of this new IHFC database structure to an existing dataset.

Heat-flow type and heat-flow transfer mechanism are two new criteria added to the database structure. The heat-flow type is related to the introduced parent-child database structure for reporting a heat-flow determination at a particular site. If the reported heat flow reflects a value for the terrestrial heat flow of the selected location, it is of type 'surface heat flow' (short: q; only parent level), if the reported value reflects the heat-flow density of a certain depth interval at the location, it is of type 'child heat flow' (type = q_c; only in child level). By introducing the item 'heat-flow type' a parent-child system of location values (parent: q) and depth-specific interval values (child: q_c) is established allowing, for example, depth-dependent geothermal analyses. The second criterion, heat-flow transfer mechanism, allows the classification of a reported heat-flow value according to the dominant heat-transfer process influencing the heat-flow value.

Table 1 - Heat-flow density related database fields.
*Fields are relevant for parent level (**P**) and/or child level (**C**), and belong to data derived from boreholes/mines (**B**) and/or probe sensing (**S**). Options not applicable for respective fields are grey-coloured. Symbols beside the field name: (M) mandatory, (R) recommended.*

	Field name and properties			Field Description
1	Heat-flow value		(M)	| **P** | **C** | – | **B** | **S** |
	Short name	q | qc		For parent: Terrestrial surface heat-flow value (q) after all corrections for instrumental and environmental effects. For child: Any kind of heat-flow value (qc)
	Unit	mW/m²		
	Type	double(7)		
	Range	-999,999.9 – 999,999.9 (P entries) -999,999.9 – 999,999.9 (C entries)		
2	Heat-flow uncertainty		(R)	| **P** | **C** | – | **B** | **S** |
	Short name	q_unc | qc_unc		Uncertainty standard deviation of the reported heat-flow value as estimated by an error propagation from uncertainty in thermal conductivity and temperature gradient (corrected preferred over measured gradient).
	Unit	mW/m²		
	Type	double(7)		
	Range	0-999,999.9		
3	Heat-flow method		(M)	| P | **C** | – | **B** | **S** |
	Short name	q_method		Principal method of heat-flow density calculation from temperature and thermal conductivity data. Allowed entries: [Fourier's Law or Product or Interval method: product of the mean thermal gradient to the mean thermal conductivity with reference to a specified depth interval] / [Bullard method: heat-flow value given as the angular coefficient of the linear regression of the thermal resistance vs. temperature data (used when there is a significant variation of thermal conductivity within the depth range over which the temperatures have been measured)] / [Boot-strapping method: iterative procedure aimed at minimize the difference between the measured and modelled temperatures by solving the 1-D steady-state conductive geotherm (radiogenic heat production of rocks is accounted for)] / [other: specify]
	Unit	-		
	Type	Text(255)		
	Range	*from description*		
4	Heat-flow interval top		(M)	| P | **C** | – | **B** | **S** |
	Short name	q_top		Describes the true vertical depth of the top end of the heat-flow determination interval relative to the land surface/ocean ground surface.
	Unit	m		
	Type	Double(6)		
	Range	-		
5	Heat-flow interval bottom		(M)	| P | **C** | – | **B** | S |
	Short name	q_bot		Describes the true vertical depth of the bottom end of the heat-flow determination interval relative to the land surface.
	Unit	m		
	Type	Double(6)		

No.	Field name and properties		Field Description
	Range - 		
6	Penetration depth *Short name* hf_pen *Unit* m *Type* Double(5), 3 digits, 2 decimal places *Range* 0-999.99		| P | **C** | – | B | **S** | Depth of penetration of marine probe into the sediment.
7	Probe type *Short name* hf_probe *Unit* - *Type* Text(255) *Range* *from description*	Ⓡ	| P | **C** | – | B | **S** | Type of heat-flow probe used for measurement. Name one of the following options: [Corer-outrigger] / [Bullard probe] / [Lister Violin-Bow probe] / [Ewing probe] / [Other probe] / [Unspecified]
8	Probe length *Short name* hf_probeL *Unit* - *Type* Double(5), 3 digits, 2 decimal places *Range* 0-999.99	Ⓡ	| P | **C** | – | B | **S** | Length of heat-flow probe.

3.2 Fields: Metadata and Flags

This subgroup of database fields hold information relevant for a thorough evaluation of the reported heat-flow values. The subgroup covers a large range of topics and information (Table 2), for example, geographical data to locate a reported heat-flow value and publication data to trace its original source (reference publication). In addition, data fields provide information on the general geological setting and on the application of any instrumental or environmental corrections.

