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### **► To cite this version:**

Salsabyl Benlalam, Benoit Derode, Fabien Engels, Jean Schmittbuhl, Aude Chambodut. CDGP data center, a gateway to cutting-edge deep geothermal data. European Geothermal Congress, Oct 2025, Zurich (CH), Switzerland. <hal-05515516>

**HAL Id: hal-05515516**

**<https://hal.science/hal-05515516v1>**

Submitted on 17 Feb 2026

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## CDGP data center, a gateway to cutting-edge deep geothermal data

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**Keywords:** CDGP, Deep Geothermal Energy, Multi-disciplinary Data, Industrial & Academic Data, Episodes, FAIR

### ABSTRACT

The Data Center for Deep Geothermal Energy (CDGP - Centre de Données de Géothermie Profonde, <https://cdgp.eost.unistra.fr>) was inaugurated in 2016 and is overseen by the Interdisciplinary Thematic Institute for Geosciences (ITI GeoT). The objective of the CDGP is to archive, preserve and distribute deep geothermal data in the Alsace region (France) for the scientific community, research and development activities. Furthermore, the CDGP serves as a regional node for EPOS TCS (Thematic Core Service) Anthropogenic Hazards. This service provides access to a range of multidisciplinary data, including industrial hydraulic information, seismic records and catalogues, geological logs, and fault maps, among other resources. The data are subjected to rigorous filtering, control and validation by analysts and are grouped into Episodes, which refer to a set of relevant geophysical data that are correlated over time, thereby establishing links between anthropogenic seismicity and industrial activity. The CDGP collates high-quality data from a range of stages in the development of deep geothermal projects, particularly from the exploration and development phases. This enables users to process and analyze the data in a way that adds significant value. As part of the European Geo-INQUIRE project (GA n. 101058518, <https://www.geo-inquire.eu/>), It is now evolving to provide new multidisciplinary data with the aim of diversifying the ability of users to analyze the data. As an example, the website now offers RINEX data from GNSS stations that are monitoring surface deformation around geothermal sites, along with dynamic 3D GeORG-based models for each site. Strategies are currently being developed in collaboration with EPOS TCS GIM (Geological Information and Modelling) with the objective of providing geological maps and borehole data for the aforementioned Episodes sites.

The intention is to take advantages of the TCS GIM services that are currently under development, thereby capitalizing on the potential synergies that may emerge from the various leading projects. Specific procedures have also been implemented to comply with

international requirements for data management. FAIR recommendations, for instance, are followed to ensure the distribution of data that is Findable, Accessible, Interoperable, and Reusable. Through its platform, the CDGP is dedicated to providing valuable scientific data on deep geothermal processes, accessible to all.

### 1. INTRODUCTION

The Upper Rhine Graben (URG) has become a pioneer European geothermal technology thanks to the development of deep geothermal energy in this region. A large number of studies on heat extraction from fractured reservoirs have been carried out at the URG since the initial trials in Soultz-sous-Forêts in the late 1980s (e.g., Sanjuan et al., 2006; Genter et al., 2010; Baujard et al., 2017). In Alsace, the sites of Rittershoffen, Vendenheim, and Soultz-sous-Forêts played a key role to the development of geothermal technology. These projects have raised a great interest both within the scientific and industrial communities. Over the past decades, these projects and the data they provided have significantly advanced our knowledge of geological resource reservoirs, particularly geothermal reservoirs, and enabled the scientific community to adapt and modernize its understanding of the mechanical response of reservoirs to the hydromechanical stresses imposed by the industrial activities they host. However, these developments also raise challenges, as they involve fluid migration, stress changes, induced seismicity, and then the need for long-term monitoring (e.g., Cuenot et al., 2008; Lengliné et al., 2017). Furthermore, the increasing complexity of deep geothermal projects highlights the critical need for reliable, accessible, and durable data to support scientific research, promote interdisciplinary collaboration, and guide the sustainable management of underground resources.

