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EEA project INFO-GEOTHERMAL &
COST ACTION CA18219 Geothermal-DHC
the international summer school in Thermogeology

Advances in developing geothermal resources for heating, cooling and electricity production
3rd to 8th July 2023, Ljubljana, Slovenia

Book of abstracts
of the student conference
on 3rd July 2023

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GEOTHERMAL DHC Towards Decarbonized Heating and Cooling!

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- EEA Grants supported project INFO-GEOTHERMAL - Supporting efficient cascade use of geothermal energy by unlocking official and public information
- COST action project CA18219 Geothermal-DHC - Research network for including geothermal technologies into decarbonized heating and cooling grids
- Geological Survey of Slovenia (GeoZS)
- Faculty of Natural Sciences and Engineering of University of Ljubljana (NTF UL)
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Content

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1. Performance analysis of GSHP borehole with PCM mixed backfill material

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Keywords: ground source heat pump, phase changer material, pcm mixed grouts, gshp performance enhancement

Abstract

The aim of the study is to investigate the performance of Ground Source Heat Pump (GSHP) boreholes utilizing Phase Change Materials (PCM) mixed backfills. Heat transfer performance of the GSHP system will be investigated in the study. PCM, known for its ability to store and release latent heat during phase transition will be incorporated into the backfill material surrounding the borehole heat exchanger pipe. In this study, effect of various PCMs will be analyzed and optimum PCM with adequate concentration will be adopted.

The performance analyses will be conducted through combination of numerical and experimental techniques. In the first stage, a numerical model will be formulated to understand the effect of phase transition phenomenon and its effect on the overall performance of the GSHP. The model will then be tested for various conditions and PCMs, to obtain an optimized operational condition.

After obtaining the data through simulation and experiments both will be compared for model validation and understanding the phenomenon of melting/ solidification in boreholes and its effect on the overall efficiency of the GSHP. It will also help us in understanding the possibility of thermal energy storage by the PCM mixed grouts, and suitable PCM candidate for such applications.

Overall this research will contribute to the advancement of GSHP systems by evaluating the performance of PCM mixed backfill material for Ground Heat Exchangers.

2. Study of Heat Transfer to the Ground and its Accumulation Properties to Increase the Energy Efficiency of Underground Buildings

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Keywords: heat transfer, accumulation properties of soil, underground buildings, building's energy consumption

Abstract

To maintain a comfortable indoor temperature for its residents in the colder season, heating a building is necessary. Due to the expansion in the construction sector, heating energy consumption is increasing. According to Eurostat data, in the European Union, the share of energy consumption of heating energy for space and cooling in residential buildings was around 63% in 2019. These figures indicate that heating energy still accounts for a significant portion of total energy consumption in Europe. Innovation is crucial to reduce energy consumption in buildings and achieve greater energy efficiency and sustainability. It can bring about new solutions that are smarter and more natural energy generation to reduce greenhouse gas emissions. The ground can serve as an effective and sustainable heat accumulator for heating and cooling. The temperature of the ground is higher than that of the ambient air in the colder period and lower in the warmer period. The building deep in the soil could use less thermal energy compared to the above-ground buildings that provide the same amount of thermal comfort. The temperature difference between the soil and the air inside the building decreases as the temperature of the soil increases. In progress, this process generates the condition that acts against heat loss. However, heat dissipates further to consecutive layers and reaches thermal equilibrium. The charging of the ground by heat and its dissipation through the adjacent soil layers was investigated. The results of this research showed that 31% of energy savings in completely underground buildings were derived from heating the space.

3. Underground thermal energy storage potential in Croatia

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Keywords: geothermal, UTES, Croatia

Abstract

Croatian significant geothermal resources offer the opportunity to extract and store thermal energy for heating and cooling applications using UTES technology. Croatia experiences a demand for both heating and cooling in various sectors, making UTES systems an effective solution for storing and distributing excess heat or cold during periods of low demand. UTES technology can contribute to reducing greenhouse gas emissions by replacing conventional heating and cooling methods. However, specific UTES projects in Croatia would depend on local demand, economic feasibility, site-specific geological conditions, and regulatory frameworks. There are key parameters for planning and designing underground energy storage facilities. Important factors include geology and site selection, cavern or reservoir characteristics, safety and environmental considerations, energy capacity and power rating, energy conversion efficiency, compatibility with energy sources and grid integration, and cost analysis. There are also parameters such as geothermal gradient, thermal conductivity, porosity and permeability of the surrounding medium, borehole design, choice of heat transfer fluid, operating temperatures and thermal loads, heat losses, system control and integration, and economic analysis. The specific parameters and design considerations may vary depending on the type of UTES system. Consulting with experts in the field can provide project-specific guidance and detailed information.