*Table 2 - Metadata and flag fields of the heat-flow database. Fields are relevant for parent level (**P**) and/or child level (**C**), and belong to data derived from boreholes/mines (**B**) and/or probe sensing (**S**). Options not applicable for respective fields are grey-coloured. Symbols beside the field name: Ⓜ mandatory, Ⓡ recommended, ○ optional.*

No.	Field name and properties		Field Description
9	Site name *Short name* name *Unit* - *Type* Text(255) *Range* -	Ⓜ	| **P** | C | – | **B** | **S** | Specification of the (local) name of the related heat-flow site or the related survey. Should be consistent with the publication.
10	Geographical latitude *Short name* lat *Unit* degrees *Type* DECIMAL (7), 2 digits,5 decimal places according to ISO 6709 *Range* -90 to +90	Ⓜ	| **P** | C | – | **B** | **S** | Latitude is a geographic coordinate that specifies the north–south position of a point on the Earth's surface. The Equator has a latitude of 0°, the North Pole has a latitude of 90° North (written +90), and the South Pole has a latitude of 90° South (written −90). Numeric values (2 digits) with 5 decimal places are used for this database item instead of the N or S format (e.g., -80.00000 instead of 80° S).
11	Geographical longitude *Short name* lng *Unit* degrees *Type* DECIMAL (8), 3 digits, 5 decimal places according to ISO 6709 *Range* -180 to +180	Ⓜ	| **P** | C | – | **B** | **S** | Longitude is a geographic coordinate that specifies the east–west position of a point on the Earth's surface. The Prime Meridian, which passes near the Royal Observatory, Greenwich, England, is defined as 0° longitude by convention. Positive longitudes are east of the Prime Meridian, and negative ones are west. Numeric values (3 digits) with 5 decimal places are used for this database instead of the E or W format (e.g., -50.00000 instead of 50° W).
12	Geographical elevation *Short name* elevation *Unit* m *Type* FLOAT 32 *Range* -12,000 – +9,000	Ⓡ	| **P** | C | – | **B** | **S** | The elevation of a geographic location is its height above or below mean sea level. Caution: different national reference systems are used. Also the reference level may be diverse depending on the study (drilling, lake, marine…).
13	Heat-flow transfer mechanism *Short name* q_tf_mech *Unit* - *Type* Text(255) *Range* choice box (*from description*)	Ⓡ	| P | **C** | – | **B** | **S** | Specification of the predominant heat transfer mechanism relevant for the reported heat-flow value. Possible entries: [Conductive] / [Convective unspecified] / [Convective upflow] / [Convective downflow] / [unspecified]
14	Primary reference *Short name* Ref_1	Ⓜ	| **P** | C | – | **B** | **S** | References related to the respective heat-flow entry in the form:

Unit - [First author_Year_Title_Journal/Publisher_doi
Type Text(255)
Range -

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15 Additional references — O

| P | **C** | – | **B** | **S** |

Short name Ref_2
Unit -
Type Text(255)
Range -

Additional references related to the respective heat-flow entry in the form: [First author_Year_Title_Journal/Publisher_doi

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16 Date of acquisition — R

| **P** | **C** | – | **B** | **S** |

Short name q_acq
Unit -
Type POSIX date (YYYY-MM)
Range 1900-recent year

The entry gives the year of the acquisition of the heat-flow data (which may differ from the year of publication). If the month is unknown use 01, i.e. for the year 2005 use 2005-01. For non-unique time values, define a range in the format: 'YYYY-MM; YYYY-MM'

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17 Basic geographical environment — M

| **P** | C | – | **B** | **S** |

Short name env
Unit -
Type Text(255)
Range choice box (*from description*)

Describes the general geographical setting of the heat-flow site (not the applied methodology). Possible database entries:

[Onshore (continental)] / [Onshore (lake)] / [Offshore (continental)] / [Offshore (marine)] / [unspecified]

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18 Relevant child — M

| P | **C** | – | **B** | **S** |

Short name childcomp
Unit -
Type BIT field
Range [Yes] / [No] / [Unspecified]

Specifies whether the child entry is used for computation of representative location heat-flow values at the parent level or not.

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19 Type of exploration method — R

| **P** | C | – | **B** | S |

Short name method
Unit -
Type Text(255)
Range choice box (*from description*)

Specification of the general means by which the rock was accessed by temperature sensors for the respective data entry. Possible database entries:

[drilling] / [mining] / [tunneling] / [probing (lake)] / [probing (ocean)] / [unspecified]

---

20 Original excavation purpose — R

| **P** | C | – | **B** | S |

Short name expl
Unit -
Type Text(255)
Range choice box (*from description*)

Main purpose of the original excavation providing access for the temperature sensors. Possible database entries:

[hydrocarbon] / [underground storage] / [geothermal] / [mapping] / [mining] / [tunneling] / [unspecified]

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21 Flag in-situ thermal properties — R

| P | **C** | – | **B** | **S** |

Short name corr_IS_flag
Unit -
Type BIT field
Range [Yes] / [No] / [Unspecified]

Specifies whether the in-situ pressure and temperature conditions were considered to the reported thermal conductivity value or not.

