



A global petrophysical database for igneous, metamorphic and sedimentary rocks

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Abstract. Petrophysical properties such as porosity, permeability and thermal conductivity are required to support modelling and data interpretation in many geoscientific fields, including groundwater management, carbon geo-sequestration, resource exploration, and subsurface waste disposal. Collation of petrophysical property data from the literature is time consuming, often hampered by inconsistent or incomplete metadata. Existing petrophysical property databases are limited in their geographic extent, or in the range of included properties, rock types or measurement techniques. Motivated by these challenges, a Global Petrophysical Database (GPD) has been developed (Sheldon et al., 2026), incorporating data from more than 600 publications including 10 existing databases and covering 70 countries. Both in-situ and laboratory measurements are included. The database focuses primarily on properties that control subsurface fluid flow, mass transport and heat transport. The GPD is publicly accessible at <https://doi.org/10.25919/e8f9-n090> (Sheldon et al., 2026), supported by a graphical web interface, the Global Petrophysical Database Explorer, to facilitate rapid exploration and visualization of the data.

Introduction

Knowledge of petrophysical properties is critical in many geoscientific fields, including hydrogeology, mineral/hydrocarbon/geothermal exploration, and sub-surface waste disposal. For example, safety assessments of potential underground disposal sites for radioactive waste typically involve simulations of sub-surface processes (Buscheck et al., 2002; Finsterle et al., 2021; Freeze et al., 2019; Mallants et al., 2023), which in turn require knowledge of properties that affect radionuclide transport, such as porosity, permeability, thermal conductivity and diffusion coefficients. The simulations may be site-specific (e.g. Ye et al., 2007), requiring information on petrophysical properties relevant to that location, or they may be more generic (e.g. Rutqvist et al., 2008), requiring representative values or ranges of values for the petrophysical properties in relevant lithologies.

Collation of petrophysical property data from reports, journal articles and academic theses is time consuming, with derivation of representative values for a given formation or rock type often hampered by incomplete or inconsistent metadata (e.g. sample location, depth, lithology, measurement methods and conditions) (Bär et al.,



2020b). Previous efforts to compile petrophysical data include global compilations of laboratory measurements (e.g. the P3 database; Bär et al., 2020), as well as a range of datasets developed for specific applications or property types (see Table 1 for examples). However, many of these resources are domain-specific (e.g. geothermal modelling), geographically constrained (e.g. datasets published by national geological surveys), or focus on a limited subset of petrophysical parameters (e.g. permeability), and are not consistently harmonised into a single framework.

To address these limitations, we developed a Global Petrophysical Database (GPD; Sheldon et al., 2026), which integrates geographically and geologically diverse datasets for a range of rock properties, including both laboratory and in-situ measurements. The current version of the GPD focuses primarily on properties that control fluid flow (e.g. porosity, permeability), mass transport (e.g. diffusion coefficients) and heat transport (e.g. heat capacity and thermal conductivity). The data span 6 continents and 70 countries, as well as some offshore locations (Figure 1). The GPD is applicable in many geoscientific fields, especially where simulation of sub-surface transport processes underpins decision making.

This paper describes various aspects of the GPD, including data sources; database structure; petrophysical properties and measurement types; quality control measures; how to access the database, including a web interface for exploring the data; and a discussion of accuracy and suitability of the data. The paper concludes with recommendations for future directions to ensure the database remains up-to-date and relevant for the geoscience research community.

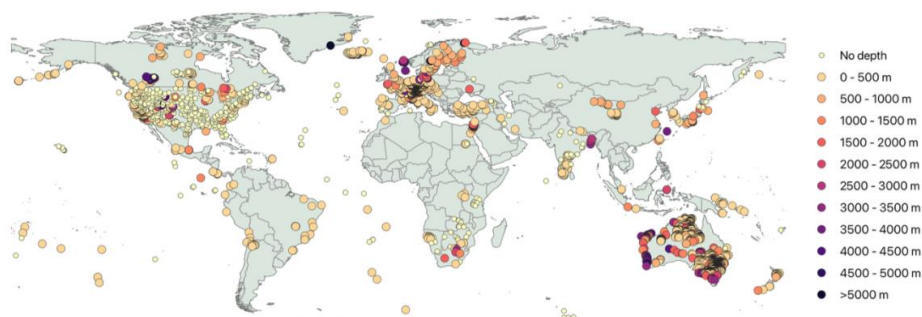


Figure 1. Data locations in the GPD classified by maximum sampled depth at each location.

Data sources

The GPD includes data from 10 existing databases (Table 1) covering 553 publications, and a further 56 individual publications that are not covered by the existing databases. A full reference list is included as a table in the GPD. The existing databases each have a narrower focus than the GPD, such as specific rock types (e.g. argillaceous rocks), measurement techniques (laboratory versus in-situ), properties (e.g. permeability) or locations (e.g. Australia).



Table 1. Existing databases incorporated into the GPD. “Short name” is the name used in the GPD.

Name	Short name	Reference	Description
Achtziger-Zupančič et al.	ALM2017	Achtziger-Zupančič et al. (2017)	Global database of 29,000 in-situ permeability estimates in crystalline rocks to 2 km depth.
Clay Club Catalogue	ClayClub	Boisson (2005)	Compilation of properties of argillaceous rocks (shale, mudstone, clay) that are or have been considered as potential host rocks for radioactive waste disposal.
GA Rock Properties Database	GAPetrophys	Roach et al. (2025)	Rock properties from Australian boreholes and field sites.
GA Thermal Conductivity Dataset	GAThCond	Weber and Kirkby (2011)	Thermal conductivity measurements from a range of sedimentary and crystalline rock types in Australian exploration and stratigraphic wells.
Hunter Valley Hydraulic Properties	Hunter	Bioregional Assessment Programme (2017)	Compilation of hydraulic properties from sedimentary rocks in the Hunter Valley region of NSW, Australia.
Kuang and Jiao	KJ2014	Kuang and Jiao (2014)	Compilation of permeability data from various sedimentary (mainly sandstone) and crystalline rock types in Germany, France and the USA. Includes data from Earth's oceanic crust.
P3 Petrophysical Properties Database	P3	Bär et al. (2020b)	Global compilation of lab-measured rock properties from a broad range of rock types.
PressurePlot	PressureDB	CSIRO (2007)	Database of formation pressure, temperature, salinity, porosity, permeability and related geological data from sedimentary rocks (predominantly sandstone) in Australian petroleum exploration wells.
Ranjram et al.	RGL2015	Ranjram et al. (2015)	Compilation of 973 in-situ permeability estimates in crystalline rocks to 2.5 km depth, from 16 data sources (Sweden, Germany and Switzerland).
Daigle and Screatton	DS2015	Daigle and Screatton (2015)	Compilation of porosity and permeability measurements from fine-grained subduction zone sediments (clay).

