Global Heat Flow Database Data Template (Version 2025.05) (https://doi.org/10.5880/fidgeo.2025.042)

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3. Data Description

Since 1963, the International Heat Flow Commission (IHFC | www.ihfc-iugg.org) has been dedicated to providing standards for heat flow measurements and maintaining the Global Heat Flow Database (GHFDB) — a collection of heat flow data from around the world. The first quality framework for heat-flow-density data was proposed by Jessop et al. (1976), reflecting the state of knowledge, measurement techniques, and technical developments at that time.

In 2019, the IHFC initiated a major revision of the GHFDB to develop an authenticated and quality-assessed database. This initiative involved multinational working groups and led to a comprehensive update of key parameters affecting heat-flow calculations. These updates included measurement methods for both temperature and thermal conductivity, as well as metadata structures. The new standard for a revised GHFDB structure was developed through a collaborative community approach and published in 2021 (Fuchs et al., 2021). This standard reflected changes in database technology and scientific documentation and served as a template for users submitting data to the GHFDB.

It was further developed into the currently valid data and metadata standard in 2023, which also introduced an enhanced quality evaluation framework (Fuchs et al., 2023). The ongoing assessment work and the latest release of the GHFDB (Global Heat Flow Database Assessment Group et al., 2024), along with its frequent use, revealed the need for additional refinements. These refinements were particularly necessary in aspects related to metadata consistency, measurement techniques, and classification criteria. Consequently, further updates were implemented to improve the reliability and applicability of the dataset, ensuring a more robust evaluation of global heat-flow data.

Here, we present the 2025.05 version of the GHFDB Data Template. The previous template introduced by Fuchs et al. (2023) has been improved based on the latest data assessment process. The current version of the template incorporates the advancements in data collection methodologies, the IHFC quality evaluation framework, and metadata management, ensuring that data submitted to the GHFDB follows the IHFC standards for the GHFDB.

To promote open access, the template is also hosted on the official GitHub repository of the IHFC: https://github.com/ihfc-iugg. Users can download both the original version from 2023 and the revised template. Maintaining the GHFDB Data Template in a version-controlled environment ensures transparency regarding changes over time and fosters a documentation style that sets high standards to support the reproducibility of research results. Moreover, it supports a smooth and fast integration of data from the research community into the Global Heat Flow Database of the IHFC.

4. File description

The updated GHFDB Data Template preserves the metadata structure established by Fuchs et al., (2023), which consists of 62 fields categorized into four main sections: heat-flow density, metadata and flags, temperature, and thermal conductivity. In addition, the template includes an administrative section consisting of eight additional columns which are used internally during the assessment process. This section is important for data traceability for IHFC custodians.

For many of the metadata fields, controlled vocabularies are used for descriptive categories. The current template version introduces updates for the controlled vocabulary of selected database fields, reflecting the experiences collected during the ongoing assessment process. The definition of the structure or format of data fields was not changed. The modifications mainly reflect new methodological descriptions for data collection of evaluation, along with the correction of minor typographical errors from the previous version. The following tables outline the fields for which entries of controlled vocabularies were modified compared to the prior version.

4.1 Updates of metadata properties and controlled vocabularies

Table 1 presents the modified controlled vocabulary in the different database fields. Additions are made at the parent level (P12), along with 10 corresponding child-level entries. In Table 2, updates in the data structure are reported. Totally 7 child-level entries were revised to enhance the clarity of the data reporting process.

Table 1 Recently added entries to the controlled vocabulary (2025.05 version)

ID	Field name	New Entry	Explanation
P12	Type of exploration method	[Indirect (GTM-BSR-CPD, etc.)]	Added as a controlled vocabulary.
P12	Type of exploration method	[Drilling-Clustering] and [Probing-Clustering]	Added as a controlled vocabulary. Please provide individual site names and total borehole depths in the comment field separated by a semicolon.
C3	Heat-Flow method	[unspecified]	Added as a controlled vocabulary.
C20	Platform, Vessel, Expedition	[D/V Glomar Challenger] and [D/V JOIDES Resolution]	Added as a controlled vocabulary.
C21	Probe type	[Outrigger probe (Haenel) in-situ TC], [Outrigger probe (Ewing) without corer] and [Outrigger probe (Lister) with corer]	Added as a controlled vocabulary.
C25	Lithology[a]	acidic_igneous_material acidic_igneous_rock alkali_feldspar_granite alkali_feldspar_rhyolite alkali_feldspar_syenite alkali_feldspar_syenitic_rock alkali_feldspar_trachyte alkali_feldspar_trachytic_rock alkali-olivine_basalt amphibolite andesite anorthosite anorthositic_rock anthracite_coal anthropogenic_material anthropogenic_unconsolidated_material aphanite aplite arenite ash_and_lapilli ash_breccia_bomb_or_block_tephra ash_tuff_lapillistone_and_lapilli_tuff basalt basanite basanitic_foidite basic_igneous_material basic_igneous_rock bauxite biogenic_sediment biogenic_silica_sedimentary_rock bituminous_coal boninite boulder_gravel_size_sediment boundstone	Added as a controlled vocabulary.