---

22 Flag temperature corrections (instrumental correction) — R

| P | **C** | – | **B** | **S** |

Short name corr_T_flag
Unit -
Type BIT field
Range [Yes] / [No] / [Unspecified]

Specifies if corrections to the measured temperature data were performed.

---

23 Flag heat production of the overburden (heat-flow correction) — R

| **P** | C | – | **B** | **S** |

Short name corr_HP_flag
Unit -
Type BIT field
Range [Yes] / [No] / [Unspecified]

Specifies if corrections to the calculated heat flow consider the contribution of the heat production of the overburden to the terrestrial surface heat flow q.

---

24 Flag sedimentation effect (temperature correction) — R

| P | **C** | – | **B** | **S** |

Short name corr_S_flag
Unit -
Type BIT field
Range [Yes] / [No] / [Unspecified]

Specifies if corrections with respect to sedimentation/subsidence effects were performed to the reported heat-flow value.

---

25 Flag erosion effect (heat-flow correction) — R

| P | **C** | – | **B** | **S** |

Short name corr_E_flag

Specifies if corrections with respect to erosion effects were applied to the reported heat-

<table>
<tr><td></td><td>Unit -
Type BIT field
Range [Yes] / [No] / [Unspecified]</td><td></td><td>flow value.</td></tr>
<tr><td>26</td><td>Flag topographic effect (heat-flow correction)
Short name corr_TOPO_flag
Unit -
Type BIT field
Range [Yes] / [No] / [Unspecified]</td><td>®</td><td>| P | C | – | B | S |
Specifies if corrections with respect to topographic effects were applied to the reported heat-flow value.</td></tr>
<tr><td>27</td><td>Flag transient climatic effect (heat-flow correction)
Short name corr_PAL_flag
Unit -
Type BIT field
Range [Yes] / [No] / [Unspecified]</td><td>®</td><td>| P | C | – | B | S |
Specifies if corrections with respect to climatic conditions (glaciation, post-industrial warming, etc.) were applied to the reported heat-flow value.</td></tr>
<tr><td>28</td><td>Flag convection processes (heat-flow correction)
Short name corr_CONV_flag
Unit -
Type BIT field
Range [Yes] / [No] / [Unspecified]</td><td>®</td><td>| P | C | – | B | S |
Specifies if corrections with respect to convection effects were applied to the reported heat-flow value, e.g., due to numerical modeling.</td></tr>
<tr><td>29</td><td>Flag bottom-water temperature (heat-flow correction)
Short name corr_BWT_flag
Unit -
Type BIT field
Range [Yes] / [No] / [Unspecified]</td><td>®</td><td>| P | C | – | B | S |
Specifies if corrections with respect to transient bottom-water temperature effects were applied to the reported heat-flow value.</td></tr>
<tr><td>30</td><td>Flag heat refraction effect (heat-flow correction)
Short name corr_HR_flag
Unit -
Type BIT field
Range [Yes] / [No] / [Unspecified]</td><td>®</td><td>| P | C | – | B | S |
Specifies if corrections with respect to refraction effects, e.g., due to significant local conductivity contrasts, were applied to the reported heat-flow value.</td></tr>
<tr><td>31</td><td>Lithology
Short name geo_lith
Unit -
Type Text(255)
Range Multiple choice box (from description)</td><td>O</td><td>| P | C | – | B | S |
Dominant rock type/lithology within the interval of heat-flow determination. Use existing BGS rock classification scheme for naming the lithology.

Multiple entries for intervals of mixed lithology are semicolon-separated.</td></tr>
<tr><td>32</td><td>Stratigraphic age
Short name geo_strat
Unit -
Type Text(255)
Range Multiple choice box (from description)</td><td>O</td><td>| P | C | – | B | S |
Stratigraphic age of the depth range involved in the reported heat-flow determination. Possible database entries (following the international commission on stratigraphy): [Cenozoic] / [Mesozoic] / [Mesozoic – Cretaceous] / [Mesozoic – Jurassic] / [Mesozoic – Triassic] / [Paleozoic] / [Paleozoic – Permian] / [Paleozoic – Carboniferous] / [Paleozoic –Devonian] / [Paleozoic – Silurian] / [Paleozoic – Ordovician] / [Paleozoic – Cambrian] / [Proterozoic] / [Neo–Proterozoic] / [Meso–Proterozoic] / [Paleo–Proterozoic] / [Archean] / [unspecified] - Multiple age entries are semicolon-separated.</td></tr>
<tr><td>33</td><td>Bottom-water temperature
Short name wat_temp
Unit °C
Type Double(5), 3 digits, 2 decimal places
Range 0-999.99</td><td>®</td><td>| P | C | – | B | S |
Seafloor temperature where heat-flow measurements were taken. e.g. PT 100 or Mudline temperature for ODP data.</td></tr>
<tr><td>34</td><td>General comments
Short name q_comment
Unit -
Type Text(255)
Range -</td><td>O</td><td>| P | C | – | B | S |
Text field of 255 characters in size for any further comments to the reported heat-flow determination.</td></tr>
</table>