Database structure and content

- 65 Sample metadata, measurement methods/conditions and petrophysical property data are stored in a single data table with column headings as shown in Figure 2 (see Appendix A for column definitions). The columns are grouped as follows:
- Identification, including row number and sample ID. There are 112,349 rows and 58,941 unique sample IDs in the current version of the database. Each row contains a single property measurement, and some samples have more than one measurement (e.g. permeability at different confining pressures), hence the number of rows exceeds the number of sample IDs. Note that a sample ID may refer to a physical sample (for laboratory measurements) or a depth interval in a borehole (for in-situ measurements).
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- Data source (e.g. reference, existing database). References are shortened to a simple NameYear format (see Appendix A). A separate table in the database gives full bibliographic details of each reference.
- 75 • Location: Some samples have no location information, some specify only a country or area, and some have known coordinates (latitude and longitude).
- Depth: The depth at which the property was measured (for in-situ measurements) or from which the sample was obtained (for laboratory measurements), if known.
- Sample information, including type (e.g. in-situ, core, block, powder) and dimensions if known.
- 80 • Lithology (rock type), including a simplified lithological term, the corresponding GeoSciML Simple Lithology term, and a lithology category (see Table 2) based on the schema of Gleeson et al. (2014). Lithology classification is discussed further below.
- Stratigraphy: Chronostratigraphic and/or local stratigraphic unit names are provided where known.
- Measurement conditions (e.g. confining pressure, temperature) and type (i.e. in-situ or laboratory).
- 85 • Measurement, including the property that was measured, its value, and a quality indicator for some property types (refer to section on Quality Control for further information).

The data table has many empty cells, due to missing information and certain columns being irrelevant to some sample or measurement types. In addition to the data table, separate tables list the references, existing databases, column definitions, petrophysical property definitions, and abbreviations.

- 90 As noted above, each row in the data table holds one value of one property for a given sample ID. This format results in duplication of sample metadata on multiple rows for samples with more than one property measurement (e.g. multiple properties, or multiple measurements of the same property at different conditions). Duplication is undesirable due to (i) the potential for inconsistency in metadata between rows for a given sample ID, and (ii) the increased file size that results from duplication. The first point was addressed by running a scan over the data to
- 95 identify inconsistencies in sample metadata between rows, with affected rows being rectified or removed prior to publication. The second point, file size, is not currently a problem but could become an issue if the database grows significantly. Duplication of metadata could be avoided by using a relational database structure, with sample metadata held in one table and property data in another table. However, the single table structure is more accessible for non-expert users who prefer to use a spreadsheet to explore and manipulate data.

100 **Lithology classification**

- Lithology is one of the most challenging attributes to represent in a consistent and usable format, due to inconsistent nomenclature employed in the literature and existing databases. Several rock classification schemes have been developed, including those for igneous, metamorphic, and sedimentary rocks proposed by the British Geological Survey (Gillespie and Styles, 1999; Hallsworth and Knox, 1999; Robertson, 1999) and the
- 105 International Union of Geological Sciences (IUGS) (Le Bas and Streckeisen, 1991; Schmid, 1981). These frameworks can be integrated to produce comprehensive, hierarchical classifications encompassing all rock types, as demonstrated by resources such as mindat.org (MinDat, 2025) and the classification scheme used in the P3 database (Bär et al., 2020a). However, even these comprehensive schemes are not universally consistent, as comparable rocks may be classified at different levels of detail or according to differing criteria (e.g. textural,
- 110 chemical or mineralogical classifications of igneous rocks) depending on the focus of the researcher. At the other end of the spectrum are more streamlined approaches such as the GeoSciML Simple Lithology vocabulary



(GeoSciML Simple Lithology Vocabulary. CGI Geoscience Vocabularies, 2026; Open Geospatial Consortium (OGC), 2017), which provides 265 lithological terms to support standardisation and interoperability of geoscience datasets.

115 The approach taken in the GPD is to define a simplified lithological term (column “Lithology simplified”) based on either the original description in the source reference, or the rock classification ID for entries derived from the P3 database (column “Lithology descriptive”). Modifiers such as grain size, colour, and texture are removed, yielding concise terms such as sandstone, limestone, or granite. These terms are then mapped to their corresponding entries in the GeoSciML Simple Lithology vocabulary (column “GeoSciML Simple Lithology”) and assigned to a broad classification in the “Lithology category” column (see Table 2). This simplification necessarily removes some descriptive detail (e.g. grain size), which may influence certain properties. Users should refer to original descriptions (e.g. in the “Lithology descriptive” column, or the original data source) where such detail is important. Samples containing multiple rock types are represented by multiple terms separated by commas. Examples of lithological terms are shown in Table 3. This approach is straightforward to implement and results in shorter, more intuitive lithological descriptors than more complex classification schemes, while

125 providing for global interoperability through alignment with the GeoSciML framework.

Identification	Sample information	Measurement conditions
Row #	Sample type	Temperature (C)
Sample ID	Original sample ID	Pore Pressure (MPa)
	IGSN	Saturating Fluid
Source	Sample length 1 (m)	Saturation (%)
Reference	Sample length 2 (m)	Confining pressure (MPa)
Other references	Sample length 3 (m)	Effective Confining Pressure (MPa)
Source in reference	Sample diameter (m)	Sigma1 (MPa)
Existing database	Sample preservation	Sigma2 (MPa)
Row in existing database	Remarks on sample	Sigma3 (MPa)
		Effective Sigma1 (MPa)
		Effective Sigma2 (MPa)
		Effective Sigma3 (MPa)
		Measurement type
		Remarks on measurement conditions
Location	Lithology	Measurement
Continent	Lithology descriptive	Property and units
Country	Lithology simplified	Direction of measurement
Region	GeoSciML Simple Lithology	Value
Location	Lithology category	Min
Location Type	Clay Content (%)	Max
Onshore /offshore	Clay Fraction (%)	Std Dev
Borehole name	Lithification	Number of measurements
Latitude (decimal degrees)	Texture	Method
Longitude (decimal degrees)	Degree of Alteration / Weathering	Test duration (hours)
Radius of uncertainty (km)		Quality
Elevation (m)		Remarks
Depth	Stratigraphy	
Depth Min (m)	Chronostratigraphic parent unit	
Depth Max (m)	Chronostratigraphic unit	
True vertical depth Min (m)	Local stratigraphic parent unit	
True vertical depth Max (m)	Local stratigraphic unit	
Uplift/erosion (m)		
Max burial depth (m)		

Figure 2. Columns in the GPD. For column definitions see Appendix A.



