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Thermo2Pro: A tool to Help Professionals of the Geothermal Sector for Exploration in Deep Basin Context in France - Development, Update, and Perspectives

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ABSTRACT

The understanding of geology and petrophysical properties is necessary to develop deep geothermal projects. However, this knowledge must be shared within the French professional geothermal community to make the exploration process more efficient. Thermo2Pro is designed to fill the gap between the information derived from R&D projects and the authorities dealing with the deep geothermal exploration in basin context. Contracting authorities, local authorities, and design offices have been gathered in a user committee involved in the development of the project since its inception.

The main vector for Thermo2Pro is a Web application where the user accesses the information by simulating vertical or horizontal sections, or boreholes. The information is stored in 3D regular grids derived from scientific projects. The functionalities of Thermo2Pro have been demonstrated through information related to the Trias aquifer of the Paris basin acquired and inferred in the scope of the CLASTIQ-2 project. In that area, the available parameters were mainly a model of lithology, an estimation of porosity, and a model of temperature.

The initial Thermo2Pro project was dedicated to the development of the Web tool and its demonstration. The list of parameters available in Thermo2Pro is being expanded through the TRANS-CLAS project, by adding new information from the Paris basin and other areas such as Alsace and the French Massif Central. In addition, dissemination of data from the Dogger reservoir in the Paris basin is under study.

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1. INTRODUCTION

France is one of the pioneers for geothermal heating exploitation in the world but efforts must continue to double geothermal heat networks by 2020 (“Grenelle de l'environnement” target). In the Paris basin, the carbonate aquifer of the Dogger is operated between 1500 and 2000 m with temperatures between 55 and 85°C. The density of installations reached its limits, particularly in the Val de Marne and to a lesser extent, the Seine-Saint-Denis area.

On the other hand, cold water re-injected into the ground may gradually alter the production areas in the short term. Indeed, the extension of the "cold bubble" around the injection wells may result in a breakthrough in thermal production wells. These issues are discussed within the framework of the Dogger Management project (Goyénèche et al, 2004 and 2005; Hamm et al., 2010 and 2013). In parallel, it is essential to look for other potential geothermal aquifers such as the reservoir of the Trias or the Lusitanian carbonate reservoir (Fig. 1)

PERIOD	EPOCH	AQUIFERS
CRETACEOUS	LATE	
	EARLY	Albian sand Neocomian sand
JURASSIC	LATE	Lusitanian limestone
	MIDDLE	Dogger limestone
	EARLY	
TRIASSIC	LATE	Retian sandstone Chaunoy fluvial sandstone (Westward)
	MIDDLE	Donnemarie fluvial sandstone (Westward)
	EARLY	Lorraine sandstone (Eastward)

Figure 1: Geological time scale and the main aquifers of the Paris basin.

Trias is a deep reservoir that has been explored mainly for its oil potential (only 3 geothermal exploration doublets have been drilled). The Trias reservoir is the aim of the scientific project CLASTIQ-2 (Bouchot et al, 2009) following the CLASTIQ-1 project (Bouchot, 2008).

The Lusitanian aquifer, shallower than the Dogger one, can also be a target for new geothermal operations, especially in areas where the Dogger is overexploited. The Lusitanian reservoir would feed new urban heat networks designed for low consumption buildings where a lower temperature resource would be sufficient (around 50°C).

As described above, there is a need is for a better understanding of the deep geothermal aquifers in sedimentary basins. Various scientific projects are dedicated to these aquifers. However, this knowledge will be relevant only if it is useful to the geothermal industry professionals. Indeed, the regional and local authorities, and design offices need to understand the favourable areas for exploration. So far, there is no tool to forward this knowledge to professionals of the deep geothermal sector.

2. CONTEXT

The exploitation of the geothermal resource in deep sedimentary basin is managed by the non-geoscience professionals of the sector, such as decision makers (government and/or local authorities), contracting authorities and design offices.

2.1 Scientific projects

Several projects led by ADEME and BRGM have been focusing on deep aquifers during the last years. They aim is to acquire a better knowledge of the deep geothermal reservoirs in sedimentary basins in France. Below are two examples of such scientific projects.