4. Geothermal energy potential In Turkey

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Keywords: energy, geothermal energy, renewable energy

Abstract

Geothermal energy is a domestic underground resource that is renewable, clean, inexpensive, and environmentally friendly. Due to Turkey's geological and geographical location on an active tectonic belt, it is rich in geothermal resources compared to other countries. Turkey is located in a seismically active zone where the Eurasian and Arabian tectonic plates meet. Turkey is the number one country in terms of geothermal potential in Europe and the fourth country in terms of installed capacity worldwide. The western regions of Turkey, particularly areas such as Denizli, Aydın, Manisa, and Afyon, are rich in geothermal reservoirs. There are approximately 1,000 natural outlets of geothermal sources spread across different regions of Turkey, varying in temperatures. 90% of Türkey's geothermal resources are low to medium temperature and suitable for direct applications such as heating, thermal tourism and more. The remaining 10% is ideal for indirect applications such as electricity generation. With the studies in recent years, 170 geothermal fields with a source temperature of over 35°C have been discovered in Turkey. It has been determined that 13 of these fields are economically suitable for electricity generation. Kizildere, Germencik, Salavatli, and Tuzla can be given as examples of these fields. Turkey's estimated potential geothermal heat capacity is 35,500 MWt, and the electricity generation potential is estimated to be 4,500 MWe.

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Acknowledgement

The authors would like to thank YÖK for the 100/2000 scholarship, and TUBITAK for the 2211C scholarship supporting Alparslan BOZKURT.

5. Influence of aquifer heterogeneities on the efficiency of geothermal reinjection in groundwater basin

Authors: Léo Chapuis[1], Ábel Markó[2], Dr. Judit Mádl-Szőnyi[2], Dr. Anita Erőss[2], Dr. Arnaud Coutu[1]

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Keywords: geothermal exploitation, aquifer modelisation, numerical simulation, geological basin, aquifer heterogeneities

Abstract

Fluid reinjection is an essential part of a geothermal doublet, responsible for the pressure stability within the aquifer. Unfortunately, the efficiency of this reinjection is not necessarily sufficient to provide this pressure stability if the reinjected fluid cannot reach (or not efficiently enough) the production well, resulting in higher energy loss in pumping and injection and consequently a lower rentability of the doublet.

This study, dealing with groundwater basin context, adds another dimension to the topic. Indeed, hydraulic head values are impacted by this basin context, resulting in an impact on the flow conditions, mostly on the flow patterns which could be divided in 3 different scales (local, intermediate, and regional), and flow rate. Heterogeneities also has an impact on the groundwater flow conditions, depending on the different involved types (Tóth, 2009), which will be studied and analyzed through several modelling and numerical simulations. The type of involved heterogeneities and their parameters will be tested and modified in the basin aquifer, and anthropogenic parameters at the reinjected well will be studied as well. The pressure values, and the evolution of the pressure values within the aquifer between the two wells will be used as an output result to determine the impact of the different tested parameters on the efficiency of the reinjection to be able to improve its efficiency.

Reference

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6. Fifth generation district heating and cooling network coupled with geothermal energy source: A case study of Embassy of Sharing at Mälmo

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Keywords: energy sharing, 5GDHC, geothermal, sustainability

Abstract

With growing urbanization and increase in energy demand for space heating and cooling in buildings, effective assurance and distribution of energy and its efficient end use is of utmost importance particularly when emissions from energy use and indoor thermal comfort of the end users is of question. Numerous solutions have been put forth in the field of effective distribution of thermal energy to meet the space heating and cooling requirements of buildings to assure indoor comfort of which fifth generation district heating and cooling (5GDHC) is regarded as a viable solution in terms of low emissions, low distribution losses and effective energy supply. The challenges, however, lie in connecting the buildings in the network in order to facilitate the energy sharing between the buildings such that otherwise waste heat from one of the buildings can be used by another building connected to the same network. This paper presents the concept and design of such advanced 5GDHC network which facilitates energy sharing between connected buildings comprising of office spaces, residential complex, shopping centers occupying approximately 61000 square meters in Hyllie region of Malmö, Sweden. The system design consists of a unidirectional one pipe network with 111 decentralized borehole heat exchangers as the primary and only energy source for the network with heat pumps and dedicated heat exchangers to alter the temperature of district heating and cooling fluid going into the buildings. The system as such is self-sufficient and does not need any assistance from other energy sources to meet the thermal demands of the connected buildings.