130 **Table 2. Lithology categories used in the GPD (modified from Gleeson et al., 2014)**

Lithology category	Description
CARB	Carbonate (limestone, dolomite, chalk)
CRYST	Crystalline rock (igneous intrusive, metamorphic, migmatite, mixed igneous/metamorphic)
EVAP	Evaporite
MIX	Mixed types (excluding mixed sedimentary types, which are SED)
OTHER	Other
SED ^a	Sedimentary rock - mixed or unknown grain size, including mixed sedimentary rock types (e.g. interbedded sandstone/shale)
SEDC ^a	Sedimentary rock - coarse
SEDF ^a	Sedimentary rock - fine
UNC	Unconsolidated sediments - mixed or unknown grain size
UNCC	Unconsolidated sediments - coarse
UNCF	Unconsolidated sediments - fine
VOLC	Volcanic rock

^aSED categories include siliciclastic (e.g. sandstone, shale) and mixed carbonate/siliciclastic sedimentary rocks (e.g. marl, calcareous mudstone).

Table 3. Examples of lithological terms. See Table 2 for definition of lithology categories.

Lithology descriptive	Lithology simplified	GeoSciML Simple Lithology	Lithology category
Muddy dolomite	dolomite	dolomite	CARB
granite, pale green feldspar + quartz, mica, minor shears	granite	granite	CRYST
clear to greyish orange-pink halite (rock salt)	halite	evaporite	EVAP
phyllite, micaschist, anchischist, claystone, slate	phyllite, schist, claystone, slate	phyllite, schist, claystone, slate	MIX
Tectonite	tectonite	fault related material	OTHER
Interbedded Sandstone and Claystone	sandstone, claystone	sandstone, claystone	SED
Quartz- Arenite	sandstone	sandstone	SEDC
argillite	argillite	mudstone	SEDF
alluvium	alluvium	natural unconsolidated material	UNC
Gravel	gravel	gravel	UNCC
Muddy sediments	mud	mud	UNCF
Massive lithic crystal welded ignimbrite	ignimbrite	pyroclastic rock	VOLC

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Petrophysical properties

The GPD includes properties relating to transport of fluid, heat and solutes in the subsurface (Table 4). It does not currently include geomechanical properties such as elastic moduli or rock strength parameters, although they may be added in subsequent versions. The reader is referred to other compilations for geomechanical property values, e.g., Eshkalak et al. (2014) for shale gas reservoirs, Miranda et al. (2018) for volcanic rock, and Ji et al. (2018) for a range of crystalline and sedimentary rock types, as well as the P3 and Clay Club databases (Bär et al., 2020b; Boisson, 2005). Density, hydraulic conductivity, thermal conductivity, porosity and permeability are the top 5

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properties in the GPD (Figure 3), making up 89% of the 112,349 rows of data. Some petrophysical properties are related; for example, hydraulic conductivity can be calculated from permeability (or vice-versa). Relationships between properties are summarised in Appendix B.

Measurement types

The data include both laboratory values (e.g. laboratory measurements taken from drill core or a sample drilled from outcrop) and in-situ values (e.g. hydraulic conductivity estimated from drill stem or packer tests in boreholes, tunnel inflow measurements, or modelled from borehole pressure data), and as such represent a range of spatial scales from centimetres (laboratory samples) to kilometres (some in-situ measurements) (e.g. Brace, 1980; Neuzil, 1994, 2019). Laboratory-measured values make up 78% of the data, while in-situ measurements make up 20% (predominantly hydraulic conductivity) and the remaining 2% are of unknown origin (i.e. insufficient information to classify as laboratory or in-situ; Table 5).

Table 4. Petrophysical properties included in the GPD, sorted by number of data points

Property (units)	Data points	Description
Density	25027	
Density - grain (kg/m ³)	10765	Density of solid mineral phases of the rock, excluding pore space and pore fluid (mineral or solid density)
Density (kg/m ³)	6051	Density of rock - saturation state not specified
Density - dry (kg/m ³)	5818	Density of rock in the absence of pore fluid (dry bulk density)
Density - wet (kg/m ³)	2393	Density of rock partially or fully saturated with aqueous pore fluid (wet bulk density)
Hydraulic conductivity (m/s)	22421	Hydraulic conductivity
Thermal conductivity	20381	
Thermal conductivity (W/m/K)	10036	Thermal conductivity of rock - saturation state not specified
Thermal conductivity - dry (W/m/K)	6856	Thermal conductivity of rock in the absence of pore fluid
Thermal conductivity - wet (W/m/K)	3179	Thermal conductivity of rock partially or fully saturated with aqueous pore fluid
Thermal conductivity - grain (W/m/K)	310	Thermal conductivity of solid mineral phases of the rock, excluding pore space and pore fluid
Porosity	19542	
Porosity - effective (%)	10559	Porosity that is accessible to advective flow of water or gas (i.e. connected porosity)
Porosity (%)	5502	Type of porosity unspecified
Porosity - total (%)	3351	Total porosity
Porosity - diffusion accessible (%)	130	Porosity that is accessible for diffusion



Table 4 (continued)

Property (units)	Data points	Description
Permeability	13124	
Permeability - apparent (m^2)	6439	Permeability measured with gas as the saturating fluid, no corrections applied
Permeability (m^2)	4034	In-situ permeability, or lab permeability with insufficient information to determine whether intrinsic or apparent
Permeability - intrinsic (m^2)	2655	Permeability measured with water/brine as the saturating fluid, or gas permeability with corrections applied e.g. Klinkenberg
Heat capacity	5553	
Heat capacity - specific - dry (J/kg/K)	2894	Specific heat capacity of rock in the absence of pore fluid
Heat capacity - specific (J/kg/K)	1766	Specific heat capacity of rock - saturation state not specified
Heat capacity - volumetric - dry ($\text{J/m}^3/\text{K}$)	373	Volumetric heat capacity of rock in the absence of pore fluid
Heat capacity - specific - wet (J/kg/K)	237	Specific heat capacity of rock partially or fully saturated with aqueous pore fluid
Heat capacity - volumetric ($\text{J/m}^3/\text{K}$)	232	Volumetric heat capacity of rock - saturation state not specified
Heat capacity - volumetric - wet ($\text{J/m}^3/\text{K}$)	51	Volumetric heat capacity of rock partially or fully saturated with aqueous pore fluid
Thermal diffusivity (m^2/s)	3141	Thermal diffusivity = (thermal conductivity)/(volumetric heat capacity)
Radiogenic heat production (W/m^3)	2049	Radiogenic heat production
Hydraulic diffusivity (m^2/s)	385	Hydraulic diffusivity. For 1D linear flow this is (hydraulic conductivity)/(specific storage).
Diffusion coefficient (m^2/s)	203	Diffusion coefficient for tracer transport through fluid-saturated rock
Specific storage (1/m)	148	Volume of water that an aquifer releases from storage, per unit volume of the aquifer, per unit decline in hydraulic head. A function of compressibility of the rock and pore fluid.
Specific surface area (m^2/g)	139	Surface area of pores or fractures per unit mass of rock
Water content (%)	114	Ratio of weight of water to weight of solids in a sample, expressed as a percentage
TOC (%)	50	Total organic carbon
Coefficient of consolidation (m^2/s)	32	Coefficient of consolidation
Tortuosity (-)	29	Square of the ratio of the effective path length through the pore space to the straight line distance between 2 points
Cation exchange capacity (cmol/kg)	11	Amount of positive charge that can be exchanged per unit mass of rock
Total	112349	