The Dogger Management project (Goyénèche et al, 2004 and 2005; Hamm et al., 2010 and 2013) focuses on the exploitation of the Dogger aquifer in the Paris Basin. It essentially aims at designing and supplying a database from operators and design offices. This database is used to model the thermal breakthrough and "cold bubbles". The objective is to inform decision makers dealing with permit applications rehabilitation processes. The knowledge of "cold bubbles" - due to injection - distribution is one of the criteria to optimize the selection of spots to be developed or renovated.

COPGEN (Genter, 2004) and CLASTIQ-1 (Bouchot, 2008) and CLASTIQ-2 (Bouchot et al, 2009) projects search for geothermal resources in French clastic reservoirs in France. They aim at improving the understanding of silicoclastic formations, such as Trias (CLASTIQ-2), in deep sedimentary basin mainly from the existing oil bore holes data.

The geological knowledge produced by these projects is scale-dependent.

At regional scale:

- 3D geometric models of reservoirs (Alsace, Paris basin, Limagne, …) including porosity and permeability estimation.
- 3D temperature models at the basin scale (Alsace, Bresse, Limagne, Paris basin, South-East basin).
- Quantification of the geothermal potential (Paris basin, Bresse, Limagne, Alsace).

At local scale:

- Spatial evolution of transmissivity in the Dogger aquifer (Val de Marne, Seine-Saint-Denis).
- Model of the "cold bubbles" extension resulting from fluid injection.
- Brine flow simulation for a geothermal doublet (Dogger and Trias).

2.2 Technical Committee for geothermal exploitation in deep aquifers

The Technical Committee for geothermal exploitation in deep aquifers (CTGAP), created in 2013, follows previous initiatives in response to a request from the deep geothermal professionals of the Ile-de-France area (Goyeneche et al., 2009). The design of deep geothermal operations in such context implements complex techniques and require high budgets. The CTGAP's mission is to help the professionals of the geothermal sector by capitalizing knowledge and know-how, by facilitating the improvement of techniques, and by disseminating information.

CTGAP is a natural vector to link the knowledge inferred from scientific projects with the professionals of the geothermal sector.

2.3 European context

The European Community (EC) context is favourable to the development of tools for knowledge dissemination for deep geothermal energy.

At the R&D level, the EC Joint Programme on Geothermal Energy of the European Energy Research Alliance (EERA-JPGE, www.eera-set.eu/index.php?index=22) is involved in the medium term to the development of databases and tools to assist in the exploration of geothermal resources across Europe. This work is mainly conducted within the JPGE's "Resource assessment" subprogramme.

At the agencies and government level, the EC 7th FP Geothermal European Research Area Network (GEO ERA-NET, www.geothermaleranet.eu) coordinates national initiatives with a special focus on a European geothermal database.

2.4 State of the art for dissemination

In France, the main national tool to disseminate information about geothermal energy is dedicated to shallow aquifers. It aims at promoting geothermal energy among the general public and contracting authorities. This tool has been developed since 2005 in partnership with ADEME and BRGM over several French regions.