3.3 Fields: Temperature

The measured subsurface temperature and calculated temperature gradients have a first order control on heat-flow determination. In total, eleven database fields are included in the new database structure (Table 3, Figure. 2). Nine of the fields are newly established, although partly reflect previous descriptive codes that will no longer be used. The new fields of *measured* and *corrected* temperature gradients allow the reporting of subsequent corrections using newly developed approaches that are more sophisticated. In addition, the methods, correction approaches and shut-in times/relaxation times can be reported separately for the top and bottom depths of the respective heat-flow interval, allowing the proper reporting of different data origins and methodologies, if relevant, for each interval boundary. Ideally, a reported corrected temperature gradient shall represent the site-specific, unperturbed, terrestrial conductive conditions of the reported heat-flow interval at depth.

*Table 3 - Temperature related database fields. Fields are relevant for parent level (**P**) and/or child level (**C**), and belong to data derived from boreholes/mines (**B**) and/or probe sensing (**S**). Options not applicable for respective fields are grey-coloured. Symbols beside the field name: M mandatory, ® recommended, O optional. N/A = not available.*

No.	Field name and properties		Field Description
35	Calculated or inferred temperature gradient *Short name* T_grad_mean_meas *Unit* K/km *Type* Double(8), 5 digits, 2 decimal places *Range* -99,999.99 – 99,999.99, N/A	M	| P | **C** | – | **B** | **S** | Mean temperature gradient measured for the heat-flow determination interval.
36	Temperature gradient uncertainty *Short name* T_grad_unc_meas *Unit* K/km *Type* Double(8), 5 digits, 2 decimal places *Range* -99,999.99 – 99,999.99, N/A	®	| P | **C** | – | **B** | **S** | Uncertainty standard deviation of mean measured temperature gradient [T_grad_mean_meas] as estimated by an error propagation from the uncertainty in the top and bottom temperature determinations.
37	Mean temperature gradient corrected *Short name* T_grad_mean_cor *Unit* K/km *Type* Double(8), 5 digits, 2 decimal places *Range* -99,999.99 – 99,999.99, N/A	O	| P | **C** | – | **B** | **S** | Mean temperature gradient corrected for borehole (drilling/mud circulation) and environmental effects (terrain effects/topography, sedimentation, erosion, magmatic intrusions, paleoclimate, etc.) Name the correction method in the corresponding item.
38	Corrected temperature gradient uncertainty *Short name* T_grad_unc_cor *Unit* K/km *Type* Double(8), 5 digits, 2 decimal places *Range* -99,999.99 – 99,999.99, N/A	O	| P | **C** | – | **B** | **S** | Uncertainty standard deviation of mean corrected temperature gradient [T_grad_mean_meas] as estimated by error propagation from the uncertainty of the measured gradient and the applied correction approaches.
39	Temperature method (top) *Short name* T_method_top *Unit* - *Type* Text(255) *Range* *from description*	M	| P | **C** | – | **B** | S | Method used for temperature determination at the top of the heat-flow determination interval. Possible types of temperature measurements are: [BHT]: bottom hole temperature--uncorrected / [CBHT]: corrected bottom hole temperature / [DST]: drill stem test / [PT100]: Pt-100 probe / [PT1000]: Pt-1000 probe / [LOG]: continuous temperature logging using semiconductor transducer, or thermistor probe / [CLOG]: corrected temperature log / [DTS]: distributed temperature sensing / [CPD]: Curie Point/Depth estimates / [XEN]: Xenolith / [GTM]: Geothermometry / [BSR]: bottom-simulating seismic reflector / [APCT/SET-2]: Ocean Drilling Temperature Tool / [SUR]: surface temperature
40	Temperature method (bottom) *Short name* T_method_bot *Unit* - *Type* Text(255) *Range* *from description*	M	| P | **C** | – | **B** | S | Method used for temperature determination at the bottom of the heat-flow determination interval. Possible types of temperature measurements are: [BHT]: bottom hole temperature--uncorrected / [CBHT]: corrected bottom hole temperature / [DST]: drill stem test / [PT100]: Pt-100 probe / [PT1000]: Pt-1000 probe / [LOG]: continuous temperature logging using semiconductor transducer, or thermistor probe /[CLOG]: corrected temperature log / [DTS]: distributed temperature sensing / [CPD]: Curie Point/Depth estimates / [XEN]: Xenolith / [GTM]: Geothermometry / [BSR]: bottom-simulating seismic reflector / [APCT/SET-2]: Ocean Drilling Temperature Tool] / [SUR]: surface temperature
41	Shut-in time (top) *Short name* T_shutin_top *Unit* hours *Type* Integer(5) *Range* 0 – 99,999	®	| P | **C** | – | **B** | S | Time of measurement at the interval top in relation to the end of drilling/end of mud circulation. Positive values are measured after the drilling, negative values are measured during the drilling.
42	Shut-in time (bottom) *Short name* T_shutin_bot *Unit* hours *Type* Integer(5) *Range* 0 – 99,999	®	| P | **C** | – | **B** | S | Time of measurement at the interval bottom in relation to the end of drilling/end of mud circulation. Positive values are measured after the drilling, negative values are measured during the drilling.
43	Temperature correction method (top)	®	| P | **C** | – | **B** | S |