Table 5. Distribution of data by measurement type

Property type	In-situ	Lab	Unknown	Total
Density		25027		25027
Hydraulic conductivity	21088	1133	200	22421
Thermal conductivity		20381		20381
Porosity	11	19445	86	19542
Permeability	1436	11609	79	13124
Heat capacity		5553		5553
Thermal diffusivity		3141		3141
Radiogenic heat production		2049		2049
Hydraulic diffusivity		179	206	385
Diffusion coefficient	5	198		203
Specific storage	81	49	18	148
Specific surface area		139		139
Water content		114		114
TOC		50		50
Coefficient of consolidation		32		32
Tortuosity		29		29
Cation exchange capacity		11		11
Total	22621	89139	589	112349
Total (%)	20%	79%	1%	100%

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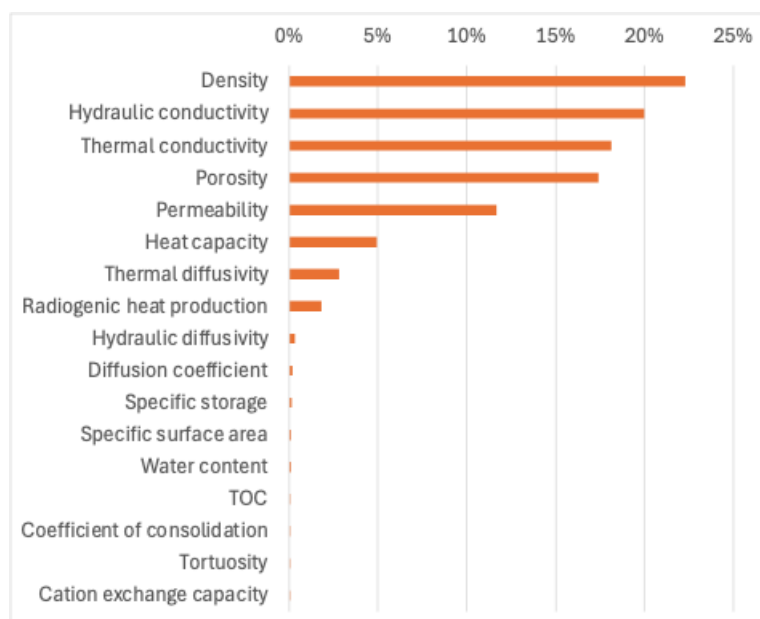


Figure 3. Distribution of data by property type, shown as percentage of total data points



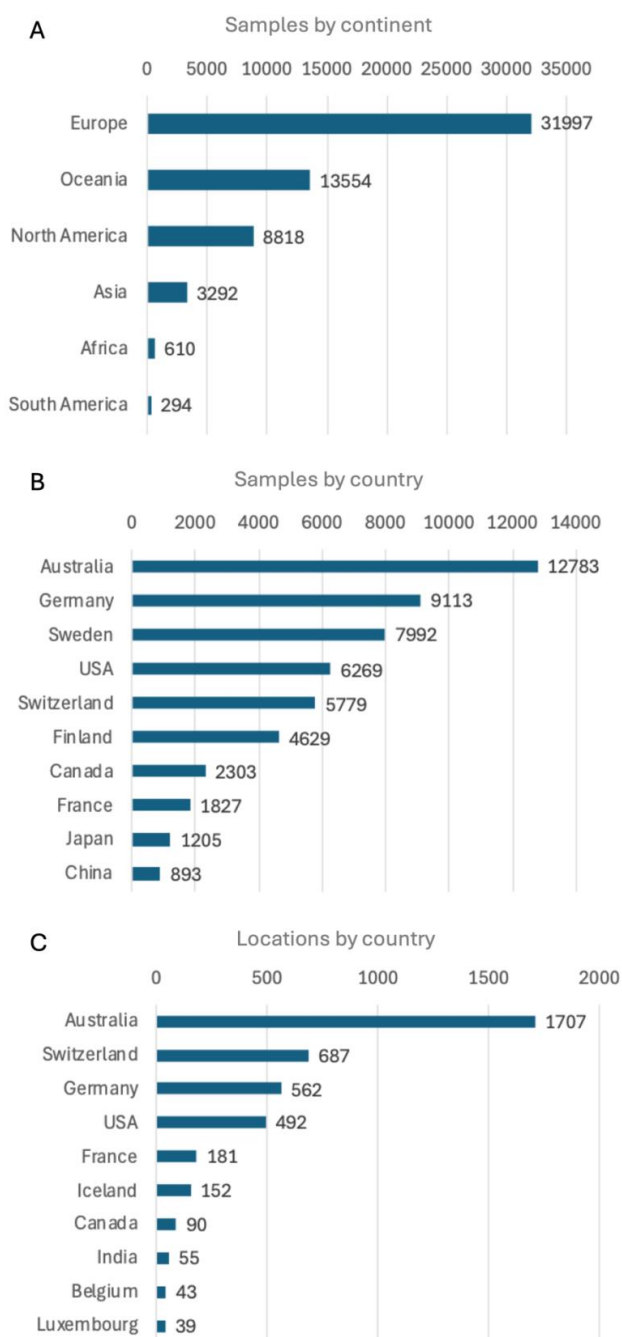
Spatial distribution of data

Approximately 91 % of samples in the GPD have known spatial coordinates (Figure 1). The remaining samples have varying levels of detail regarding their location, ranging from no information at all to a named location (Table 6). The data are heavily weighted towards Europe, Australia and North America (Figure 1, Figure 4), reflecting global data availability and the foci of existing databases. Australia is better represented in the GPD than in previous databases due to the inclusion of data from 4 Australia-specific databases (GAPetrophys, GAThCond, Hunter and PressureDB; see Table 1) and 6 additional reports/papers not included in previous compilations. Offshore data currently make up only 7% of the dataset; this could undoubtedly be increased given the large body of data from offshore oil and gas wells and research drilling programs.