		breccia breccia_gouge_series calcareous_carbonate_sediment calcareous_carbonate_sedimentary_material calcareous_carbonate_sedimentary_rock carbonate_mud carbonate_mudstone carbonate_ooze carbonate_rich_mud carbonate_rich_mudstone carbonate_sediment carbonate_sedimentary_material carbonate_sedimentary_rock carbonate_wackestone carbonatite cataclasite_series chalk chemical_sedimentary_material chlorite_actinolite_epidote_metamorphic_rock clastic_sediment clastic_sedimentary_material clastic_sedimentary_rock clay claystone coal cobble_gravel_size_sediment composite_genesis_material composite_genesis_rock compound_material clastic_conglomerate crystalline_carbonate dacite diamictite diamicton diorite dioritic_rock dioritoid doleritic_rock dolostone dolomitic_or_magnesian_sedimentary_material dolomitic_or_magnesian_sedimentary_rock dolomitic_sediment duricrust eclogite evaporite exotic_alkaline_rock exotic_composition_igneous_rock exotic_evaporite fault_related_material fine_grained_igneous_rock foid_bearing_alkali_feldspar_syenite foid_bearing_alkali_feldspar_trachyte foid_bearing_anorthosite foid_bearing_diorite foid_bearing_gabbro foid_bearing_latite foid_bearing_monzodiorite foid_bearing_monzogabbro foid_bearing_monzonite foid_bearing_syenite	

		foid_bearing_trachyte foid_diorite foid_dioritoid foid_gabbro foid_gabbroid foid_monzodiorite foid_monzogabbro foid_monzosyenite foid_syenite foid_syenitoid foidite foiditoid foidolite foliated_metamorphic_rock fragmental_igneous_material fragmental_igneous_rock framestone gabbro gabbroic_rock gabbroid generic_conglomerate generic_mudstone generic_sandstone glass_rich_igneous_rock glassy_igneous_rock glaucophane_lawsonite_epidote_metamorphic_rock gneiss grainstone granite granitoid granodiorite granofels granulite gravel gravel_size_sediment rock_gypsum_or_anhydrite high_magnesium_fine_grained_igneous_rocks hornblendite hornfels hybrid_sediment hybrid_sedimentary_rock igneous_material igneous_rock impact_generated_material impure_calcareous_carbonate_sediment impure_carbonate_sediment impure_carbonate_sedimentary_rock impure_dolostone impure_dolomitic_sediment impure_limestone intermediate_composition_igneous_material intermediate_composition_igneous_rock iron_rich_sediment iron_rich_sedimentary_material iron_rich_sedimentary_rock kalsilitic_and_melilitic_rock komatiitic_rock latite latitic_rock lignite	

		limestone marble material_formed_in_surficial_environment metamorphic_rock metasomatic_rock mica_schist migmatite monzodiorite monzodioritic_rock monzogabbro monzogabbroic_rock monzogranite monzonite monzonitic_rock mud mud_size_sediment clastic_mudstone mylonitic_rock natural_unconsolidated_material non_clastic_siliceous_sediment non_clastic_siliceous_sedimentary_material non_clastic_siliceous_sedimentary_rock ooze organic_bearing_mudstone organic_rich_sediment organic_rich_sedimentary_material organic_rich_sedimentary_rock orthogneiss packstone paragneiss peat pebble_gravel_size_sediment pegmatite peridotite phaneritic_igneous_rock phonolilte phonolitic_basanite phonolitic_foidite phonolitic_tephrite phonolitoid phosphate_rich_sediment phosphate_rich_sedimentary_material phosphorite phyllite phyllonite porphyry pure_calcareous_carbonate_sediment pure_carbonate_mudstone pure_carbonate_sediment pure_carbonate_sedimentary_rock pure_dolomitic_sediment pyroclastic_material pyroclastic_rock pyroxenite quartz_alkali_feldspar_syenite quartz_alkali_feldspar_trachyte quartz_anorthosite quartz_diorite quartz_gabbro quartz_latite	