<table>
<tr><td></td><td>Short name T_corr_top
Unit -
Type Text(255)
Range from description</td><td></td><td>Applicable only if gradient correction for borehole effects is reported. Approach applied to correct the temperature measurement for drilling perturbations at the top of the interval used for heat-flow determination. Possible entries:
[HP: Horner plot] / [CSM: Cylinder source method] / [LSM: Line source explosion method] / [IM: Inverse numerical modelling] / [Other (‘Authors’)] / [unspecified] / [not corrected]</td></tr>
<tr><td>44</td><td>Temperature correction method (bottom)
Short name T_corr_bot
Unit -
Type Text(255)
Range from description</td><td>Ⓡ</td><td>| P | C | – | B | S |
Applicable only if gradient correction for borehole effects is reported. Approach applied to correct the temperature measurement for drilling perturbations at the bottom of the interval used for heat-flow determination. Possible entries:
[Horner plot] / [Cylinder source method] / [Line source explosion method] / [Inverse numerical modelling] / [Other published correction (‘Authors’)] / [unspecified] / [not corrected]</td></tr>
<tr><td>45</td><td>Number of temperature recordings
Short name T_numb
Unit -
Type Integer(6)
Range null, 0-999,999</td><td>Ⓡ</td><td>| P | C | – | B | S |
Number of discrete temperature points (e.g. number of used BHT values, log values or thermistors used in probe sensing) confirming the mean temperature gradient [T_grad_mean_meas]. Not the repetition of one measurement at a certain depth.</td></tr>
<tr><td>46</td><td>Probe tilt
Short name T_tilt
Unit deg
Type Integer(2)
Range null, 0-99</td><td>Ⓡ</td><td>| P | C | – | B | S |
Tilt of the marine heat-flow probe.</td></tr>
</table>

3.4 Fields: Thermal Conductivity

Nine specific fields in the database describe the topic *thermal conductivity* in the context of heat-flow determination (Table 4). Six of the fields are newly established and partly picked up former applied descriptive codes. Most of the fields in this group are important to understand the quality and status of the reported thermal conductivity value, and are therefore relevant to the evaluation of the quality of the associated heat-flow value. Ideally, the reported mean thermal conductivity of an interval (item 47 in Table 4) shall consider the in-situ pressure, temperature and fluid conditions prevailing within the relevant heat-flow interval at depth.

*Table 4 - Thermal conductivity related database fields. Fields are relevant for parent level (**P**) and/or child level (**C**), and belong to data derived from boreholes/mines (**B**) and/or probe sensing (**S**). Options not applicable for respective fields are grey-coloured. Symbols beside the field name: ⚠M mandatory, Ⓡ recommended, O optional. n/a = not available.*

<table>
<tr><th></th><th>Field name and properties</th><th></th><th>Field Description</th></tr>
<tr><td>47</td><td>Mean thermal conductivity
Short name tc_mean
Unit W/(mK)
Type Double(4), 2 digits, 2 decimal places
Range 0 - 99.99, N/A</td><td>⚠M</td><td>| P | C | – | B | S |
Mean conductivity in vertical direction representative for the interval of heat-flow determination specified in fields 4+5. The value should reflect the true in-situ conditions for the corresponding heat-flow interval.</td></tr>
<tr><td>48</td><td>Thermal conductivity uncertainty
Short name tc_unc
Unit W/(mK)
Type Double(4), 2 digits, 2 decimal places
Range 0 - 99.99, N/A</td><td>Ⓡ</td><td>| P | C | – | B | S |
Uncertainty of mean thermal conductivity [tc_mean] given as one-sigma standard deviation.</td></tr>
<tr><td>49</td><td>Thermal conductivity source
Short name tc_source
Unit -
Type Text(255)
Range from description</td><td>⚠M</td><td>| P | C | – | B | S |
Nature of the samples upon which thermal-conductivity was determined [tc_mean] Name one of the following options:

[outcrop samples] / [core samples] / [cutting samples] / [mineral computation] / [well log interpretation] / [core-log integration] / [in-situ probe] / [other (‘shortly describe the method’)] / [unspecified]</td></tr>
<tr><td>50</td><td>Thermal conductivity method
Short name tc_meth
Unit -
Type Text(255)
Range from description</td><td>Ⓡ</td><td>| P | C | – | B | S |
Method used for thermal-conductivity determination for [tc_mean]. Name one of the following options and fill in ‘technique’ or ‘approach’:

[Lab - (‘Technique’)] / [Probe (‘Technique’)] / [Well logging (‘Technique’)] / [Estimation (‘Approach’)] / [Unspecified]
<u>Techniques:</u> [divided bar/comparator apparatus] / [optical scanning] / [needle probe] / [half space line source] / [transient plane source] / [pulse technique] / [Angstrom method/periodic heating] / [Mongelli method/plane-heat source] / [other (‘shortly describe the method’)]
<u>Approaches:</u> [correlation with nearby values (e.g. other boreholes)] / [lithology mixtures</td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td>with values from literature] / [water content] / [chlorine content] / [estimated from lithology]</td></tr>
<tr><td>51</td><td>Thermal conductivity saturation
Short name tc_satur
Unit -
Type Text(255)
Range from description</td><td>M</td><td>| P | C | – | B | S |
Saturation state of the rock sample studied for thermal conductivity [tc_mean]. Name one of the following options:

[drymeas = Dry measured (rocks have been technically dried before measurement)] / [satmeas = Saturated measured (rocks have been technically saturated completely before measurement)] / [insitusatmeas = Insitu saturated measured (measurements with probe sensing / marine measurements)] / [coresatmeas = saturated measured on closed sediment cores on-board] / [satcalc = Saturated calculated (thermal conductivity has been calculated from dry measured rocks, porosity and pore-filling fluid)] / [recov = As recovered (rocks have been preserved and measured in close to their natural saturation state)] / [other = Other] / [unspec = Unspecified] / [n/a = N/A (if not measured on samples)]</td></tr>
<tr><td>52</td><td>Thermal conductivity pT conditions
Short name tc_pTcond
Unit -
Type text, 255
Range from description</td><td>M</td><td>| P | C | – | B | S |
Qualified conditions of pressure and temperature under which the mean thermal conductivity [tc_mean] used for the heat-flow computation was determined. ‘Recorded’ means determinations under true conditions at target depths (e.g. sensing in boreholes). ‘Replicated conditions’ means determinations where the conditions at target depths are replicated under laboratory conditions. ‘Actual’ means the condition at the respective depth of the heat-flow interval.

[Unrecorded ambient pT conditions] / [Recorded ambient pT conditions] / [Actual in-situ (pT) conditions] / [Replicated in-situ (p)] / [Replicated in-situ (T)] / [Replicated in-situ (pT)] / [Unspecified]</td></tr>
<tr><td>53</td><td>Thermal conductivity assumed pT function
Short name tc_pTfunc
Unit -
Type Text(255)
Range from description</td><td>R</td><td>| P | C | – | B | S |
Technique or approach used to correct the measured thermal conductivity towards in-situ pT conditions:

[Published correction (‘Authors’)] / [Site-specific experimental relationships]

Replace ‘Authors’ with the publication or approach used for the correction.</td></tr>
<tr><td>54</td><td>Thermal conductivity number
Short name tc_numb
Unit -
Type Integer(4)
Range 0-9,999</td><td>R</td><td>| P | C | – | B | S |
Number of discrete conductivity determinations used to determine the mean thermal conductivity [tc_mean], e.g. number of rock samples with a conductivity value used, or number of thermistors used by probe sensing techniques..
Not the repetition of one measurement on one rock sample or one thermistor.</td></tr>
<tr><td>55</td><td>Thermal conductivity averaging methodology
Short name tc_strategy
Unit -
Type Text(255)
Range from description</td><td>R</td><td>| P | C | – | B | S |
Strategy that was employed to estimate the thermal conductivity [tc_mean] over the vertical interval of heat-flow determination:
[Random or periodic depth sampling (number)] / [Characterize formation conductivities (number of samples per formation?)] / [Well logging] / [Computation from probe sensing] / [Other] / [unspecified]</td></tr>
<tr><td>56</td><td>IGSN
Short name Ref_IGSN
Unit -
Type Text(255)
Range -</td><td>O</td><td>| P | C | – | B | S |
International Geo Sample Numbers (IGSN, semicolon separated) for rock samples used for laboratory measurements of thermal conductivity.</td></tr>
</table>

3.5 Fields: Database administration and auto-added fields

The fields in this group are used for database queries and administration. They are auto-generated, and not editable by a general user. The fields are: heat-flow type (parent or child); entry id (unambiguous identity number for each entry), parent id, child id, quality code (from the old database), editor and last-modification date or literature id for the link to the associated literature database. Content fields auto-filled from coordinates and GIS data web services are, for example: continent, country, geographic domain or region, palaeoclimate region, and underwater-feature (oceanic crust region).