The depth distribution of samples is shown in Figure 1 and Table 7. 17% of samples have no depth information, and 57% fall in the 0 – 500 m depth range. The deepest data point is an in-situ permeability measurement at 9030 – 9100 m in the KTB borehole in Germany.

Table 6. Distribution of sample ID's according to their most precise location specifier

Best location information	No. of samples	Percentage
Known coordinates	53327	91%
Named location	1787	3.0%
Region	723	1.2%
Country	2884	4.9%
No location information	220	0.4%



185 **Figure 4. Spatial distribution of samples in the GPD. (A) Number of samples by continent; (B) Number of samples by country (top 10); (C) Number of sample locations by country (top 10). Note that a sample location may include more than one sample, e.g. a borehole is a single location but may have many samples at different depths.**



Table 7. Distribution of sample ID's by depth

Depth range	Number of samples	Percentage
No depth	10259	17%
0 - 500 m	33503	57%
500 - 1000 m	5235	8.9%
1000 - 1500 m	3508	6.0%
1500 - 2000 m	1685	2.9%
2000 - 2500 m	1172	2.0%
2500 - 3000 m	1177	2.0%
3000 - 3500 m	813	1.4%
3500 - 4000 m	525	0.9%
4000 - 4500 m	929	1.6%
4500 - 5000 m	123	0.2%
>5000 m	12	<0.1%

190 Quality control

A key issue for any database is to have some mechanism of quality control (QC). QC can occur on 2 levels:

1. Inclusion criteria: Determining whether a given data point is of sufficient quality to include in the database; and
2. Filtering/ranking criteria: Determining whether a given data point is appropriate/relevant for a specific purpose.

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Level 1 QC: Inclusion criteria

Availability of lithological information was considered essential for inclusion of data in the GPD. The “Lithology simplified”, “GeoSciML Simple Lithology” and “Lithology category” columns are populated for every row in the GPD. Many rows in the PressureDB database (CSIRO, 2007) lack lithology information and were therefore omitted from the GPD.

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Other examples of level 1 QC applied to the GPD include:

- Removal of property values at or below detection limit of the measurement technique. These were identified by non-numeric values (e.g. “<0.1” for porosity) or a frequently repeated minimum value in a dataset (e.g. 1E-20 for permeability).
- Removal of duplicates, both within and between existing databases or publications.
- Removal of obviously erroneous property values.
- Removal of rows from existing databases with inconsistent metadata for the same sample.

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Level 2 QC: Filtering/ranking criteria

The criteria for level 2 QC depend on the property being measured and the purpose for which the data will be used. Users can filter relevant columns in the GPD to extract data meeting their criteria, such as a specific depth

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range, rock type, location accuracy or measurement conditions. In addition, the GPD includes ranking schemes for two specific data types: laboratory-measured permeability of fine-grained siliciclastic rocks, and in-situ measurements of hydraulic conductivity in all rock types. These are described further below. The resulting rank is recorded in the “Quality” column of the data table.

215 **Ranking criteria for laboratory-measured permeability in fine-grained siliciclastic rocks (shale)**

Permeability measurements in fine-grained siliciclastic rocks (hereafter referred to as “shale”) are very sensitive to sampling procedures and measurement conditions. Immediate preservation of the sample on recovery from the borehole is critical, as loss of native pore fluid can alter microstructure (e.g. development of desiccation fractures) and modify petrophysical properties (Ewy, 2015). Ideally, recovered whole core should be preserved under a non-
 220 polar mineral spirit (e.g. Ondina 15 or Ondina 68) or decane (e.g. Ewy, 2015; Ewy et al., 2008) such that the fluid does not interact with the clays and to prevent native pore fluid escaping from the sample.

The fluid used for fully-saturated permeability testing in shale should be chemically compatible and similar to the native pore fluid, in order to minimise swelling or shrinkage of the clay minerals (e.g. Ewy, 2018; Minaeian et al., 2017; Pervukhina et al., 2015). It is also important to run tests under load and with a back pressure. Using a
 225 loading range that spans the in-situ effective stress conditions is most appropriate, usually with a backpressure that exceeds 2 MPa to ensure that air stays in solution and the sample remains fully saturated during testing (e.g. Ewy, 2018; Sønstebo and Horsrud, 1996; Wu et al., 1997).

To address these issues, a set of criteria has been developed for ranking laboratory-measured permeability values in shale (Table 8). The criteria take into account:

- 230 • Sample preservation.
- The fluid used during permeability measurement.
- The measurement conditions, including stress and fluid pressure.



Table 8. Ranking criteria for laboratory-measured shale permeability.

Rank	Description	Experimental conditions			Sample Preservation
		Pore fluid	Back-pressure	In-situ stress	
A - High reliability	Preserved samples, under in situ stress conditions and matching pore fluids: As below, plus the use of a pore fluid that is a close match to the native pore fluid, either a synthetic pore fluid closely matched to the measured in-situ fluid composition, or a pore fluid that will prevent clay swelling (e.g. NaCl/KCl bearing brine)	Native or close match	Yes	Yes	Native pore fluid
B - Good reliability	Preserved samples, measured under in-situ stress conditions and a backpressure: As below with permeability measurements made across a range of stress conditions, including the in-situ stress, with pore pressure sufficient to ensure air is kept in solution	Water/brine	Yes	Yes	Native pore fluid
C - Moderate reliability	Preserved samples: samples that have been preserved from the moment of recovery by preventing loss of native pore fluids e.g. by sealing within the core liner, resination, storage under an appropriate non-polar fluid (e.g. decane, Ondina), clingfilm or wax coating (short term only)	Water/brine			Native pore fluid
D - Low reliability	Resaturated samples: samples that have dried out or partially dried out which are subsequently re-saturated with water/brine and tested using water permeability methods	Water/brine			Dried, re-saturated with water/brine
E - Very low reliability	Unpreserved samples: dry or partially dried shale samples tested using gas permeability or water permeability methods	Gas or water/brine			Dried

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Ranking criteria for in-situ permeability/hydraulic conductivity measurements

Another ranking scheme has been developed for in-situ measurements of permeability/hydraulic conductivity (i.e. estimates derived from various kinds of tests conducted in boreholes) in all rock types (Table 9). The ranking is based on the testing method, with higher ranking for methods that sample the largest volume of rock; however, it should be noted that this might not always be the most important factor for a given application, depending on the scale of interest. Note also that there is considerable variability within a given method, including variations in test duration, number of wells used, or the suitability of the inversion method used to infer permeability/hydraulic conductivity values from auxiliary measurements such as pressure. For example, the results of in-situ tests involving multiple wells are considered more robust than those obtained from single well tests (whether pumping or slug tests). Such details have been included in the database where they are known, to enable the user to make their own decision as to the suitability of a given dataset for their purpose.