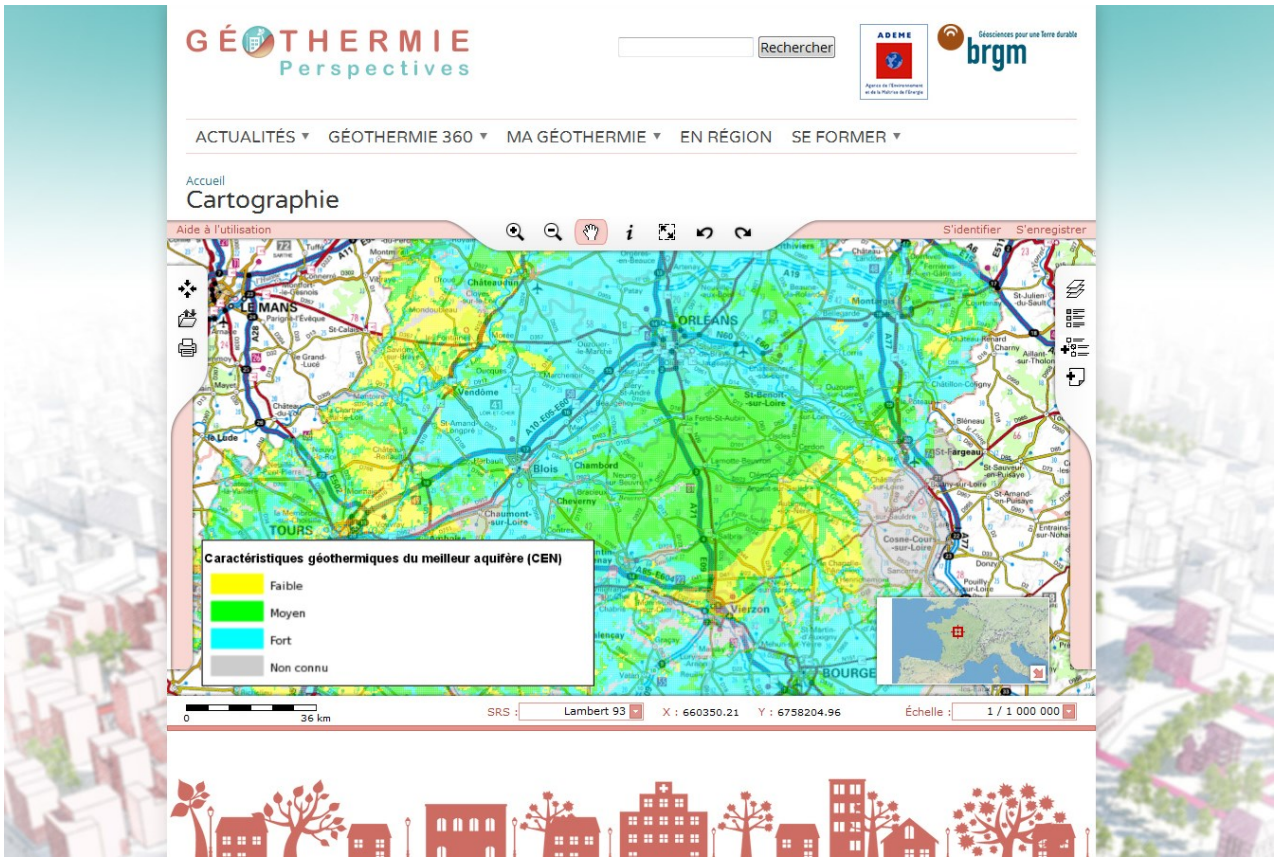

Figure 2: GIS for the geothermal potential of shallow aquifers in France, dedicated to the general public (ADEME-BRGM). Zoom on the "région Centre". Colours indicate a qualitative geothermal potential combining the estimated flow rate and depth of the aquifer: High (blue), Medium (green) and Low (red).

This tool is based on an atlas of groundwater resources that can be exploited for geothermal energy in a shallow slice between 0 and 100 m deep. The Atlas proposes a Geographic Information System (GIS, Fig. 2) available online via the "Geothermie perspectives" website www.geothermie-perspectives.fr.

Although the process of dissemination is comparable to the needs expressed above, this tool is not designed to meet the needs of the professionals who work on the use of deep geothermal resources.

In Europe, the dissemination tools dedicated to geothermal deep sedimentary basins are few. Among them there is GeotIS developed in Germany by LBEG and LIAG (Pester et al., 2010), and ThermoGIS, developed by TNO in the Netherlands (Kramers et al., 2012).

GeotIS (www.geotis.de) is mainly an electronic geothermal atlas. It displays thematic maps and socio-economic information. Although it covers the whole German territory, information is mainly provided in basin areas: Rhine graben, molasse basin, and North German basin. 3D geological models are available in some locations.

