The CRM-geothermal database: harmonised geoscientific and geochemical data on geothermal systems, with emphasis on fluids and critical raw materials in Europe and East Africa (https://doi.org/10.5880/fidgeo.2026.012)

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1. Licence

2. Citation

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3. Data description

The CRM-geothermal database provides harmonised geoscientific and geochemical data on geothermal systems and their associated critical raw materials (CRMs) across Europe and Eastern Africa, with a primary focus on the chemistry of geothermal fluids as the main carriers of dissolved CRMs. The database was developed within the Horizon Europe project CRM-geothermal (Grant Agreement No. 101058163) to support the evaluation of geothermal systems with respect to both energy utilisation and the potential co-production of critical raw materials

The dataset integrates legacy data compiled from peer-reviewed scientific literature, national geological and geothermal databases, and previous European research projects (e.g., REFLECT, PERFORM), together with new data obtained through targeted field sampling and laboratory analyses carried out by project partners. The database contains detailed records on geothermal fluids, complemented by contextual information on wells, host rocks, gases, and mineral precipitates, allowing the geochemical data to be interpreted within their geological and operational framework (see also Seres et al., 2024, 2025, 2026).

All data have been harmonised using a unified metadata schema, standardised in terms of units and parameter naming, and subjected to automated and manual quality-control procedures. Each record is accompanied by provenance information documenting data origin and traceability. The CRM-geothermal database is fully compliant with FAIR data principles and is provided as structured tabular datasets in XLSX format, enabling straightforward reuse in statistical, modelling, and GIS-based analyses.

3.1. Sampling method

Data included in the CRM-geothermal database originate from two main sources: newly collected samples acquired within the CRM-geothermal project and legacy datasets compiled from previously published studies and databases. New sampling campaigns were carried out by project partners at selected geothermal sites across Europe and Eastern Africa, including volcanic, sedimentary, and rift-related geothermal systems.

Sampling focused primarily on geothermal fluids, which represent the main carrier of dissolved critical raw materials, but was complemented by the collection of rock, gas, and mineral precipitate (scale) samples where available. Samples were collected from geothermal wells, springs, and surface manifestations, as well as from operational geothermal installations. Sampling locations were documented using geographic coordinates referenced to the WGS84 coordinate system.

Legacy datasets were obtained from peer-reviewed scientific publications, national geological and geothermal databases, technical reports, and previous European research projects (e.g. REFLECT, PERFORM). These data were incorporated as secondary sources. Where available, original sampling dates, locations, and contextual information were preserved to ensure traceability. The temporal coverage of the database spans from historical geothermal observations dating back to the mid-19th century to the most recent sampling campaigns conducted within the CRM-geothermal project.

3.2. Analytical procedure:

Analytical data included in the CRM-geothermal database were generated using established laboratory techniques commonly applied in geothermal and geochemical research. For newly collected samples, laboratory analyses were carried out in multiple laboratories affiliated with the CRM-geothermal consortium and collaborating institutions, following standard operating procedures and internal quality assurance protocols.

Major and trace element concentrations in geothermal fluids and rocks were primarily determined using inductively coupled plasma mass spectrometry (ICP-MS) and X-ray fluorescence spectroscopy (XRF), while mineralogical compositions of rocks and mineral precipitates were analysed using X-ray diffraction (XRD). Gas samples were analysed for chemical composition using gas chromatography and, where available, noble gas mass spectrometry.

For each dataset, information on the analytical laboratory, applied methods, and detection limits is documented in the metadata fields of the accompanying XLSX files and linked references. Legacy data compiled from literature and existing databases reflect a variety of analytical techniques and laboratory settings; these data were not re-analysed but harmonised in terms of units, parameter naming, and metadata documentation to ensure transparency and comparability.

3.3. Data processing and harmonisation

All datasets included in the CRM-geothermal database were processed and harmonised using a unified data and metadata schema developed within the CRM-geothermal project. The data processing workflow was designed to ensure internal consistency, transparency, and reusability across datasets originating from heterogeneous sources.