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Table 9. Ranking criteria for in-situ permeability/hydraulic conductivity measurements

Rank	Method	Rationale
A – high reliability	Pumping tests	Generally have the longest duration (typically hours to days) and therefore represent the largest volume of support
B - Good reliability	Packer/ drill stem/ lugeon tests	Typically performed over tens of minutes to hours and therefore sample a smaller volume of support
C- Moderate reliability	Slug tests	Use relatively smaller forcings and therefore typically represent the smallest volume of support
D - Low reliability	Passive pressure or flow monitoring	Poorly constrained
E - Very low reliability	Other / not specified	Insufficient information to assign other rank

Accessing and interrogating the database

- 250 The database is provided as a Microsoft Excel spreadsheet, as well as separate CSV files corresponding to each worksheet of the spreadsheet. These files are published with open access under a Creative Commons license at <https://doi.org/10.25919/e8f9-n090> (Sheldon et al., 2026). This paper refers to Version 6 of the GPD; the version number is incremented whenever changes are made to the database, but the URL will always provide a link to the latest version.
- 255 In addition, a web interface known as the GPD Explorer has been developed to facilitate exploration, querying and visualization of the data (Sheldon et al., 2023). The GPD Explorer is a Shiny app (<https://shiny.posit.co>) written in the R programming language, utilizing various packages including leaflet (for displaying and manipulating data on a map; <https://rstudio.github.io/leaflet/>), SummaryTools (for summarizing data; <https://github.com/dcomtois/summarytools>) and Plotly (for producing plots; <https://plotly.com>).
- 260 Functionality of the GPD Explorer includes:
- filtering by column values or map area;
 - summaries of numeric and categorical values in the filtered data;
 - plots showing the distribution of property values;
 - plotting a property versus a measurement condition or depth;
 - plotting one property versus another where both properties have been measured on one or more samples.
- 265 Further details can be found on the Help page of the GPD Explorer, which can be accessed at <https://shiny.csiro.au/GPDEXplorer/>.

Example: Granite permeability

- The following example illustrates use of the GPD Explorer to extract and analyse granite permeability data. The
- 270 “Table filter” tab in the GPD Explorer is used to extract data on granite permeability, by setting “Lithology simplified” to granite and selecting the permeability data types (i.e. Permeability, Permeability – apparent and Permeability – intrinsic) from the “Property and units” column. The filter reports 863 rows of data satisfying these criteria. Switching to the “Map filter” tab shows the spatial distribution of the extracted data (
- Figure 5 top), noting there may be additional points with unknown coordinates that cannot be displayed on the map. The “Summarise” tab provides statistical summaries of categorical and numeric column values in the
- 275 extracted data; for example, it shows that the granite permeability data are derived from 26 references; there are



768 in-situ measurements and 95 laboratory measurements; and the minimum, median and maximum permeability values are 2.5×10^{-22} , 6.07×10^{-18} and $7.9 \times 10^{-9} \text{ m}^2$, respectively. The distribution of permeabilities is shown graphically in the “Observed value summaries” tab, which provides a diagram for each permeability type comprising a combined violin plot, scatter plot and box-and-whisker plot (Figure 5 middle). These plots show the range of values and their degree of clustering. For permeability data it is helpful to check “Use logscale for all plots”. In the “Plot – Property vs. condition” tab it is possible to plot a single property versus depth or a measurement condition (e.g. temperature, confining pressure). Two examples are included in Figure 5, showing permeability versus depth (bottom left), which are all in-situ measurements, and apparent permeability versus true vertical depth (bottom right), which are all laboratory measurements. Further analysis can be conducted outside the GPD Explorer, either directly in the GPD spreadsheet or using filtered data exported from the GPD Explorer using the “View and download” tab.