7. Simulation of Direct Use Geothermal Systems (DUGS) with open source code and examples

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Keywords: DUGS, numerical simulation, sensitivity analysis

Abstract

Simulation of Direct Use Geothermal Systems can serve as a guidance for geothermal resource assessment, where the energy production, system life time and heat recovery ratio are used as performance indicators. In this work we present reference examples on the design of a DUGS simulation model using the open-source software Delft Advanced Reservoir Terra Simulation (DARTS). The DARTS platform enables accurate and efficient sensitivity and uncertainty analysis. We identify the common, optimal cartesian grid resolution to resolve the real thermal response of a 3D homogeneous model, a 3D stratified model and a 3D heterogeneous model in a computationally efficient way for a given reservoir domain and discharge rate. Subsequently, we identify the optimal number of confining layers ensuring a sufficient heat recharge without boundary layer interactions that remains computationally efficient. The models with optimal resolution and the number of confining layers is utilized to do sensitivity analysis and demonstrate the use of DARTS in geothermal applications. The optimal parametrization and computational efficiency of the DARTS platform provides fundamental input to research on project feasibility, risk management, system optimization, and environmental impact.

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Daniilidis, A., Nick, H. M., & Bruhn, D. F. (2020). Interdependencies between physical, design and operational parameters for direct use geothermal heat in faulted hydrothermal reservoirs. Geothermics, 86.

8. Developing machine learning tool to advance energy production from high temperature deep igneous geothermal resources

Authors: Aliaa Hammoud[1], Marlene Villeneuve[1], Eva Caspari[2]

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Keywords: crystalline rocks, IDDP-1, drilling , electricity , machine learning

Abstract

In the Krafla area in Iceland, IDDP_1 is one of the deep wells that was drilled to produce energy from supercritical conditions. Drilling was meant to reach 4-5 km depth, however, due to intersecting a magmatic body at 2.1 km, drilling was terminated. KMT is looking to drill again in Krafla close to IDDP-1 well to extract heat directly from the magma(1). The project looks into correlating the geophysical logs (Gamma, Neutron and Resistivity) with the drilling logs (WOB, ROP, Torque, RPM, and caliper) to provide a mean for assessing the rock mass as the magma is being approached without referring to ditch cuttings. This correlation will help in developing a machine learning tool that can predict the crystalline rock mass characteristics based on drilling data to better inform drilling decisions on the surface. It will also aid in implementing safe and smooth drilling programs by better interpreting the drilling parameters during drilling, which will save time and cost. The obtained results will also support future drilling in Krafla by providing a method to determine the rock-magma interface. This will aid in identifying the appropriate depth near to the magma body with high thermal gradient for optimal electricity production which is estimated to be 36 MW (2)

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9. Technoeconomic Feasibility of Geothermal waste heat for space cooling purposes in Indonesia

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Keywords: waste heat, space cooling, energy geostructure

Abstract

The Java Island of Indonesia, which is part of the "Ring of Fire," has the worst pollution in the world as well as one of the highest geothermal potentials. One of the main problems is large amount of fossil fuel usage for electricity production. The aim of this paper is providing an information about feasibility of reducing fossil fuel usage by shifting the primary energy consumption for space cooling purposes using geothermal waste heat with cooling absorption rather than conventional electric air conditioning. This also aligns with the Indonesian's government incentives which aim to reduce carbon emissions and its ambitious plan of involving geothermal power into its energy transition.
The proposed paper aims to find whether the technology was economically viable to implements in Indonesia. However, the actual research has not been completed yet. The previous study has been undertaken in University of Western Australia (Wang et al., 2013) which proposed use of the waste heat in the sedimentary basin with range of 70°C to 100°C for geothermal direct air absorption air conditioning system which resulted in a positive result for the economic feasibility. This article gives an optimistic guess to the research paper since Perth, Australia relatively warm which means similar conditions to most of city in Indonesia.
In the technical section, the paper proposed to summarize the possible technological implementation of the future project. According to research by (Limberger et al., 2018), the subsurface conditions broadly in Java Island are technologically viable to implement any geothermal space cooling technology in the area. Hence, this gives an initial optimistic guess on the technical aspect.
Potentially, the fifth generation of energy geostructure will potentially be used in this case. Energy geostructures are innovative engineering solutions that integrate the functions of traditional civil structures with energy-related systems. These structures are designed to harvest, store, or utilize various forms of energy, such as geothermal, solar, or wind energy, within their built environment. These technologies are suitable for densely populated areas in metropolitan area of Indonesia because its space efficient characteristic and could easily integrated into current infrastructure.
In conclusion, geothermal space cooling would be one of the solutions for Indonesia's pollution problem by shifting one primary energy consumption into more efficient technology. Despite its initial optimistic guess, there are factors that could hinder the project that will mainly in politics and economic sectors.