4. Summary and outlook

The new database structure makes it possible to interconnect the GHFD to other digital data resources, like map data (continents, geology, ocean region), sample data (IGSNs), library services (DOI), etc. The new GHFD structure will also provide a basis for a live plausibility check for newly submitted data. New data relevant to heat-flow determinations may in the future be generated through the interpretation of spatial exploration data and satellite images (e.g. spatial data of bottom surface reflections or other temperature raster data). Such data may be linked to the GHFD as an add-on service in a separate database. The main goal of past editions of the GHFD was to provide a comprehensive compilation of global heat-flow data. The new GHFD shall be also the starting point to deliver well documented and reliable heat-flow values, representing the new IHFC database standard. Aligned with this publication, a restructured version of the existing database is published as a data publication (Fuchs et al., 2021). The process of data screening and revision of incomplete, wrong or empty data entries will be an ongoing process and will rely on this new database. In parallel, the IHFC will provide a new quality scheme allowing a user to select appropriate reliable heat-flow values for their specific purpose.

5. Acknowledgments

The International Heat Flow Commission initiated the discussion on the revision of the Global Heat Flow Database during the 27th IUGG General Assembly (Montreal, Canada, 07/2019) – the new structure presented in this study is the first public result of this initiative. Many scientists, current and former members of the IHFC, have contributed to the discussion, opening new perspectives and sharing their experiences. We would like to thank, in particular Alan Jessop, as well as (in alphabetic order): Irina Artemieva, Vladimír Čermák, Christoph Clauser, Petr Dědeček, Andrea Förster, Valiya Mannathal Hamza, Derrick Hasterok, Shaopeng Huang, Francis Lucazeau, Sukanta Roy, and Jan Szewczyk. We also thank Kirsten Elger (GFZ) for fruitful discussions on digital data and information services.

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Appendix

Appendix A - List of database fields for heat-flow data derived from boreholes and mines. M = mandatory, R = recommended, O = optional.

Entry	Category	No.	Boreholes / Mines		Unit	Example
Parent entry	Heat Flow	1	**Heat-flow value q**	M	mW/m²	74.2
		2	Heat-flow q uncertainty	R	mW/m²	4.6
	Meta data & flags	9	**Site name**	M	-	Gt Ss 1/85
		10	**Geographical latitude**	M	°	54.31308
		11	**Geographical longitude**	M	°	13.03945
		14	**Primary reference**	M	-	Fuchs & Förster, 2010
		17	**Geographical environment**	M	-	Onshore (continental)
		19	Type of exploration method	R	-	Drilling
		20	Original exploration purpose	R	-	Geothermal
		23	Flag heat production	R	-	YES
		12	Geographical elevation	R	m	8.7
		16	Date of acquisition	O	-	2010-01-01
		34	General comments	O	-	-