		quartz_monzodiorite quartz_monzogabbro quartz_monzonite quartz_rich_igneous_rock quartz_syenite quartz_trachyte quartzite residual_material rhyolite rhyolitoid rock rock_salt sand sand_size_sediment clastic_sandstone sapropel schist sediment sedimentary_material sedimentary_rock serpentinite shale silicate_mud silicate_mudstone siliceous_ooze silt siltstone skarn slate spilite syenite syenitic_rock syenitoid syenogranite tephra tephrite tephritic_foidite tephritic_phonolite tephritoid tholeiitic_basalt tonalite trachyte trachytic_rock trachytoid travertine tuff_breccia_agglomerate_or_pyroclastic_breccia tuffite ultrabasic_igneous_rock ultramafic_igneous_rock unconsolidated_material wacke	
C26	Stratigraphic age[b]	Aalenian Aeronian Albian Anisian Aptian Aquitanian Archean Artinskian Asselian	Added as a controlled vocabulary.

		Bajocian Barremian Bartonian Bashkirian Bathonian Berriasian Burdigalian Calabrian Callovian Calymmian Cambrian CambrianSeries2 CambrianSeries3 CambrianStage10 CambrianStage2 CambrianStage3 CambrianStage4 CambrianStage5 Campanian Capitanian Carboniferous Carnian Cenomanian Cenozoic Changhsingian Chattian MiddlePleistocene Cisuralian Coniacian Cretaceous Cryogenian Danian Dapingian Darriwilian Devonian Drumian LowerCretaceous LowerDevonian LowerJurassic LowerMississippian LowerOrdovician LowerPennsylvanian LowerTriassic Ectasian Ediacaran Eifelian Emsian Eoarchean Eocene Famennian Floian Fortunian Frasnian Furongian Gelasian Givetian Gorstian Greenlandian Guadalupian Guzhangian	

		Gzhelian Hadean Hauterivian Hettangian Hirnantian Holocene Homerian Induan Ionian Jiangshanian Jurassic Kasimovian Katian Kimmeridgian Kungurian Ladinian Langhian UpperCretaceous UpperDevonian UpperJurassic UpperMississippian UpperOrdovician UpperPennsylvanian UpperPleistocene UpperTriassic Llandovery Lochkovian Lopingian Ludfordian Ludlow Lutetian Maastrichtian Meghalayan Mesoarchean Mesoproterozoic Mesozoic Messinian Miaolingian MiddleDevonian MiddleJurassic MiddleMississippian MiddleOrdovician MiddlePennsylvanian MiddleTriassic Miocene Mississippian Moscovian Neoarchean Neogene Neoproterozoic Norian Northgrippian Olenekian Oligocene Ordovician Orosirian Oxfordian Paibian Paleoarchean Paleocene	

		Paleogene Paleoproterozoic Paleozoic Pennsylvanian Permian Phanerozoic Piacenzian Pleistocene Pliensbachian Pliocene Pragian Precambrian Priabonian Pridoli Proterozoic Quaternary Rhaetian Rhuddanian Rhyacian Roadian Rupelian Sakmarian Sandbian Santonian Selandian Serpukhovian Serravallian Sheinwoodian Siderian Silurian Sinemurian Statherian Stenian Telychian Terreneuvian Thanetian Tithonian Toarcian Tonian Tortonian Tournaisian Tremadocian Triassic Turonian Valanginian Visean Wenlock Wordian Wuchiapingian Wuliuan Ypresian Zanclean	
C31	Temperature method (top)	[GRT] (Geothermal response test) and [EGRT] (Enhanced geothermal response test)	Added as a controlled vocabulary. If [EGRT] is used for the Temperature method, the TC method should be [Probe - pulse technique].
C32	Temperature method (bottom)	[GRT] (Geothermal response test) and [EGRT] (Enhanced geothermal response test)	Added as a controlled vocabulary.

C35	T correction method (top)	[AAPG correction]	Added as a controlled vocabulary.
C36	T correction method (bottom)	[AAPG correction]	Added as a controlled vocabulary.
C46	Thermal conductivity pT assumed function	[T - Birch & Clark (1940)], [pT - Langseth (1965)] and [pT - Hyndman et al. (1974)]	Added as a controlled vocabulary.

[a]Richard (1999), [b]Cox & Richard (2005).