ThermoGIS (www.thermogis.nl, Fig. 3) is a decision support tool for geothermal exploitation of the Netherlands territory down to 1500 to 4000 m deep. The GIS-type user interface displays maps of geological formations thickness, petrophysical parameters, positions of boreholes, as well as uncertainties associated with these data. This tool also proposes economic simulations for exploitation by a geothermal doublet based on transmissivity modelling.

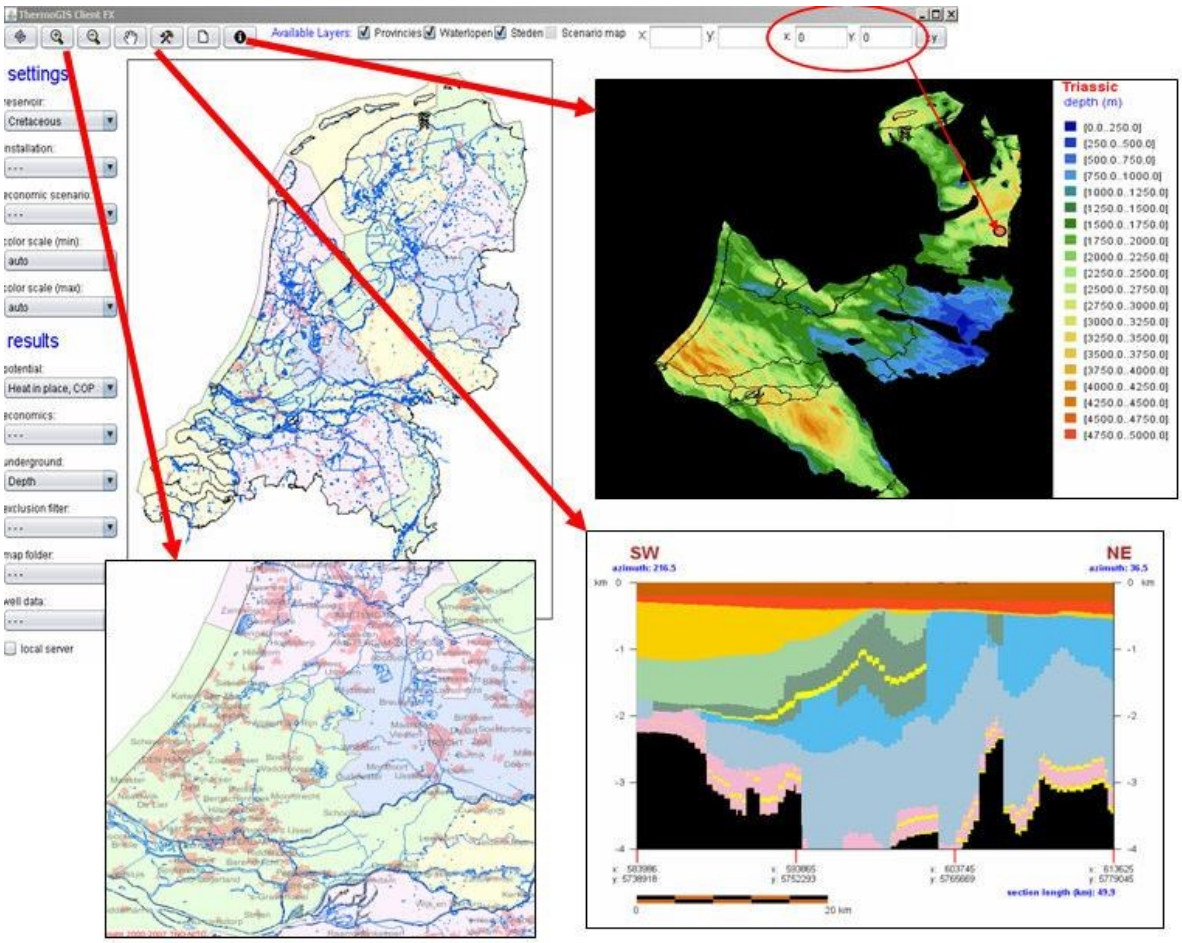

Figure 3: ThermoGIS (The Netherlands).