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10. Characteristics of the Polish political model in the context of geothermal development

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Keywords: geothermal energy, renewable sources, geothermal applications, geothermal uses.

Abstract

Geothermal energy is a natural and renewable asset of the region. In Poland, there are natural sedimentation-structural basins filled with geothermal waters. Geothermal reservoirs are located on 40-55% of the land area of the country. Water temperatures at depths from 500 m to 4000 m – depending on the location – range from 20 to 100°C.

In Poland, the primary area of geothermal energy use is district heating. For district heating purposes, the first geothermal plant in Poland was commissioned in 1992 in Biały Dunajec (mountain region Podhale). Currently, there are 6 municipal geothermal heating plants in the country.

In recent years, the Ministry of Climate and Environment has published the “Multiannual Programme for the Development of the Use of Geothermal Resources in Poland”. The aim of this programme is to set the path for the development of geothermal energy by 2040. The project focus on: the development of medium and deep hole heat exchangers, the introduction of innovative technologies for heat storage in orogen, streamlining procedures and public education.

In the years 2016–2020, approx. 20 new geothermal holes. For the most part, the effects of these drilling were positive. Most of the drilling operations were co-financed by public support programmes. The government are going to drill next 58 holes by the end of 2040 year. In recent years, these programmes have played a key role in the dynamic development of geothermal energy use in Poland. Poland’s leading scientific institutions, including Polish Geological Institute, conducted research projects to determine the geothermal potential in Poland.

Increasing the use of geothermal energy in Poland is supported by the need to decarbonise the economy by introducing clean energy carriers instead of fossil fuels.

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11. Application project: Use of geothermal energy for heating and cooling a greenhouse in Slovenia

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Keywords: greenhouse, heating and cooling, Slovenia (Pomurje), feasibility study, 3D geothermal model

Abstract

PROJECT DESCRIPTION: The main goal of the project is the construction of a greenhouse (approx. 10 ha) in the NE part of Slovenia (Pomurje) for food production with the possibility of heating and cooling with geothermal energy. The project is currently still in the initial phase of finding the most suitable area in Pomurje, where geothermal potential is taken into account.

Before the start of the implementation works of the project, a feasibility study will be prepared for the following segments:

- SETTING UP A GREENHOUSE: the possibility of setting up a greenhouse for food production in compliance with current legislation and regulations in the field of agriculture and the environment;
- HEATING AND COOLING: possibility of heating and cooling the greenhouse using geothermal energy;
- WORK PREPARATION: construction of a greenhouse, construction of geothermal wells for heating and cooling, construction of a deep and surface geothermal system;
- FINANCIAL CONSTRUCTION: necessary financial resources for the construction and operation of the greenhouse (CapEX and OpEx) with a set timeline and decision tree for confirmation or rejection of project implementation.

From the company Geološke storitve Geo-Rock s.p. and involving other partners, a feasibility study will be given on the concept of heating and cooling a greenhouse using geothermal energy. A 3D geothermal model will be included in the study, which will be based on a mathematical model of the flow of thermal water for heating and the flow of underground water for cooling with included heat transfer for a given aquifer. The main goal of the conceptual model will be to obtain possible scenarios of pumping and re-injecting thermal and underground water under different simulated conditions over a longer period of time.

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12. Geothermal system of Bőny

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Keywords: deep geothermal system, heating, cascade system

Abstract

In 2015 PannErgy cascade geothermal energy development system was created and the partnership between the *Győr-Szol Zrt.*, the *Audi Hungaria*, the *Exim Bank*, and the general assembly president of Győr-Moson-Sopron was realized within the framework of the "Győr Geotermikus Projekt" in Bőny. This geothermal energy development system decreases the CO_2 and nitrogen-oxides pollution by approximately 67000 tons/year, and the use of this green energy reduce the natural gas use around with 35 million m^3. Furthermore, this geothermal energy system covers the energy cost of 24266 housekeeping's taxes and 1046 another heating users, and the AUDI factory 60% of energy use. The cost of the system was altogether 10,2 billion HUF. This cascade system can provide annual energy volume between 1100-1200 TJ.