In this context, the LabEx G-EAU-THERMIE PROFONDE program (2012-2020) launched the Deep Geothermal Data Center (CDGP), designed as a centralized platform to collect, archive, and distribute multidisciplinary geothermal datasets. Following the end of the LabEx G-EAU-THERMIE PROFONDE, the scientific and organizational activities launched during the program have been strengthened and expanded within the Interdisciplinary Thematic Institute for Geosciences and Energy Transition (ITI GeoT), established in 2021

at the University of Strasbourg. This institutional framework builds on the LabEx’s multidisciplinary foundations and supports long-term research efforts to address the major challenges of the energy transition. In line with these aims, the Deep Geothermal Data Center has been integrated as a central infrastructure driving interdisciplinary research.

The CDGP infrastructure supports the European scientific initiative EPOS and is integrated into the EPOS Thematic Core service for Anthropogenic Hazards (TCS AH), which aims to bring together systems dedicated to the study of anthropogenic seismicity caused by human activities and to examine the risks associated with the exploration and exploitation of georesources, a major issue in the current context of economic development and natural resource use. As the French local node, our platform provides structured access to a wide range of datasets from geothermal sites in Alsace, a leading French region for deep-geothermal projects—particularly EGS—and a national cradle for the development of the Enhanced Geothermal Systems (EGS) approach.

Since 2022, in addition to the datasets provided to the EPOS EPISODES platform, the CDGP distributes raw GNSS data in RINEX format from GNSS stations installed by operators and by the Strasbourg School and Observatory of Earth Sciences (EOST) near geothermal sites. These GNSS stations enable permanent monitoring of surface deformation and provide complementary constraints for studying the mechanical response of the reservoirs. Simultaneously, the CDGP has added geological sections (1D and 2D) for several sites to its data catalogue by extracting targeted sections from the GeORG project (Geopotentials of the Deep Upper Rhine Graben, <https://www.geopotenziale.org>), whose aim was to create a 3D model of the geological structure of the Rhine Graben. These sections provide a detailed view of the geological formations at geothermal sites, enabling researchers to better understand extent and geometry of the reservoir and improve reservoir models.

## 2. THE CDGP: A SPECIALIZED INFRASTRUCTURE FOR DEEP GEOTHERMAL ENERGY DATA

### 2.1 Data and Episodes organization

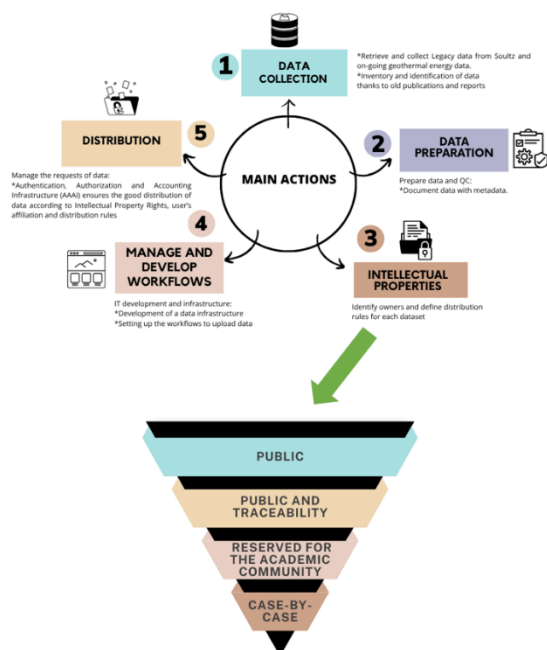
Each dataset distributed by the CDGP is associated to a specific site (location) and time period. The periods are defined by project operators’ industrial activities, such as exploration drilling, hydraulic stimulation, fluid circulation, or occurrence of induced-seismicity swarms (Schaming et al., 2019). These datasets, grouped into large sets, containing comprehensive information about industrial operations (e.g., hydraulic pressure and/or flow rate) and on the hydromechanical response of the stimulated medium (induced seismicity), form collections known as Episodes, linking industrial activities to observed geophysical responses. These episodes