3. OBJECTIVES

Thermo2Pro (Calcagno et al., 2013) is a project started in 2011 and dedicated to the French territory in the context described above. The two main objectives of this project are: (i) to make professionals of the geothermal sector able to access the knowledge from scientific projects by developing a dedicated tool that will be demonstrated through a pilot site, and (ii) to promote the geothermal sector by gathering the players throughout the project and by allowing them to participate to the development of the tool.

The following describe in more details how these objectives are tackled. The next chapters focus on the Thermo2Pro tools and data management.

3.1 Develop a tool to favour geothermal exploration

The aim of Thermo2Pro is the development of a Web-based tool to provide relevant knowledge to professionals working at geothermal exploration in deep sedimentary basins. The information displayed by Thermo2Pro is intended to give indications prior to a feasibility study.

The targeted information is (i) the geometry of the aquifer through maps and sections, and (ii) the estimation of reservoir properties (temperature, permeability, transmissivity, etc.) This material will be derived from 3-dimensional models and simulations performed in scientific projects (see above).

On top of that, uncertainties need to be associated with the information displayed as much as possible to help users with the interpretation. This could be, for instance, an indication of the most favourable and the most unfavourable values of a given parameter at a given position. In addition, indication of the processes that led to the information is to be given to ensure traceability. If possible, methodologies and softwares used in the process as well as references will be mentioned.

3.2 Demonstration area

Thermo2Pro's capabilities were demonstrated using information from the Trias in an area of the Paris basin. Suitable knowledge acquired in this demonstration area during the project CLASTIQ-2 (Bouchot et al, 2009) was used. The main geothermal parameters were:

- Lithology
  Geological model including 10 sequences interpreted from borehole logs.
- Temperature

Interpolated from borehole measurements (profiles and/or Bottom Hole Temperature).

- Porosity
  Interpolated from logging electric measurements.
- Permeability
  Computed using Phi.K law. Two qualitative results, optimistic and pessimistic, were provided.
- Transmissivity
  Computed using permeability and geological formations thickness. Two qualitative results, optimistic and pessimistic, were provided.

3.3 Promote the geothermal sector

In France, the geothermal energy sector is still under development and needs visibility. Thermo2Pro is likely to contribute to the development of the sector by facilitating access to technical information to a large number of users. In addition, the project is an opportunity to disseminate information about on-going research on alternative aquifers to the professionals of the sector who mainly deal with the Dogger aquifer. The User Committee of Thermo2Pro is the devoted place for such an exchange.

4. USER COMMITTEE

Thermo2Pro is developed in close cooperation with professionals via the CTGAP. A User Committee has been established to define the needs and issues and to guide the development of the tool. The committee is also involved in the tests and the validation process.

The User Committee is composed of about twenty people representing key professionals involved in deep geothermal resource: contracting authorities, state and local authorities, operators, and design offices. They meet on a regular basis to follow the developments of the project.

5. THERMO2PRO TOOLS

Dissemination of the information is achieved through the Thermo2Pro Website that presents the project and proposes a cartographic application to make queries on the available geothermal parameters.

5.1 Web site

Thermo2Pro Website is implemented in HTML 4 (HyperText Markup Language). Webpages are presented with CSS2 (Cascading Style Sheet). They are based on a content management system developed with the SPIP software. This makes easy administration and updating via a back-office area of the site from any Web browser.

The Website is reachable at the following address: www.thermo2pro.fr. It presents the project and updated news (Fig. 4). It is also the portal to access the available information on geothermal parameters using a cartographic tool.

Figure 4: Thermo2Pro Website homepage at www.thermo2pro.fr.

5.2 Cartographic application

The cartographic tool is a Web interface that makes the user able to visualize and check the geothermal parameters (geology, temperature, porosity, etc.).

The 1st step consists in locating the zone of interest (Fig. 5). This is achieved using a GIS type design where various layers can be displayed such as geographic maps and cartographic data on a given area. In addition to the layers embedded in the cartographic tool, extra information can be reached and displayed via the Internet using the WMS protocol (Web Map Service).

