CHEAP and safe, an European Project for cheaper and safer low enthalpy geothermal applications. A geological context point of view.

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ABSTRACT

The success and widespread diffusion of new technologies are always strictly related to their affordability. Nowadays, the energy price fluctuations and the economic crisis jeopardize the development and diffusion of renewable technologies and sources. With the aim of both reduce the overall costs of shallow geothermal systems and improve their installation safety, an European project has recently took place, under the Horizon 2020 EU Framework Programme for Research and Innovation. The acronym of this project is Cheap-GSHPs, meaning "cheap and efficient application of reliable ground source heat exchangers and pumps"; the Cheap-GSHPs project involves 17 entities among 9 European countries such Belgium, France, Germany, Greece, Ireland, Italy, Romania, Spain, Switzerland. In order to achieve the planned targets, a holistic approach is adopted, where all involved elements that take part of shallow geothermal activities are here integrated. This project is therefore going to look at many other heat geoexchange subjects.

The present work is mainly focused on the underground properties and on their mapping methodologies for ground heat exchange purposes. Ground thermal properties are going to be detected through standardized laboratory methods, in order to provide an updated thermal catalogue for the most common consolidated and unconsolidated rocks among the involved European countries. Moreover, this project is going to suggest an updated underground heat exchange mapping method, according to the previous European and national projects. Cheap-GSHPs project would suggest a new method for the drilling cost estimation, based on the rate of drilling, which is strictly connected to the geological conditions.

1. MAPPING PROPOSAL

In order to simplify and provide at the same time the available geological data at European scale, a simplified mapping has been proposed.

In order to suggest a simplified geological texture map for thermal properties purposes, the European Soil Data Centre (ESDAC) has been considered (European Commission, 2015). The Soil Geographical Database (SGDBE) of Pedological and geological dataset constitutes a database of dominant lithological parental materials and 212 subunits dataset from the so-called PAR-MAT-DOM database (meaning

dominant parental material) (European Commission, 2015).

The European Soil Data Center provides moreover an the additional database PAR-MAT-CON1 (European Commission, 2015) where the 212 PAR-MAT-CON sub-units are merged on 9 major groups. A new database is then suggested, according to these major groups (Bertemann et al., 2016):

-No Information;
-Igneous and Metamorphic Rocks;
-Consolidated Sedimentary Rocks;
-Unconsolidated Material (undefined);
-Sand (unconsolidated);
-Clay (unconsolidated);
-Gravel (unconsolidated); and
-Organic Material.

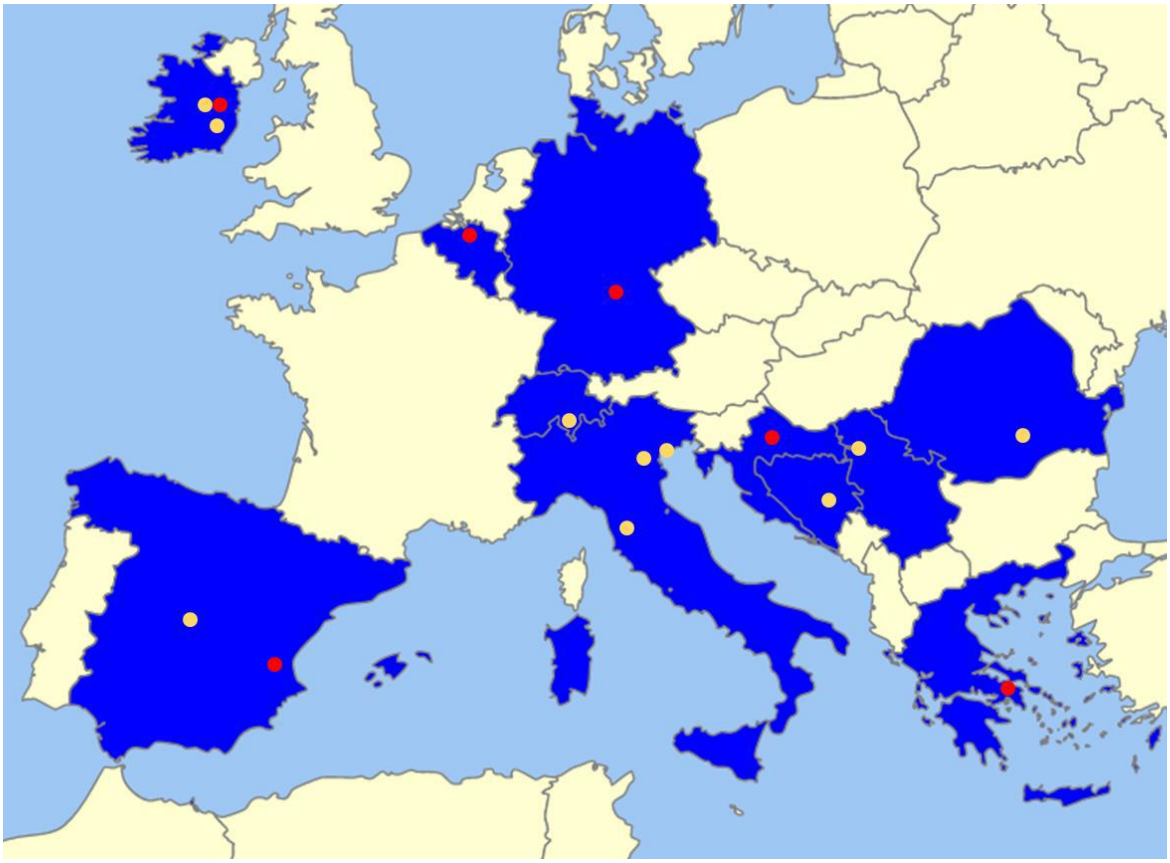


Figure 2: EU countries involved in the demo site of Cheap-GSHPs project. Yellow dots represent the virtual cases, red ones the real cases.