organize the data into time-correlated sets, facilitating the analysis of interactions between industrial activities and geophysical responses. CDGP episodes originate essentially from the geothermal sites of Soultz-sous-Forêts, Rittershoffen, and Vendenheim, providing information on the different phases of industrial activity at these sites. For example, Boyet (2023) highlights the importance of understanding post-injection seismicity in Enhanced Geothermal Systems (EGS), particularly for sites such as Soultz-sous-Forêts and Vendenheim, in order to ensure the safety and sustainability of geothermal operations. The episode approach of the CDGP, which combines multidisciplinary data, allows for in-depth analysis of the interactions between fluid injections and seismic responses, thereby facilitating the monitoring and optimization of geothermal operations.

### 2.2 Data management and FAIRness

The CDGP guarantees the collection, preparation, and distribution of data in accordance with European standards. The CDGP ensures the availability of data, while complying with strict rules on intellectual property and the protection of sensitive data. The data are accessible via a secure platform, ensuring that all associated metadata complies with ISO 19115 standards, which is essential for guaranteeing interoperability and enabling future reuse. Managing Digital Object Identifiers (DOIs) is central to ensuring that the data remain traceable and long-lived. These identifiers not only guarantee permanent access to datasets but also adhere to FAIR principles (Findable, Accessible, Interoperable, Reusable), making it easier for researchers to access and reuse the data over time. The assignment of DOIs links each episode to detailed information about creators, publisher/repository, rights/license, rights holder, related identifiers, documenting provenance, governance and terms of use.

In order to comply with Intellectual Property Rights (IPR) requirements, specific terms of use and procedures have been established. A unique feature of the infrastructure is that an Authentication, Authorization, and Accounting Infrastructure (AAAI) ensures fair distribution of data in accordance with IPR, user affiliation (e.g., academic, industrial, etc.), and distribution rules. This operation can be performed automatically or with the agreement of the data owner. This procedure is an important attribute of the infrastructure, which helps build trust between industry and the academic scientific community (Fig. 1).



**Figure 1:** CDGP infrastructure organization and main actions. The CDGP seeks to collect, prepare and curate the data, respecting the intellectual properties of the data and the fairness of its distribution. It develops and manages workflow leading to a wide distribution to the industrial, scientific and civil society communities.

## 2.3 Data collection

The data collected cover all stages of geothermal projects, from area exploring to drilling, stimulating wells, circulating fluids, producing energy and cleaning up the area afterwards. A comprehensive presentation and description of the different datasets is available on Schaming et al. 2019. As a short summarize, main data are about seismic reflection, passive seismic imaging and seismic log profiles (VSP), MT and gravimetric data, 3D geological models and fractures geometries, well trajectories and T/gamma ray logs, seismic waveforms and induced seismicity catalogues. Petrophysical properties can also be explored thanks to X-ray experiments conducted on geological samples from Soultz-sous-Forêts boreholes.

**Episode: 1993 Stimulation Soultz-sous-Forêts**

16

After the deepening of well GPK1 to 3590m in 1992, an extensive stimulation program was performed in September and October 1993. GPK1 was stimulated with large scale hydraulic injections to investigate the behavior and the extension of large natural fractures ...

CDGP - EOST

**Episode: Geoven geothermal project at Vendenheim**

9

Geoven (<http://www.geoven.fr>) was a geothermal power plant project initially managed by Fonroche Géothermie, later taken over by Arverne ([https://arverne.earth/wp-content/uploads/2023/02/Communique\\_Presse\\_Georhin\\_130223.p](https://arverne.earth/wp-content/uploads/2023/02/Communique_Presse_Georhin_130223.p))

CDGP - EOST

**Episode: 2000 Stimulation Soultz-sous-Forêts**

17

During June/July 2000 a hydraulic stimulation program was conducted in the well GPK2 at the European Hot Dry Rock project, Soultz-sous-Forêts, France. The stimulation was performed over the openhole section of GPK2 from 4431 m measured depth (MD) to the bottom of ...