During the program 2 producer and 2 reinjection wells were drilled by *DD Energy Kft*. and *Arrabona Geotermia Kft*. The perforated intervallum is between 2450-2470 m and 2430-2450 m depth, in a Triassic dolomite formation. The reinjection wells are in Pér, and depth of the wells are 2296 m and 2324 m. The flowing rate is more then 19,2 m^3/h and the temperature of the water in the formation is 120°C. This geothermal potential comes from thinned crust and domed asthenosphere and is covered by thick Miocene postrift strata.

The infrastructure includes a 17 km long heat transport section from the geothermal heat center to the users, and the cascade system. This system was built by financial support of European Union (1 billion HUF) and by the *Exim Bank*.

13. The GeoT– a practical tool for estimating the geothermal reservoir temperature

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Keywords: geothermal system, reservoir temperature, multicomponent geothermometry

Abstract

The GeoT App is based on the multicomponent geothermometry method presented by Reed and Spycher (1984). Full chemical analyses of water samples are used to calculate the saturation indices (log(Q/K)) of reservoir minerals within the temperature range. The mineral saturation index is obtained from the calculated ion activity product (Q) and the thermodynamic equilibrium constant (K) for each selected mineral. It is crucial to enter relevant mineral composition of the studied geothermal waters into the input file and select the minerals with which the solution will reach the equilibrium (by analysing the rock medium it is possible to select appropriate minerals which could equilibrate with selected water type). The reservoir temperature can be obtained from the graph, where saturation indices are plotted as a function of temperature, and a clustering of log(Q/K) curves are close to zero at any given temperature (for a group of selected deposit minerals). The line indicating zero is the equilibrium expected to be achieved. When the obtained result is inaccurate, consideration should be given to equilibrate the studied waters with another mineral or/and dilute or concentrate the solution (in addition, it is possible to modify the proportion of contained gas). This approach has advantages over classical geothermometers, because it relies on complete fluid analyses and a thermodynamic equilibrium in contrast to classical geothermometers, which are based on the dilution of a few minerals (Spycher et al. 2016).

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14. Laboratory Thermal Conductivity Measurements for Shallow Geothermal Potential Mapping

Authors: Aleksandra Łukawska[1], Mateusz Żeruń[1], Grzegorz Ryżyński[1], Przemysław Wojtaszek[1], Ewa Jagoda[1] (project team)

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Keywords: thermal conductivity of soils, geothermal potential mapping, shallow geothermal energy

Abstract

The presentation features the methodology of conducting serial laboratory measurements of thermal conductivity of soils and rocks in the Polish Geological Institute-NRI. The measurements are conducted based on a proprietary methodology developed in PGI-NRI.

The presented research procedure has been designed for the purpose of supplementing the Thermal Parameters of Soil and Rocks PGI-NRI Database. The data contained in the Database is the basis for developing of geothermal 3D models and for low-temperature geothermal potential mapping. The aforementioned deliverables derived from the Database are published online and used for the assessment of geothermal potential and support for the sustainable development of low enthalpy geothermal energy and general promotion of RES in Poland.

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15. Invasion percolation method as a way of describing displacement processes in a porous media

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Keywords: petroleum geology, CO_2 storage, percolation, pore, reservoir

Abstract

Percolation describes movement and filtering of fluids through porous materials. There are two different fluid phases: wetting phase (e.g., water), which fills every narrow part (*pore throat*), as well as the corners of the pore spaces, while flowing through the porous media, and non-wetting phase that displaces the water and fills the pores (*pore body*) regarding to their size, choosing the widest throats, which must be connected to the *inlet*. The process of percolation in the wetting phase is “normal” percolation, whereas in the non-wetting phase it is defined as the invasion percolation. This method is based on a branch of statistical physics and probability theory, studying the behaviour of random systems in which fluid or gas flows through a porous medium. It determines that the non-wetting fluid only enters the pore throat when the pressure in the non-wetting fluid exceeds the pressure in the wetting fluid by a value equal to the threshold capillary pressure. Topological description is used as a simplified illustration of the pore space, where pores are defined as a sphere with a known radius and throats as a bounding surface between the two pores. The throat area is determined by the smallest radius (sphere). This simplification of the pore system allows the description of even the most complex pore systems. These methods can be used to create a 2D or 3D model at the pore or reservoir scale, making them a useful tool for addressing CO_2 migration problems underground.