2. THERMAL PROPERTIES OF HARD ROCKS, CONSOLIDATED AND UNCONSOLIDATED SEDIMENTS

The EU Cheap-GSHPs aims to apply the outcomes of the project on several demo real and virtual cases that are spread along many different EU countries, from Spain to Romania, from Ireland to Greece, at different climate, energy buildings loads and geological conditions.

Therefore, in order to highlights the main lithologies for all these demo cases, a preliminary investigation of the geological texture has been carried out, according to the geothermal mapping at municipal level.

As results, an average distribution of geological texture allowed to overview the main lithologies at Cheap-GSHPs project demo sites (figure 1), which are covering 10 virtual cases and 6 real ones.

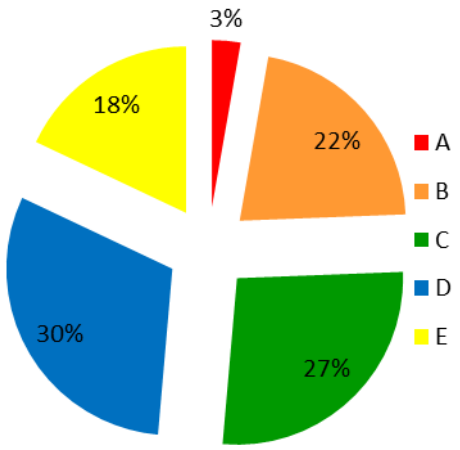


Figure 1: geological texture as average distribution among all the demo sites. A: Igneous & Metamorphic Rocks; B: Consolidated Sedimentary Rocks; C: Sand

(unconsolidated); D: Clay (unconsolidated); E: Gravel (unconsolidated).

According to the geological texture distribution and to the available databases, several thermal and petrophysical measurements started both on samples from the demo sites and relevant samples from several European locations. Aim of these measurements is to integrate the available databases (g.e. VDI 4640) and compare several methodologies, laboratories, instruments (Eskilson, 1987).

Table 1 shows the instruments types and the devices used in the Cheap-GSHPs project in order to define the main thermal parameters, such thermal conductivity, specific heat and thermal diffusivity (Schön, 2011; Robertson, 1988).

The parameters listed on table 1 only show the main ones (third column of table 1), since most of devices may detect directly or indirectly many other thermal parameters like thermal effusivity, diffusivity, heat capacity, thermal resistance, etc. (Schön, 2011).

Thermal characterization of hard rocks, consolidated and unconsolidated sediments, are always coupled to physical properties, like porosity, density, hydraulic conductivity, granulometry, Attemberg limits, consolidation ratio, etc, according to the type of material; all measurements are carried out under similar laboratory conditions in terms of temperatures and humidity. Finally, for each sample, both dry and fully wet conditions are considered for the thermal properties analysis (Eppelbaum et al., 2014).

Most of the thermal parameter analysis has been carried out in laboratory, where it is possible take the control of the environmental boundary conditions(Clauser and Huenges, 1995).



Figure 2: dolomite rock sample used for thermal parameter analysis in wet and dry conditions and according to the two main anisotropy directions.

Few measurements on unconsolidated material are performed in the field, in order to investigate a larger amount of Representative Elementary Volume and keep the environmental conditions closest to the real ones as much as possible. In this case, KD 2Pro and ISOMET are the most used devices, by the mean of a long steal needle.

Table 1: list of instruments and devices used for thermal properties analysis of rocks and unconsolidated material.

Device	Parameter	Lithology
KD 2Pro	Thermal conductivity	Sand to clay
TCS Scanner	Thermal conductivity	Consolidated sediments and hard rocks
TK04	Thermal conductivity	Consolidated and unconsolidated sediments, hard rocks
C-THERM	Thermal conductivity	Consolidated sediments and hard rocks
ISOMET	Thermal conductivity	Consolidated and unconsolidated sediments, hard rocks
Laser Flash Equipment	Thermal diffusivity	Consolidated sediments and hard rocks
Differential Scanning Calorimeter	Specific heat	Consolidated and unconsolidated sediments, hard rocks
Double Plates	Thermal conductivity	Sand and gravel

In order to understand the behaviour of thermal properties under stress setting, laboratory analyses have been carried out at different temperature conditions and after 16 full frozen-thaw cycles, from -10°C to +20°C (figure 2). Aim of these analyses is the definition of the thermal and geotechnical-structural properties according to the temperature stress due to shallow heat geoexchange underground systems.

3. CONCLUSIONS

The first laboratory measurements highlighted several interesting results, such the wildly variability of thermal properties on the same samples. Indeed, different devices provide not unique values for the same samples, even under same laboratory and environmental conditions.

Therefore, standards, methods, instruments and devices for thermal properties measurements of rocks and unconsolidated rocks should be always well defined; moreover, the scientists should define in advance the environmental boundary conditions for

these measurements, the instruments errors, the range of confidence and the instrumental precision.

Furthermore, numerical simulations, environmental impact of shallow geothermal systems and other underground thermal applications should take into account the type of underground material and the methods used for the thermal parameters characterization.

Cheap-GSHPs EU is an ongoing project and the next steps will be the increasing of the number of samples for thermal properties measurements and in field surveys such Thermal Response Tests. Moreover, the thematic mapping is going to be updated according to the European standards on GIS environment.

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