As a first step, data compiled from literature, national databases, and project-generated measurements were standardised with respect to parameter names, units, and value formats. Where original data were reported in different unit systems or using non-standard conventions, values were converted into a common, harmonised unit system. Original values were preserved where relevant through metadata documentation to maintain traceability. Geographic coordinates were validated and, where necessary, converted into WGS84 decimal degrees to ensure spatial consistency across all records.

Automated validation routines were applied to identify missing values, implausible numerical ranges (e.g. temperature, pH, or elemental concentrations), and inconsistencies between related parameters. These automated checks were complemented by manual expert review conducted by project data curators to verify scientific coherence, correct attribution of samples to sites and wells, and consistency between analytical results and contextual information.

Each record in the database was assigned a quality flag reflecting both the origin of the data and the level of traceability of the source information. Bibliographic references and provenance metadata were systematically linked to individual records wherever possible, allowing users to assess data reliability and comparability. Legacy datasets were harmonised in a transparent manner that preserves the original analytical results while enabling cross-dataset comparison.

The final harmonised data were organised into thematic tables representing the main components of geothermal systems (wells, fluids, rocks, gases, and mineral precipitates) and exported as a structured Excel (XLSX) file. This format maintains the relational structure of the data while enabling straightforward reuse in statistical analysis, modelling, and GIS-based applications.

4. File description

The CRM-geothermal database is provided as a single structured Excel workbook (XLSX format) containing multiple thematic data tables. The XLSX format was chosen to ensure broad accessibility and compatibility with commonly used statistical, modelling, and GIS software. Each worksheet represents a specific data category (e.g. wells, fluids, rocks, gases, mineral precipitates - scales) and follows a consistent structure and naming convention. Separate worksheets are provided for PGE and REE data for fluids and rocks to facilitate data handling and to keep individual tables at a manageable size.

Tabular data are organised in rows representing individual records (e.g. wells, fluid, gas, rock, or scale samples), while columns represent parameters or metadata fields. Column headers follow a consistent and descriptive naming scheme, including parameter names and units. Most data columns contain numerical values, while any explanatory text or qualifiers are documented in dedicated remarks columns. Zero values indicate measured values equal to zero; missing or not applicable data are represented by empty cells. For measurements below the analytical detection limit, the detection limit value is reported numerically, and the corresponding remarks column documents this condition. These conventions were applied consistently across all tables to ensure transparency and comparability of the data. Geographic coordinates are provided in decimal degrees using the WGS84 coordinate reference system. Dates are reported using the ISO 8601 format (YYYY-MM-DD), where available.

4.1. File inventory

The data publication consists of the following files:

File name	Description
2026-012_Seres-et-al_CRM-geothermal_data.xlsx	Harmonised geoscientific and geochemical database containing wells, fluids, rocks, gases, and mineral precipitate data, including metadata, quality flags, and bibliographic references
2026-012_Seres-et-al_CRM-geothermal_data-dictionary.pdf	Data dictionary document explaining database structure, table contents, column definitions, units, coordinate systems, and data value conventions to support interpretation and reuse.

The Excel workbook contains multiple worksheets corresponding to the main components of geothermal systems:

- Well
- Fluid+ PGE-REE in fluid
- Rock + PGE-REE in rock
- Gas
- Scale / Precipitate

4.2. Description of data tables

The CRM-geothermal dataset is provided as a single Excel workbook containing multiple worksheets. Each worksheet represents a thematic data table corresponding to a major component of geothermal systems. All tables follow a consistent structure and share common metadata fields (e.g. site and sample identifiers with the well_ID linking all tables together, geographic coordinates, data source, quality flag, and bibliographic reference), enabling cross-referencing between data categories.

The CRM-geothermal dataset is provided as a single Excel workbook containing multiple worksheets. Each worksheet represents a thematic data table corresponding to a major component of geothermal systems. All tables follow a consistent structure and include a common identifier (well_ID), which enables relational linking between wells, fluids, rocks, gases, and scale data. Additional metadata fields such as geographic coordinates, data source information, quality flags, and bibliographic references are provided at the record level within each table.