Entry	Category	No.	Field		Unit	q_{c1}	q_{c2}	q_{c3}	q_{c4}
Child entry	Heat Flow	1	**Heat-flow value q_c**	M	mW/m²	79.3	68.4	73.3	75.9
		3	**Heat-flow method**	M	-	Interval	Interval	Interval	Interval
		4	**Heat-flow interval top**	M	m	1405.9	1434	1421.3	1483.8
		5	**Heat-flow interval bottom**	M	m	1415.95	1475.3	1434.3	1498.1
		2	Heat-flow qc uncertainty	R	mW/m²	9.4	7.9	2.2	3.5
	Data flags	18	**Relevant child**	M	-	YES	YES	YES	YES
		13	Heat-flow transfer mechanism	R	-	Conductive	Conductive	Conductive	Conductive
		21	Flag in-situ properties	R	-	YES	YES	YES	YES
		22	Flag temp correction	R	-	NO	NO	NO	NO
		24	Flag sedimentation effect	R	-	NO	NO	NO	NO
		25	Flag erosion effect	R	-	NO	NO	NO	NO
		26	Flag topographic effect	R	-	NO	NO	NO	NO
		27	Flag transient climate effect	R	-	NO	NO	NO	NO
		28	Flag convection effect	R	-	NO	NO	NO	NO
		30	Flag heat refraction effect	R	-	NO	NO	NO	NO
		15	Additional references	O	-	n/a	n/a	n/a	n/a
		16	Date of acquisition	O	-	01.01.2010	01.01.2010	01.01.2010	01.01.2010
		31	Lithology	O	-	Sandstone	Sandstone	Sandstone	Sandstone
		32	Stratigraphic age	O	-	Triassic	Triassic	Triassic	Triassic
	Tempera-ture	35	**Temperature gradient**	M	K/km	23.53	22.65	27.25	23.07
		39	**T method (top)**	M	-	LOG	LOG	LOG	LOG
		40	**T method (bottom)**	M	-	LOG	LOG	LOG	LOG
		36	Gradient uncertainty	R	K/km	0.1	0.1	0.1	0.1
		41	Shut-in time (top)	R	hr	26280	26280	26280	26280
		42	Shut-in time (bottom)	R	hr	26280	26280	26280	26280
		43	T correction method (top)	R	-	n/a	n/a	n/a	n/a
		44	T correction method (bottom)	R	-	n/a	n/a	n/a	n/a
		45	Number T recordings	R	-	40	164	52	56
		37	Average gradient corrected	O	K/km	n/a	n/a	n/a	n/a
		38	Gradient cor. uncertainty	O	K/km	n/a	n/a	n/a	n/a
	Thermal conductivity	47	**TC mean**	M	W/(mK)	3.37	3.02	2.69	3.29
		49	**TC source**	M	-	core samples	core samples	core samples	core samples
		51	**TC saturation**	M	-	satmeas	satmeas	satmeas	satmeas
		52	**TC pT conditions**	M	-	Replicated in-situ (T)	Replicated in-situ (T)	Replicated in-situ (T)	Replicated in-situ (T)
		48	TC uncertainty	R	W/(mK)	0.4	7.9	2.2	4.6
		50	TC method	R	-	optical scanning	optical scanning	optical scanning	optical scanning
		53	TC pT assumed function	R	-	Published correction (Sass et al., 1992)	Published correction (Sass et al., 1992)	Published correction (Sass et al., 1992)	Published correction (Sass et al., 1992)
		54	TC number	R		3	3	3	1
		55	TC averaging method	R		Random or periodic depth sampling (3)	Random or periodic depth sampling (3)	Random or periodic depth sampling (3)	Random or periodic depth sampling (1)
		56	IGSN	O	-	n/a	n/a	n/a	n/a

Appendix B - List of database fields for heat-flow data derived from probe sensing. M = mandatory, R = recommended, O = optional.

Entry	Group	No.	Sensing		Unit	Example
Parent entry	*Heat Flow*	1	**Heat-flow value q**	M	mW/m²	195
		2	Heat-flow q uncertainty	R	mW/m²	20
	Meta data & flags	9	**Site name**	M	-	HC19-07
		10	**Geographical latitude**	M	°	46.7450
		11	**Geographical longitude**	M	°	-126.1767
		14	**Primary reference**	M	-	Harris et al. (2020)
		17	**Geographical environment**	M	-	Offshore (Marine)
		23	Flag heat production	R		
		12	Geographical elevation	R	m	-2636
		16	Date of acquisition	O	-	2013-08-13
		34	General comments	O	-	Cascadia subduction zone
						q_{c1}
Child entry	*Heat Flow*	1	**Heat-flow value q_c**	M	mW/m²	113
		3	**Heat-flow method**	M	-	Bullard
		4	**Heat-flow interval top**	M	m	0
		6	Penetration depth	R	m	3.5
		7	Probe type	R	m	Lister
		8	Probe length	R	m	3.5
		2	Heat-flow qc uncertainty	R	mW/m²	11
	Data flags	18	**Relevant child**	M		YES
		13	Heat-flow transfer mechanism	R	-	Conductive
		21	Flag in-situ properties	R	-	Yes
		22	Flag temp correction	R	-	No
		24	Flag sedimentation effect	R	-	Yes
		25	Flag erosion effect	R	-	No
		26	Flag topographic effect	R	-	No
		27	Flag transient climate effect	R	-	No
		28	Flag convection effect	R	-	No
		29	Flag bottom-water effect	R	-	No
		30	Flag heat refraction effect	R	-	No
		33	Bottom-water temperature	R	°C	3.7
		15	Additional references	O	-	
		16	Date of acquisition	O	-	2015-01
		31	Lithology	O	-	
		32	Stratigraphic age	O	-	
	Tempera-ture	35	**Temperature gradient**	M	K/km	126
		36	Gradient uncertainty	R	K/km	1.3
		45	Number T recordings	R	-	11
		46	Probe tilt	R	-	
		37	Average gradient corrected	O	K/km	
		38	Gradient cor. uncertainty	O	K/km	
	Thermal conduc-tivity	47	**TC mean**	M	W/(mK)	0.9
		49	**TC source**	M	-	in-situ
		51	**TC saturation**	M	-	in-situ - saturated
		52	**TC pT conditions**	M	-	in-situ
		48	TC uncertainty	R	W/(mK)	0.04
		50	TC method	R	-	pulse technique
		53	TC pT assumed function	R	-	in-situ
		54	TC number	R	-	11
		55	TC averaging method	R	-	Bullard
		56	IGSN	O	-	