CDGP - EOST

**Petrophysical properties - Soultz-sous-Forêts**

Data on the petrophysical properties of samples from geothermal wells at the Soultz-sous-Forêts site.

CDGP - EOST

Completed

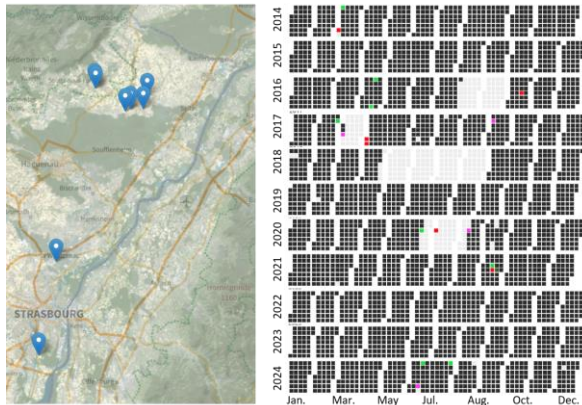
**Figure 2:** Example of the data collection displayed when visiting the CDGP website. Data are classified by Episode datasets, containing all the data available for a specific industrial activity (e.g. 1993 stimulation at Soultz-sous-Forêts), or by data type (e.g. Petrophysical properties – Soultz-sous-Forêts). All these data are accessible from a single front page <https://cdgp.eost.unistra.fr/geonetwork/srv/fre/catalog.search#/home>

## 3. RECENT INCREASE AND IMPROVEMENT OF THE CDGP DATA COLLECTION

### 3.1 Geodetic data

The recent addition of GNSS data, essential for studying surface deformation, now allows to connect the macroscopic (static) mechanical response of the reservoir to the industrial stimulation. A partnership

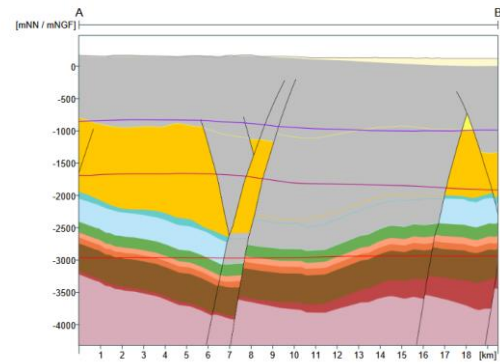
agreement has indeed been signed by the companies involved in deep geothermal energy in Alsace and by EOST, under the patronage of the Regional Department for the Environment, Planning and Housing (DREAL). These data, which actually concern 8 geodetic stations (ECOG, GPK1, GPK2, HATN, ILLK, REIC, RITT and STUN) located in and around the industrial sites, are for some collected since 2013 and are now used for real-time surface monitoring of the sites. All these data are now available in near-real time and linked to the corresponding episodes (e.g., Fig.3).



**Figure 3:** Location of the 8 geodetic stations (GNSS) used for real-time monitoring the deformation of the hydraulically stimulated reservoirs (left). On the right, an example of the data availability for the ECOG station from January 2014 to December 2024. More than 90% of the eleven-year period is available on request from the CDGP website.

### 3.2 GeORG Model Data

As part of the European Geo-INQUIRE project, the CDGP has worked to add complementary data types for each existing episode and to create new episodes. Several products from the GeORG map viewer (Geopotentials of the Deep Upper Rhine Graben, <https://www.geopotenziiale.org/home/>) around the geothermal sites in Alsace (Soutz-sous-Forêts, Vendenheim, Rittershoffen) have been extracted and are available on the CDGP website. In addition to the geophysical data associated with a specific episode, these geological cross-sections provide complementary information on the reservoir, which can be used as inputs for 1D or 3D numerical hydromechanical or thermochemical modeling. GeORG offers a complete geoscientific information base, with maps showing the deep structure and spatial distribution of geological layers and temperatures. The products provided via the CDGP contain, among others, the stratigraphic position and spatial stacking of layers (e.g., Fig. 4), as well as 1D synthetic stratigraphic logs.