4.3.1 CRM-geothermal data file

File name: ***2026-012_Seres-et-al_CRM-geothermal_data.xlsx***

This file contains harmonised geoscientific and geochemical data compiled from literature, existing databases, and new sampling and analytical work carried out within the CRM-geothermal project.

The data are organised into the following worksheets: well, Fluid, Rock, PGE-REE in fluids, PGE-REE in rocks, Gas, Scale.

4.2.1. Wells

Geographic, technical, and contextual information on geothermal wells (Total 34 columns)

Column header	Unit	Description
Well ID	Free text, unique identifier	Free text, unique identifier
Country	Dropdown list	name of country (ISO country names or codes)
Local ID for the well	Free text ID format	local ID of well as found in original paper
Well type (injection, production, etc)	Dropdown list	type of well, e.g. injection, production, gas well, observation, abandoned etc
Name of the facility	free text	name of the facility where the well is found
Power (thermal)	MWth	power produced in MWth
Latitude	DD.dddd	Latitude in WGS84 decimal degrees, value between -90 and 90
Longitude	DD.dddd	Longitude in WGS84 decimal degrees, value between -180 and 180
Date of well completion	year	year when well was completed
Wellhead elevation	m amsl	elevation above mean sea level in meters
Surface elevation	m amsl	elevation above mean sea level in meters
True vertical well depth	m	distance between wellhead and bottom of well (postive number), measured along a vertical line
Measured well depth	m	distance between wellhead and bottom of well (postive number), measured along the well
Top of screened interval (below wellhead, true vertical depth)	m	
Bottom of screened interval (below wellhead, true vertical depth)	m	
Top of screened interval (below wellhead, measured depth)	m	
Bottom of screened interval (below wellhead, measured depth)	m	
Hydraulic head	m amsl	Height of a vertical column of water at rest referenced to a datum plane. Derived as p/(ρg)
PZ data	MPa/m	Pressure (P) change along a vertical axis (Z), given as the gradient of the pore pressure: how the pressure is changing over a unit depth: (P2-P1)/(Z2-Z1) [MPa/m].
PZ data depth	m	Depth of the measured pressure change (PZ).
Bottomhole temperature	°C	temperature at the bottom of the well in °C.
Depth of measured bottomhole temperature	m	Depth of the measured bottomhole temperature
Outflow temperature	°C	Outflow temperature in °C
Year of outflow temp. measurement	year	Year of the outflow temperature measurement
Well yield	m^3/hour	Well yield in m3/h.
Year of well yield measurement	year	

Remarks on well yield measurement	free text	e.g. artesian, pumping
Scaling exists	Y/N	yes or no
Inhibitor added	Y/N	yes or no
Geothermal gradient in well	°C/100 m	
References	free text	Full reference
Remarks	free text	general remarks
Data quality	A, B1, B2, C1, C2	Data quality from best to least good: A, B1, B2, C1, C2
Source	free text	REFLECT, PERFORM, Literature, New data

4.2.2. Fluids

Chemical and physical data of geothermal fluid (Total 132 columns), typical columns include:

Column header	Unit	Description
Fluid sample identification	ID format, free text, dropdown list, m, date (YYYY.MM.DD)	Fluid sample identification includes: Well ID, Fluid sample ID, Local ID for fluid sample, Sampling method (please select), Sample depth (m), Sample location, Sampling date, Analysis date, Remarks
Physical properties	dropdown list, °C, MPa, m amsl, kg/dm3, m2/s, kg/m/s, J/K/kg, µS/cm	Phase of sample (please select), Temperature (°C), Pressure (MPa), Hydraulic head (m amsl), Density (kg/dm3), Kinematic viscosity (m2/s), Dynamic viscosity (kg/m/s), Specific heat capacity (J/K/kg), Electrical conductivity (µS/cm, EC25), Remarks
Chemical properties - general	numeric, °C, mg/l, mV, meq/l, Nml/kg	pH, pH temperature (°C), Dissolved oxigen (mg/L), Eh (mV), Total alkalinity (meq/L), Carbonate alkalinity (meq/L), TDS (mg/L), TDG (Nml/kg), GLR, Remarks
Chemical properties – dissolved major cations	mg/l	Ca, K, Mg, Na, Si, TMC, Remarks
Chemical properties – dissolved major anions	mg/l	Cl, S, F, CO3, HCO3, SO4, PO4, HBO2, TMA, Remarks
Chemical properties – trace elements	mg/l	Ag, Al, As, Au, B, Ba, Be, Bi, Br, Co, Cr, Cu, Cs, Fe, Ga, Ge, Hf, Hg, I, In, Li, Mn, Nb, Ni, Pb, PGE, Rb, REE, Sb, Sc, Sr, Ta, Ti, W, Zn, Remarks
Chemical properties - Organics and petroleum components	mg/l	TOC, TPH, BTEX, Remarks
Chemical properties - Dissolved gas	vol%	CO2, O2, H2S, N2, CH4, Ar, H2, He, Remarks
Chemical properties - Isotopes	‰	Oxigen-18, Deuterium (2H), Tritium (3H), Oxigen-18 (SO4), Sulfur-34 (SO4), Sulfur-34 (H2S), Carbon-13 (CO2), Lithium-7, Boron-11, 87Sr/86Sr, Remarks
References	free text	Full reference
Remarks	free text	general remarks
Data quality	A, B1, B2, C1, C2	Data quality from best to least good: A, B1, B2, C1, C2
Source	free text	REFLECT, PERFORM, Literature, New data

4.2.3. PGE-REE in Fluids

Platinum Group Element and Rare Earth Element content of the fluids (Total 27 columns)

Column header	Unit	Description
Fluid sample identification	ID format	Well_ID, Fluid_ID
PGE	ppm	Os, Ir, Ru, Rh, Pt, Pd
Data quality	A, B1, B2, C1, C2	Data quality from best to least good: A, B1, B2, C1, C2
Source	free text	REFLECT, PERFORM, Literature, New data

4.2.4. Rocks

Geochemical and mineralogical data for rock, core, or cutting samples (Total 76 columns)

Column header	Unit	Description
Rock sample identification	ID format, free text, m, year	Well_ID, Rock_ID, Local ID for rock sample, Sampling method, Sample depth (m), Sampling date (year), Analysis date (year)
Reservoir data	dropdown list, m/s	Reservoir type (please select), Reservoir pressure (please select), Hydraulic conductivity (m/s)
Geological information	dropdown list, free text	Rock type (please select), Age of rock (please select), Mineralogical composition, Formation name, Formation code on geological map, Link to geological map
Main elements	weight percent	SiO2, Al2O3, Fe2O3, MgO, CaO, Na2O, K2O, Ti2, P2O5, MnO, SO3, LOI, Remarks
Trace elements	ppm	Ag, As, B, Ba, Be, Bi, Cd, Ce, Co, Cr, Cs, Cu, Ga, Ge, Hf, Hg, In, Li, Mo, Nb, Ni, Pb, PGE, Rb, REE, S, Sb, Se, Sn, Sr, Ta, Th, Tl, U, V, W, Zn, Zr, Remarks
Physical properties	D, %, J/K/kg, W/m/K	Permeability (D), Porosity (%), Heat capacity (J/K/kg), Thermal conductivity (W/m/K)
References	free text	Full reference
Remarks	free text	general remarks
Data quality	A, B1, B2, C1, C2	Data quality from best to least good: A, B1, B2, C1, C2
Source	free text	REFLECT, PERFORM, Literature, New data

4.2.5. PGE-REE in Rocks

Platinum Group Element and Rare Earth Element content of the rocks (Total 27 columns)

Column header	Unit	Description
Rock sample identification	ID format	Well_ID, Rock_ID
PGE	ppm	Os, Ir, Ru, Rh, Pt, Pd
Data quality	A, B1, B2, C1, C2	Data quality from best to least good: A, B1, B2, C1, C2
Source	free text	REFLECT, PERFORM, Literature, New data

4.2.6. Gas

Chemical and isotopic data for free and dissolved gases (Total 128 columns)