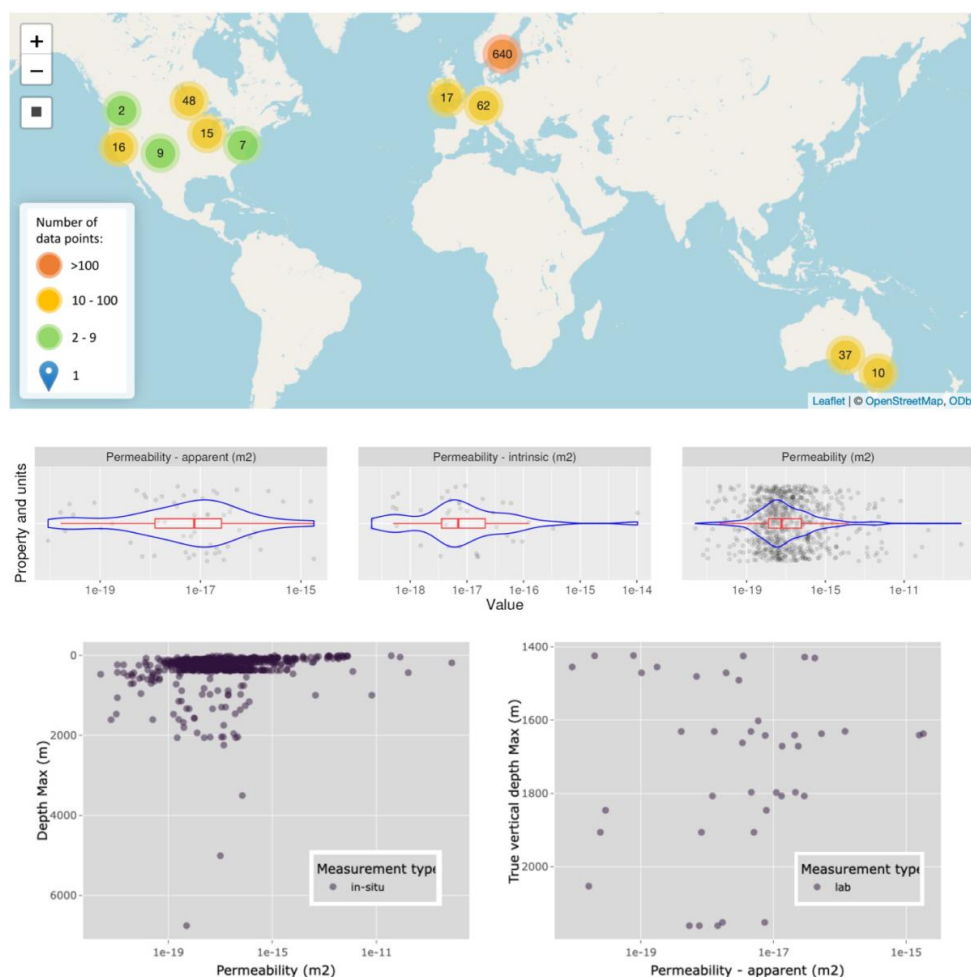


Figure 5. Using the GPD Explorer to analyse granite permeability data. Top: Map showing spatial distribution of the extracted data. Map rendered with Leaflet; data © OpenStreetMap contributors, OdbL. Middle: Summary plots



295 showing distribution of permeability values. Blue curves are violin plots where the width of the blue outline is proportional to the probability density. Red box and whisker plots indicate the median, interquartile range and 5th/95th percentiles. Grey dots are individual data points spread randomly along the vertical axis. Bottom: Permeability-depth plots.

Accuracy and suitability of data

The GPD provides significant value to researchers by consolidating diverse datasets and associated metadata, reducing the need for users to independently compile information for locations or lithologies of interest. As with
 300 any aggregated dataset, however, the accuracy and suitability of the data are influenced by several factors that should be considered during interpretation and analysis.

Data quality reflects many factors such as sample collection and preservation methods, experimental and analytical techniques, instrument calibration, and measurement conditions. While considerable effort has been made to identify and exclude clearly erroneous data, some inaccuracies from the original publications may persist.

305 Users are therefore encouraged to apply appropriate quality checks for their specific applications.

Some samples include measurements conducted under varying conditions (e.g. permeability measured at varying confining pressure or temperature). These data can be used to evaluate property dependence on such conditions, or to estimate property values under specific conditions. Laboratory measurements should not be assumed to represent in-situ property values unless the measurement conditions are comparable to those in the subsurface.

310 Variations in measurement methods and conditions should be taken into account when undertaking statistical analyses.

The precision of sample location and depth information varies considerably across the database. In some cases, locations are defined by detailed borehole survey data, whereas in others only general locality or region information are available. For studies requiring high spatial accuracy, users should consult the original source
 315 publications to verify location details.

Finally, it is important to recognise differences in measurement scale. In-situ measurements (e.g. hydraulic conductivity tests in boreholes) typically integrate properties over larger rock volumes and may reflect the influence of features such as fractures, whereas laboratory measurements represent smaller, more homogeneous samples. Users should consider the scale most relevant to their objectives when selecting and interpreting data.

320 Conclusions and future directions

The GPD is a significant compilation of global petrophysical data, integrating over 112,000 measurements from diverse rock types and geographic locations, with potential applications in a broad range of geoscientific fields. The accompanying GPD Explorer web interface facilitates efficient exploration, analysis and visualization of the data, enabling users to discover data relevant to their application, or explore relationships between properties.

325 The database currently focuses on properties relevant to fluid, heat and mass transport in the subsurface, but could be expanded to include geomechanical properties in future releases. Other enhancements could include populating missing metadata (e.g. deriving approximate geographic coordinates from named locations) or adding functionality to the GPD Explorer to calculate derived properties (e.g. permeability derived from hydraulic conductivity). While the database already conforms to many aspects of the FAIR data principles (Wilkinson et al., 2016), its interoperability could be enhanced by further alignment with established controlled vocabularies
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and ontologies in the geosciences, such as the CGI/IUGS geoscience vocabularies encompassed by GeoSciML, and the International Chronostratigraphic Chart (Cohen et al., 2024; CGI Geoscience Vocabularies, 2026; Open Geospatial Consortium (OGC), 2017).

Such a database can never be regarded as complete due to the vast amount of legacy data residing in unpublished/unknown reports (e.g. well completion reports) and other databases (e.g. state or national geological survey databases), and the rapid rate at which new datasets are created. Artificial intelligence could assist with discovery and extraction of data and metadata from online sources. Another option would be to build a dynamic system to enable researchers to upload their own data – still requiring human oversight to ensure quality and consistency, but much less onerous than the task of discovering and collating data manually. An international collaboration to establish such a system would be worthwhile, in order to maximise benefit from the growing body of global petrophysical data.

Appendix A

Table A1. Columns in the GPD data table

Group	Column heading	Description
Identification	Row #	Row number
	Sample ID	Sample identifier, comprising Reference_XXXXX, where XXXXX is the ID number of the sample for that reference, padded to 5 digits. For example, Dai2016_00003 identifies sample 3 from reference Dai2016.
Source	Reference	Data source. References are shortened to the format NameXXXXa/b/c, where Name is the surname of the first author, XXXX is the year and a/b/c is a suffix used when there is more than one reference with the same first author and year. References that do not end with year(letter) are borehole reports.
	Other references	Supplementary references
	Source in reference	Source of data in Reference, e.g. figure or table number
	Existing database	Short name of existing database, if data came from an existing database.
	Row in existing database	Row number of data in existing database, if applicable
Location	Continent	Continent or ocean
	Country	Country
	Region	Region
	Location	Location
	Location Type	Type of location e.g. borehole, outcrop, tunnel
	Onshore /offshore	Onshore or offshore
	Borehole name	Name of borehole (if location type is borehole)
	Latitude (decimal degrees)	Latitude