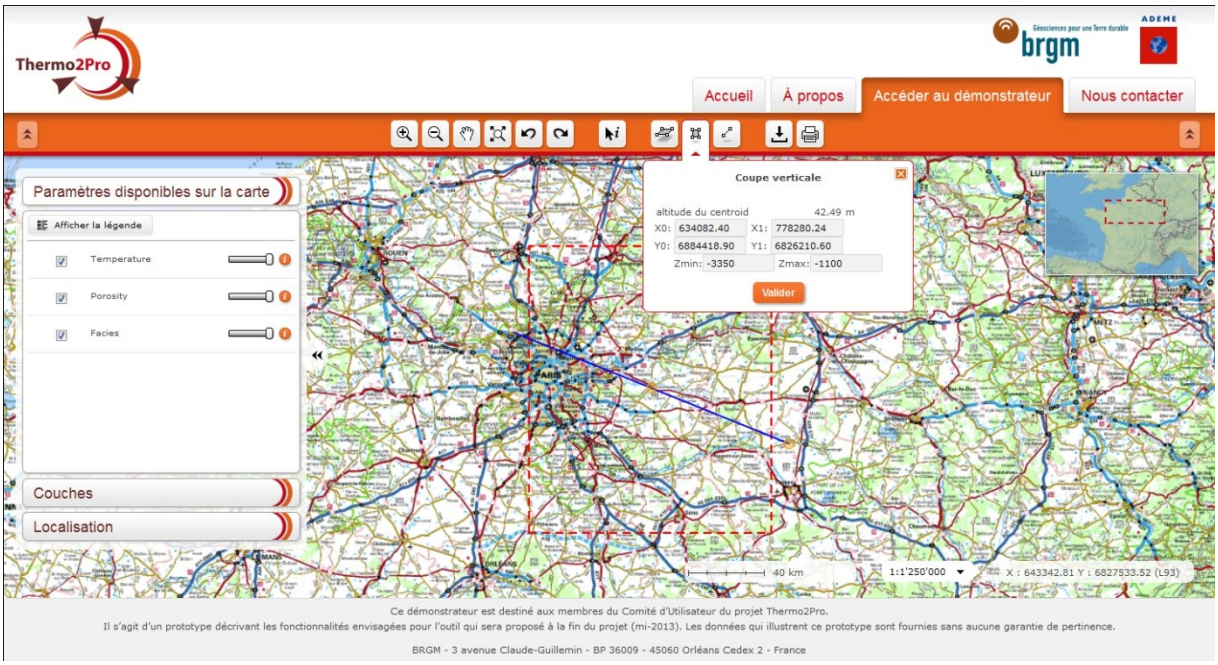

Figure 5: Cartographic page for queries.

In a 2nd step, the geothermal parameters are visualized using 3 main queries:

- Horizontal section. The user chooses the altitude of the section.
- Vertical section. The user defines the origin and the extremity of the section on a map and sets the vertical extension.
- Borehole. The user defines the location of the borehole collar on a map and sets the vertical extension. An option allows to make an inclined borehole by giving its azimuth and dip.

This process allows the user to spot interesting values of parameters - or combination of parameters –at depth. A picking functionality on the image of the resulting section or borehole returns the value of the parameters (Fig. 6).

Figure 6: Result of a query on a vertical section.

In addition, a report of the queries and results can be automatically generated, printed, and saved.

6. DATA MANAGEMENT

The sections or boreholes simulated during the queries are computed using the information about geothermal parameters that is stored in 3D regular grids.

6.1 3D grids for 2D and 1D queries

As described above, geographical queries are performed in Thermo2Pro on 2D (vertical or horizontal sections) or 1D (borehole) profiles. The visualization of parameter on these profiles is computed via the information stored in 3D regular grids (Fig. 7).