Table 2 Updated entries of the controlled vocabulary and database field names (2025.05 Version)

ID	Field name	Version 2023	Version 2025.05
C3	Heat-Flow method	[Numerical inversion]	[Other numerical computations]
C24	Surface temperature	Bottom-water temperature	Surface/Bottom-water temperature
C31	Temperature method (top)	[DST]	[HT-FT] Hydraulic Test Formation temperature. e.g. Drill Stem test, Aquifer temperature
C32	Temperature method (bottom)	[DST]	[HT-FT] Hydraulic Test Formation temperature. e.g. Drill Stem test, Aquifer temperature
C31	Temperature method (top)	[cDST]	[cHT-FT] Hydraulic Test Formation temperature corrected for effects. e.g. Drill Stem test, Aquifer temperature
C32	Temperature method (bottom)	[cDST]	[cHT-FT] Hydraulic Test Formation temperature corrected for effects. e.g. Drill Stem test, Aquifer temperature
C48	Thermal conductivity averaging methodology	[Random or periodic depth sampling (number)]	[Random or periodic depth sampling]

4.2. Comments

In addition to the above-mentioned updates, minor typographical errors are also corrected in the new template. The obligation status of Thermal conductivity pT assumed function (C46), is now Mandatory due to its weight on the M score.

Reporting of the temperature gradient is also clarified to distinguish between the temperature gradients corrected for borehole/mud circulation and for the environmental effects (terrain effects/topography, sedimentation, erosion, magmatic intrusions, paleoclimate, etc.).

Users should report mean temperature gradient data corrected for drilling/mud circulation (if necessary) in column C29 (Corrected temperature gradient) while uncorrected temperature gradients should be provided in column C27. Relevant correction methods should be indicated in columns C31 and C32. However, If a temperature gradient is corrected for the environmental effects it should also be still stored in column C27 and the corresponding P-score flag should be selected as [Present and corrected]

The following comments provide additional clarification on recently included entries. These explanations ensure consistency in data reporting and guide users in correctly utilizing the template.

Drilling-Clustering Method: If the *Type of exploration* method is "Drilling-Clustering" method, different site names and total or true vertical borehole depths (P10, P11) should be reported under the C10 field in the *General comments child level* section. This ensures that data from multiple drill sites within a cluster is appropriately documented and distinguished.

Enhanced Geothermal Response Test (EGRT): When the *Temperature method (top)* and *Temperature method (bottom)* indicate the use of the Enhanced Geothermal Response Test [EGRT] method, the corresponding *Thermal conductivity method* should be recorded as [Probe - Pulse Technique] to maintain consistency in reporting thermal conductivity measurements.

Metadata Source: Metadata should primarily be derived from the related literature that describes the data. However, in cases where the mandatory entries are missing from the primary source but are available in related documents (e.g., cruise reports, technical reports, etc.), these can be incorporated with appropriate documentation by reporting under (C8, C10). Additionally, if authors submit data improved with supplementary information such inclusions should be indicated.

References

Cox, S. J., & Richard, S. M. (2005). A formal model for the geologic time scale and global stratotype section and point, compatible with geospatial information transfer standards. Geosphere, 1(3), 119-137. https://doi.org/10.1130/GES00022.1

Fuchs, S., Beardsmore, G., Chiozzi, P., Espinoza-Ojeda, O.M., Gola, G., Gosnold, W., Harris, R., Jennings, S., Liu, S., Negrete-Aranda, R., Neumann, F. (2021). A new database structure for the IHFC Global Heat Flow Database. International Journal of Terrestrial Heat Flow and Applications. 4(1):1–4. https://doi.org/10.31214/ijthfa.v4i1.62

Fuchs, S., Norden, B., Neumann, F., Kaul, N., Tanaka, A., Kukkonen, I. T., Pascal, C., Christiansen, R., Gola, G., Šafanda, J., Espinoza-Ojeda, O. M., Marzan, I., Rybach, L., Balkan-Pazvantoğlu, E., Ramalho, E. C., Dědeček, P., Negrete-Aranda, R., Balling, N., Poort, J., Wang, Y., Jõeleht, A., Rajver, D., Gao, X., Liu, S., Harris, R., Richards, M., McLaren, S., Chiozzi, P., Nunn, J., Madon, M., Beardsmore, G., Funnell, R., Duerrast, H., Jennings, S., Elger, K., Pauselli, C., and Verdoya, M. (2023). Quality-assurance of heat-flow data: The new structure and evaluation scheme of the IHFC Global Heat Flow Database. Tectonophysics, 863, 229976. https://doi.org/10.1016/j.tecto.2023.229976

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Jessop, A., Hobart, M. and Sclater, J. (1976). The World Heat Flow Data Collection 1975, Geothermal Services of Canada [Dataset]. Geothermal Service, 50, 55–77. https://doi.org/10.4095/8416

Lucazeau, F. (2019). Analysis and mapping of an updated terrestrial heat flow data set. Geochemistry, Geophysics, Geosystems, 20(8), pp.4001–4024. https://doi.org/10.1029/2019GC008389

Richard, S. M. (1999). Geologic concept modelling, with examples for lithology and some other basic geoscience features. Digital Mapping Techniques Proceedings 1999, 59-76. https://pubs.usgs.gov/of/1999/of99-386/richard.html