	Longitude (decimal degrees)	Longitude
	Radius of uncertainty (km)	Estimate of uncertainty in sample location
	Elevation (m)	Elevation of sampling site above sea level
Depth	Depth Min (m)	Minimum depth or distance along borehole
	Depth Max (m)	Maximum depth or distance along borehole
	True vertical depth Min (m)	Minimum true vertical depth
	True vertical depth Max (m)	Maximum true vertical depth
	Uplift/erosion (m)	Amount of uplift or erosion that has been experienced by sample
	Max burial depth (m)	Maximum burial depth experienced by sample
Sample information	Sample type	Sample type, e.g. in-situ, core, block, powder
	Original sample ID	Sample ID in Reference
	IGSN	International Geo Sample Number
	Sample length 1 (m)	First length measurement of sample (e.g. length of core or block)
	Sample length 2 (m)	Second length measurement of sample (e.g. width)
	Sample length 3 (m)	Third length measurement of sample (e.g. depth)
	Sample diameter (m)	Diameter of sample (e.g. for core)
	Sample preservation	Comments on sample preservation
Lithology	Remarks on sample	Additional information about the sample
	Lithology descriptive	Description of lithology, or term corresponding to Rock Classification ID for samples from P3 database
	Lithology simplified	Simplified lithology
	GeoSciML Simple Lithology	Lithological term from GeoSciML Simple Lithology vocabulary
	Lithology category	Lithology categories (Table 2). Sedimentary rocks categorised by grain size where possible.
	Clay Content (%)	Weight % of clay minerals in bulk rock. This is a mineralogical term.
	Clay Fraction (%)	Weight % of grains less than 2 microns diameter. This is a grain size term and may include non-clay minerals.
	Lithification	Degree of lithification (qualitative)
	Texture	Information about texture of sample
	Degree of Alteration / Weathering	Information about the degree of alteration or weathering of the sample



Stratigraphy	Chronostratigraphic parent unit	Chronostratigraphic parent unit of the sample
	Chronostratigraphic unit	Chronostratigraphic unit of the sample
	Local stratigraphic parent unit	Local stratigraphic parent unit of the sample
	Local stratigraphic unit	Local stratigraphic unit of the sample
Measurement conditions	Temperature (C)	Temperature (deg C) during measurement
	Pore Pressure (MPa)	Pore fluid pressure (MPa) during measurement
	Saturating Fluid	Fluid used to saturate the sample during measurement
	Saturation (%)	Degree of saturation of the pore space during measurement
	Confining pressure (MPa)	Confining pressure (MPa) during measurement
	Effective Confining Pressure (MPa)	Effective confining pressure (MPa) during measurement (i.e. confining pressure minus pore fluid pressure)
	Sigma1 (MPa)	Maximum principal stress (MPa) during measurement
	Sigma2 (MPa)	Intermediate principal stress (MPa) during measurement
	Sigma3 (MPa)	Minimum principal stress (MPa) during measurement
	Effective Sigma1 (MPa)	Effective maximum principal stress (MPa) during measurement
	Effective Sigma2 (MPa)	Effective intermediate principal stress (MPa) during measurement
	Effective Sigma3 (MPa)	Effective minimum principal stress (MPa) during measurement
	Measurement type	Type of measurement. Lab: measured in a laboratory; Lab (computed): computed from another lab-measured property; In-situ: measured in a borehole
	Remarks on measurement conditions	Additional information about measurement conditions
Measurement	Property and units	The property that was measured and its units
	Direction of measurement	Direction in which property was measured, e.g. parallel to bedding
	Value	Value of measured property (either a single value, or a representative value from a range)
	Min	Minimum value of measured property
	Max	Maximum value of measured property
	Std Dev	Standard deviation of measured values (where more than one value was measured)
	Number of measurements	Number of measurements
	Method	Method used to measure the property



	Test duration (hours)	Duration of test (hours)
	Quality	Quality of the measurement using ranking criteria
	Remarks	Additional information on measurement

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Appendix B

Table B1. Relationships between properties

Properties	Relationship	Parameters	Comments
Hydraulic conductivity, K (m/s) Permeability, k (m ²)	$k = K \left(\frac{\mu}{\rho_{fluid} g} \right)$	μ = dynamic viscosity of pore fluid (kg/(m s)) ρ_{fluid} = density of pore fluid (kg/m ³) g = gravitational constant (9.81 m/s ²)	μ and ρ vary with temperature, salinity and pressure (e.g. Adams and Bachu, 2002), hence conversion between k and K requires information about the experimental or in-situ conditions at which the measurement was taken.
Thermal conductivity (W/m/K): Dry porous rock, λ_{dry} Fully saturated porous rock, λ_{wet} Grain, λ_{grain}	$\lambda_{wet} = \lambda_{fluid}^{\phi} \lambda_{grain}^{(1-\phi)}$ $\lambda_{dry} = \lambda_{air}^{\phi} \lambda_{grain}^{(1-\phi)}$ (e.g. Sass et al., 1971)	$\lambda_{water} \gg 0.6$ W/m/K $\lambda_{air} \gg 0.03$ W/m/K ϕ = porosity (fraction)	λ_{dry} assumes a dry sample λ_{wet} assumes a water/brine-saturated sample λ_{grain} includes effect of mineral assemblage and cement at grain contacts
Density (kg/m ³): Dry porous rock, ρ_{dry} Fully saturated porous rock, ρ_{wet} Grain, ρ_{grain}	$\rho_{dry} = (1 - \phi) \rho_{grain}$ $\rho_{wet} = \rho_{dry} + \phi \rho_{fluid}$	ϕ = porosity (fraction)	
Porosity (fraction): Effective, ϕ_e Total, ϕ	$\phi_e = \phi - \phi_i$ $\phi = 1 - \rho_{dry} / \rho_{grain}$	ϕ_i = isolated (inaccessible) porosity; can be calculated from difference between measured total and effective porosity	
Permeability (m ²): Apparent, k_a Intrinsic, k_i	$k_a = k_i (1 + b/\bar{P})$	b = gas slip factor depending on mean free path of a gas and the average pore radius within the rock; $\bar{P}$ = mean pore pressure; b can be estimated from k_i (e.g. Li et al., 2009; Tanikawa and Shimamoto, 2009)	k_a = Gas permeability from single-phase flow experiments, not Klinkenberg-corrected k_i = Permeability from steady state, single-phase flow experiments with water or brine, or Klinkenberg-corrected k_a



Heat capacity (J/kg/K): Specific, C_p Volumetric, C_v	$C_v = \rho_b C_p$	ρ_b = bulk density	
Water content, W (%)	$W = 100 \times \frac{S \phi \rho_{fluid}}{(1 - \phi) \rho_{grain}}$	S = saturation (fraction)	Can be >100%



Data availability

The Global Petrophysical Database is available from the CSIRO Data Access Portal at <https://doi.org/10.25919/e8f9-n090> (Sheldon et al., 2026). The GPD Explorer is located at <https://shiny.csiro.au/GPDEXplorer/> (Sheldon et al., 2023).

Author contributions

HS, MR, DD and EB carried out data curation. HS and MR designed the database. DD developed the ranking criteria for laboratory-measured shale permeability. CT developed the ranking criteria for in-situ permeability and hydraulic conductivity. GW and HS developed the GPD Explorer web interface and carried out data cleaning. DM conceptualised the project and secured funding. HS prepared the manuscript with contributions from all co-authors.

Competing interests

The authors declare that they have no conflict of interest.

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