**Figure 4:** Example of a vertical geological section corresponding to the south-west-north-east at Vendenheim site, Geoven project, extracted from the Geopotentials of the Deep Upper Rhine Graben (GeORG) project.

### 3.3 New perspective of added data

The CDGP is undergoing constant evolution through its various lever projects and European integration. This involves two main objectives: firstly, to add new datasets for each existing episode, and secondly, to add new episodes to the global collection. The construction of new episodes from recent stimulations in Alsace (2020-2025) is ongoing, and the integration of new multidisciplinary datasets is under discussion. In particular, geochemical data have the potential to provide valuable insights by imposing specific constraints on the numerical modeling produced using the initial data provided. The consolidation of the extant episodes, by incorporating the data from the numerous scientific publications on the geothermal sites in Alsace (largely dealing with induced seismicity issues), should significantly improve our understanding of the geothermal reservoir response to industrial stimulations.

	<a href="#">Catalogue Schmittbuhl</a>	<input type="button" value="Open link"/>	
	<a href="#">Catalogue Fiori</a>	<input type="button" value="Open link"/>	
	<a href="#">GeORG sections</a>	<input type="button" value="Open link"/>	
	<a href="#">GNSS data</a>	<input type="button" value="Open link"/>	
	<a href="#">Microseismic catalogue from Minetto et al (2025)</a>	<input type="button" value="Open link"/>	
	<a href="#">Microseismic catalogue with magnitude from BCSF-RéNaSS</a>	<input type="button" value="Open link"/>	
	<a href="#">Microseismic surface network</a>	<input type="button" value="Open link"/>	
	<a href="#">Seismological waveforms from Résif</a>	<input type="button" value="Open link"/>	
	<a href="#">VDH-GT1 well</a>	<input type="button" value="Open link"/>	
	<a href="#">VDH-GT2 well</a>	<input type="button" value="Open link"/>	

Access and use constraints

Confidentiality Level 1: Public and traceability

How to cite: EOST & Fonroche Géothermie (2020). Episode: Geoven geothermal project at Vendenheim. EOST-CDGP. <https://doi.org/10.25577/kcz6-tc66>

**Figure 5:** Datasets available for the GEOVEN Geothermal project at Vendeheim. Screenshot from the CDGP website <https://cdgp.eost.unistra.fr/geonet-work/srv/fre/catalog.search#/metadata/VDHD>. Associated to the needed information of the episode (not shown here), for each dataset the access and use constraints are indicated. In this example the

confidentiality level is minimum, which means that the data are fully available to the public.

#### 4. RECENT SCIENTIFIC USE OF CDGP'S DATA

For many years, the CDGP has played a central role in the distribution of geothermal data to a large community of researchers, both internal and external to the ITI GeoT. These data have been used in numerous studies, and their use has increased considerably since 2019, leading to many publications in scientific journals. These publications cover a huge range of topics, from spatial distribution of induced seismic events (e.g., Minnetto et al., 2025; Li & Avouac, 2025), fracture modeling (e.g., Sáez, 2023; Sáez & Lecampion, 2023), diffusion laws for induced seismicity (e.g., Danré et al., 2024), monitoring and management of induced seismicity (e.g., Fiori et al., 2023; Romanski et al., 2024), impact of fluid injection on geothermal reservoirs (Drif et al., 2024; Lengliné et al., 2023).

As a recent example, consecutive to the PhD of Kamel Drif, a publication was published, presenting 18 new seismic catalogues: « *Induced Seismicity Controlled by Injected Hydraulic Energy: The Case Study of the EGS Soutz-Sous-Forêts Site* ». These catalogues are related to different episodes (1993, 1995, 1996, 2000, 2003, 2004, 2005, 2010) and have been added to the CDGP database. Another catalogue related for the Vendenheim geothermal site, produced as part of Fiori et al. (2023) “*Monitoring induced microseismicity in an urban context using very small seismic arrays: The case study of the Vendenheim EGS project*”, has also been included.