16. Introduction of all neccesary informations for planning a geothermal object in a Hungarian pilot area

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Keywords: geothermal energy, geological model, temperature model, geothermal reservoirs, geothermal potential

Abstract

Due to the current energy crisis in Europe geothermal information packages were requested which can be used by governmental and non-governmental companies, institutes for planting new geothermal energy utilization systems to replace the non-renewable energy sources. These geothermal systems are not only renewable but highly independent from the oil and gas imports.

Planning a geothermal energy utilization system requires a lot of different data from economical, sociological, environmental and legal background. For reaching out the potential shareholders every project requires a comprehensive report including the environmental potentials, social acceptance, financial analysis and potential risks. In the information packages the customer will receive data about the geological, topographical, geophysical parameters and hydrogeological features for defining the geothermal potential of where the geothermal plant will be placed.

The first step is to understand the geological background of the chosen area, which gives the basics of a complex geological model, which can be used later on for defining the potential reservoirs. For this geological model, we need a strong geophysical background supported by measurements close to surface using well-to-well log correlations based on geophysical borehole data and seismic measurements below 400 meters to define the exact settings of the geological units, formations. Based on these geophysical data a complex regional geological model can be created. For defining the geothermal heat potential, a regional model can be created using data from a complex database containing temperature data from different sources such as borehole temperature measurements and outflow water temperatures. Using temperature model we can define the required depth of the expected geothermal heat flow, which later helps to find the potential reservoir.

The final step for reservoir definition is the hydrogeological overview which includes hydrodynamical characterization which is a complex description of the underground water flow system of an area using hydrochemical measurements of the potential reservoirs.

With these information packages the costumers receive a complex vision of the selected project area which helps with the geothermal potential definition can be used for energy utilization. These packages can be used to improve the geothermal heating, cooling and electricity production, helping these users to redeem the non-renewable energy carriers with geothermal energy.

17. Structural-geological investigations of Daruvar hydrothermal system in Central Croatia

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Keywords: SW Pannonian basin, Mt. Papuk, 2D/3D structural modelling, hydrothermal system, geothermal gradient

Abstract

Geothermal gradients and heat flow in the Croatian part of the Pannonian Basin with values in a range of 49 °C/km and 76 mW/m^2, respectively, are significantly higher than the global average (EIHP, 1998). In this work we present the results of conducted geological and structural investigations in the Daruvar area, which is a known hydrothermal system in the central part of Croatia. Daruvar hydrothermal system is one of the three research areas investigated by research project "Multidisciplinary approach to hydrothermal system modelling" (HyTheC) funded by the Croatian Science Foundation.

Daruvar thermal aquifer (DTA) is developed in the contact area of Internal Dinarides and SW Pannonian Basin, as a part of Slavonian Mountains, i.e., Tisza-Dacia mega-unit. In order to understand the recharge/discharge areas of the DTA, we focused our investigations on the geological and structural modelling of the subsurface relations. Structural 2D/3D modelling involved extensive structural-geological field observations which enabled the definition of the lithofacies distribution of the western slopes of Mt. Papuk, reconstruction of fault geometries, identification of the potential reservoir rocks and their dominant fracture systems and, finally, hydrogeological parametrization (MILEUSNIĆ, 2022). For the structural modelling we also used published/available geological and geophysical data. 3D modelling of the studied area was based on the construction of five geological cross-sections improved with field data: bedding, foliation, fracture system orientations, and principal stress axes calculations. Results show DTA is hosted by Mesozoic carbonate complex (predominantly Triassic dolomites), which in its footwall is composed of Palaeozoic magmatic and metamorphic rocks, whereas its hanging wall is Neogene-Quaternary clastic succession. 2D and 3D structural models suggest DTA is highly deformed by polyphase fault systems, which were tectonically active/reactivated and inverted during Paleogene and Neogene-Quaternary, accommodating up to 400 m of vertical movements. The hydrothermal system is affected by at least three kinematic phases associated with Paleogene compression, Neogene extension, and Late Neogene–Quaternary compression/transpression as a result of tectonic inversion of the SW Pannonian Basin (MILEUSNIĆ, 2022).