Column header	Unit	Description
Gas sample identification	ID format, drowdown list, m, date in YYYY.MM.DD	Well ID, Fluid sample ID, Gas sample ID, Local ID for gas sample, Sampling location (please select), Sampling depth (m), Sampling date (YYYY.MM.DD), Analysis date (YYYY.MM.DD), Remarks

Basic properties	dropdown list, °C, MPa, Nml/kg	Phase of sample (please select), Temperature (°C), Pressure (MPa), pH, pH temperature (°C), Gas/Liquid ratio (GLR), Total Dissolved Gas (Nml/kg), Remarks
Chemical properties – Main gas elements	µmol/mol or ppm	Ar, CO2, H2, O2, N2, He, CH4, Remarks
Chemical properties – major cations	ppm	B, Ca, Fe, K, Mg, Na, SiO2, TMC, Remarks
Chemical properties – major anions	ppm	Cl, S, F, CO2, CO3, H2S, H2, HCO3, SO4, PO4, HBO2, S2O3, DIC (total dissolved inorganic carbon), TMA, Remarks
Chemical properties – trace elements	ppb	Ag, Al, Ar, As, Au, Ba, Be, Br, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Ga, Gd, Ge, Hf, Hg, Ho, I, La, Li, Lu, Mn, Mo, Nd, Ni, P, Pb, Pr, Rb, Sb, Sc, Se, Sm, Sn, Sr, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Remarks
Noble gas	vol-ppm, vol-ppb	20Ne, 84Kr
Noble gas isotope ratios	-	3He/4He [Ra], 20Ne/22Ne, 21Ne/22Ne, 40Ar/36Ar, 38Ar/36Ar, 128Xe/132Xe, 129Xe/132Xe, 130Xe/132Xe, 131Xe/132Xe, 134Xe/132Xe, 136Xe/132Xe
Noble gas element ratios	-	4He/20Ne, 4He/40Ar (10–3), 20Ne/40Ar (10–3), 40Ar/84Kr (10^3), 40Ar/132Xe (10^3), 84Kr/132Xe, 20Ne/36Ar, Remarks
References	free text	Full reference
Remarks	free text	general remarks
Data quality	A, B1, B2, C1, C2	Data quality from best to least good: A, B1, B2, C1, C2
Source	free text	REFLECT, PERFORM, Literature, New data

4.2.7. Scales/precipitates

Mineralogical and geochemical data for mineral precipitates and scaling materials (Total 94 columns)

Column header	**Unit**	**Description**
Scale sample identification	ID format, free text, dropdown list, m, year	Well ID, Scale sample ID, Local ID of scale sample, Sampling location (please select), Sample depth (m), Sampling date (year), Analysis date (year), Remarks
Chemical properties - Oxides	weight percent	SiO2, Al2O3, Fe2O3, MnO, MgO, CaO, Na2O, K2O, TiO2, P2O5, LOI, Total oxides ppm, Remarks
Chemical properties – main elements	ppm	Al, C, Ca, Fe, K, Mg, Mn, Na, S, Ti, Remarks
Chemical properties – trace elements	ppm	Ag, As, Au, B, Ba, Bi, Be, Br, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Ga, Ge, Gd, Hf, Hg, Ho, In, Ir, La, Li, Lu, Mo, Nb, Nd, Ni, Pb, Pd, Pr, Rb, Re, Ru, Sc, Sb, Se, Sm, Sn, Sr, Ta, Tb, Te, Th, Tl, Tm, U, V, W, Y, Yb, Zn, Zr, Remarks
References	free text	Full reference
Remarks	free text	general remarks
Data quality	A, B1, B2, C1, C2	Data quality from best to least good: A, B1, B2, C1, C2
Source	free text	REFLECT, PERFORM, Literature, New data

4.3.2 CRM-geothermal data description file

File name: *2026-012_Seres-et-al_CRM-geothermal_data-dictionary.pdf*

The CRM-geothermal data description file explains the meaning of individual database columns, including parameter definitions, applied units, and, where relevant, expected value ranges. It supports correct interpretation of the data values.

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