#### 5. THE CDGP'S ROLE IN EUROPEAN FRAMEWORKS

As mentioned above, as the French node of the EPOS TCS AH, the CDGP also distributes its data to the EPISODES platform, which offers tools for data processing, analysis and visualization, facilitating interdisciplinary research. The CDGP also collaborates with other EPOS thematic core services, such as the TCS GNSS (Global Navigation Satellite System) for surface deformation data. The aim is to distribute GNSS products such as velocity and displacement through the CDGP. This TCS provides access to a variety of European and regional geodetic data, metadata, products and software in support of solid earth sciences. The CDGP also works closely with the TCS GIM (Geological Information and Modeling) to produce maps and drilling data for geothermal sites. This TCS develops and consolidates information and data infrastructures produced by the international geological community.

The CDGP is a partner in the European Geo-INQUIRE (Geosphere INfrastructures for QUestions into Integrated REsearch) project (GA n. 101058518, <https://www.geo-inquire.eu/>), which began in October 2022. The aim of this project is to provide and improve access to data and overcome the cross-domain barriers.

The CDGP is part of Work Package 4, “Access to products enabling curiosity-driven science for geo-resources exploration and exploitation”. This WP concentrates on improving access to data and research infrastructures related to the exploration and exploitation of geo-resources. The CDGP is especially involved in task 4.3, which is the multidisciplinary and multiscale extension of the EPOS AH EPISODES platform. Several tasks can be mentioned for this assignment, the first is to add well data in collaboration with TCS GIM, the second to integrate 3D geological models into CDGP episodes, and finally to include various multi-scale data types for geothermal sites.

The CDGP is also involved in the European DT-GEO (Digital Twin for GEophysical Extremes) project (<https://dtgeo.eu/>), which aims to develop pre-operational digital twin for geophysical extremes, such as earthquakes, volcanoes, tsunamis and anthropogenic seismicity/geo-reservoir responses. The goal is to improve understanding, forecasting and management of these risks through advanced simulations and real-time data integration. CDGP data are integrated into the digital twin models developed by DT-GEO to simulate and analyze seismicity in the region. Some of the results of this project will be added to the CDGP database.

#### 6. PERSPECTIVES

As a new underway project, the CDGP will be a cornerstone of a new regional infrastructure, the Deep Reservoir Observatory (Observatoire des Réservoirs Profonds, ORP), aiming to develop and implement a multidisciplinary monitoring system to study deep reservoirs in real time at the regional scale of the Rhin graben. Currently operated with the support of existing observatories, the ORP structure is coordinated by the EOST observatory which is under the governance of the University of Strasbourg and CNRS. Based on actual features and the mid-term projection of the CDGP infrastructure, in 2024 user feedback was collected to identify interface improvements, thus initiating a restructuring of the CDGP platform. This restructuring, currently underway thanks to the recruitment of an IT specialist, allows the development a more intuitive interface that meets user expectations while respecting the guidelines set out in Geo-INQUIRE, and bringing more flexibility to adapt the structure to the future projects.

#### 7. CONCLUSIONS

The CDGP is a major actor in the field of deep geothermal energy and in the development of geoscientific data infrastructures in Europe. Through its contribution to projects such as Geo-INQUIRE and DT-GEO, the CDGP facilitates access to data while ensuring responsible management of geophysical information. It represents a fundamental tool for scientific innovation and the development of geothermal projects on a European scale.

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## Acknowledgements

This work was performed under the framework of the Interdisciplinary Thematic Institute GeoT (ANR-10-IDEX-0002, ANR-20-SFRI-0012), as part of the ITI 2021-2028 program of the University of Strasbourg, and in the framework of the project EPOS TCS AH (European Plate Observing System, Thematic Core Services Anthropogenic Hazard). The CDGP is part of the European project Geo-INQUIRE (GA n. 101058518, <https://www.geo-inquire.eu/>).