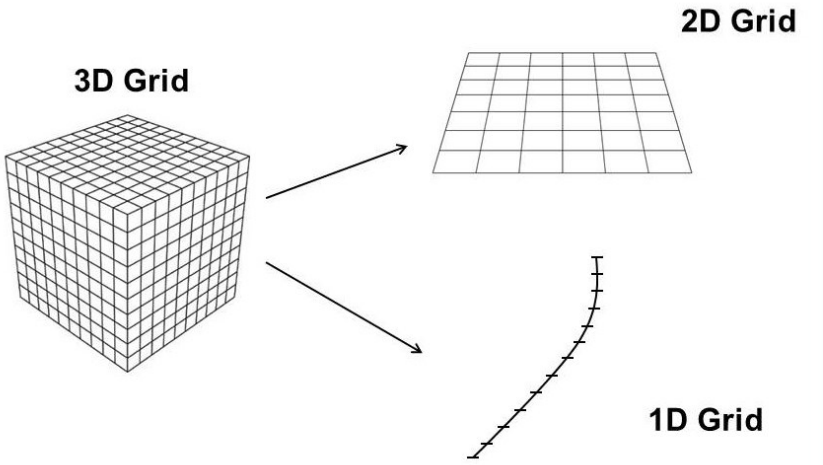

Figure 7: Parameters are stored in 3D grids and displayed as 2D or 1D grids (images) in sections and boreholes.

Parameter management is one of the main originality of Thermo2Pro. Working with 3D grids allows to retrieve information at depth and not only on a map. In addition, 3D regular grids have been chosen to overcome specific formats considering the variety of parameters and consequently the variety of tools that produce the information about these parameters. A 3D regular grid is a quite generic object that is also suitable for 2D information, e.g. a temperature map (2D) can be stored in a 3D grid.

A 3D regular grid covers the volume where parameters are available (values of temperature, porosity, etc.) A given cell of the grid hosts the value of each parameter available at the 3D location of the cell. The 3D grids are described in an eXtensible Markup Language (XML) file. Such a file contains the topology of the 3D grid, the values of the parameters, color scales and metadata.

6.2 Implementation of the query service

Following the request of the user, an image is computed on the fly and displayed on the cartographic client. A scalar grid is associated to the image for picking the value of the parameter at any location of the picture. Both the image and the scalar grid are calculated from the 3D grid containing the values of the parameters.

The process of querying the 3D grid is made through a Web Processing Service (WPS) defined by the Open Geospatial Consortium (OGC) and based on a WPS 52th North server developed in Java.

Computations are done by a stand-alone program developed in C++. This program loads the grids, processes them and generates images or probing results using VTK (Visualization Tool Kit), an open-source library dedicated to 2D and 3D scientific data processing and visualization developed by Kitware.

7. CONCLUSION, UPDATE AND PERSPECTIVES

The first stage of Thermo2Pro was achieved in 2013 by developing the basic functionalities dedicated to the dissemination (Calcagno et al., 2013). These functionalities of the Thermo2Pro's Webtool web demonstrated on a part of the Trias in the Paris basin area. However, the tools of Thermo2Pro are designed to host information from other aquifers and other basins, as long as they are stored in 3D grids. The plan for Thermo2Pro is to be the cradle for accessing such information on the French territory. In addition, the first stage of Thermo2Pro ended with recommendations for future developments and improvements of Thermo2Pro in relation with the User Committee work.

Following these recommendations, a new project was launched in 2013: TRANS-CLAS. This is a BRGM+ADEME ongoing project for making available more information via Thermo2Pro than the existing demonstrator. The goal is to disseminate information from clastic environments in the Paris basin, the Rhine graben, and the Limagne d'Allier basin.

Furthermore, a strong expectation has been expressed by the User Committee of Thermo2Pro to include data from the Dogger aquifer that is exploited for more than 30 years in the Paris basin. This objective raises two main issues. On one hand, displaying

information from the Dogger aquifer through Thermo2Pro will require some adaptations because data are in 2 dimensions. On the other hand, models describing the parameters, including "cold bubbles" spread need to be updated on a regular basis to provide comprehensive and up to date information to the French professionals of the geothermal sector. This work is currently under study.

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