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18. Geothermal situation in Slovenia

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Keywords: geothermal energy, Pannonian basin, Slovenia

Abstract

Appearance of surface thermal springs in Slovenia is connected to edges of sedimentary basins. These are areas that have experienced intensive tectonic movement along normal faults which caused blocs to sink. Especially steep vertical faults are capable of deep circulation of groundwater. Cold water moves along them towards the interior and warm and hot water towards the surface, where it appears as thermal springs. This is the reason that hot springs are indicators of deep tectonic movements, however, they are not base for determination of thermal capacity for the whole area. For these purposes is better suited geothermal research in wells. Hot springs may be connected to a large reservoir of hot water in depths, but they can also be part of fractured geothermal system without connections to larger central reservoir.

Temperatures of natural hot springs in Slovenia are between 17 to 37 degrees Celsius, however, temperatures in wells in vicinity of springs have been determined to be double that amount. Mixing of hot thermal water and cold surface water is source for these differences in temperatures.

Weak heat flow is more successful in heating up the impermeable rock formations in comparison to permeable formations on same depth. Decisive factors for formation of successful geothermal system are source of heat, confined aquifer, and its connection to the surface. Important factors are also temperature of water in aquifer, chemical properties of said water and abundance of water in the spring. With consideration of these factors there have been determined three regions in Slovenia that could be used for geothermal energy. The three regions are tertiary Pannonian basin in north-eastern Slovenia, tertiary synclines on the western edge of Pannonian basin and quaternary Ljubljana basin.

Thickness of sediments in these regions are up to 4000 meters, average thickness is few hundred up to one thousand meters. Most prominent results for geothermal exploitation are expected in north-eastern parts of Slovenia where previously mentioned factors are mostly fulfilled. Temperature gradient of this region is 40 mK/m in the upper 3000 meters, and 50 mK/m in greater depths. Data used for this determination was gathered form oil wells that were drilled to maximum depth of 4000 meters.

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19. Multidisciplinary Research of Thermal Springs Area in Topusko (Croatia)

Authors: Mirja Pavić[1], Ivan Kosović[1], Marco Pola[1], Kosta Urumović[1], Maja Briški[1], Staša Borović[1], Tihomir Frangen[1]

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Keywords: thermal spring, hydrogeochemical characteristics, electrical resistivity tomography, hydrogeological parameters, hydrothermal system

Abstract

Thermal springs in Topusko, with temperatures of up to 53 °C, are the second warmest in Croatia and are located at the southwestern edge of the Pannonian Basin System, which has favourable geothermal characteristics. In the 1980s, shallow drilling in the springs area and a few short-term monitoring campaigns of thermal water were carried out. Thermal water with temperatures of up to 65 °C has since been used for heating, health care, and recreational tourism. However, much of that data is lacking, making these efforts insufficient for the current study of sustainable resource management. Therefore, multidisciplinary investigations were conducted during 2021 and 2023, including a hydrogeochemical characterisation of the naturally emerging thermal water, thermal imaging, an electrical resistivity tomography (ERT) investigation to reconstruct the subsurface geology, and a hydrogeological parameterisation of the geothermal aquifer, all with the aim of improving the existing local conceptual model. The results show the Ca-HCO_3 facies of the thermal water hosted in a Mesozoic carbonate aquifer. The stable water isotopes, the SO_4^{2-} isotopic composition, and the determined radiocarbon groundwater age of 10 - 14 kyr suggest a meteoric origin of the thermal water, which may have been recharged during the cooler climatic conditions of the late Pleistocene (Clark, 2015). The equilibrium temperature of the water in the geothermal aquifer is estimated to be 78 °C based on the SiO_2 quartz geothermometer, and the fault zone that allows its upwelling was identified by ERT surveys.

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20. Geothermal Energy for Urban Regeneration in Milan Metropolitan Area

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Keywords: shallow geothermal energy, ground-coupled heat pumps, geothermal potential, Milan metropolitan area, urban aquifer

Abstract

The Milan Metropolitan Area is one of the most densely populated regions in Italy and Europe (mean population density: 7.684.6 inhabitants/km^2 (ISTAT, 2020)), consequently, has an extremely high thermal power demand. Here, the subsoil and the aquifers have a great potential for shallow geothermal exploitation due to their advantageous hydrogeological settings (e.g. the equivalent horizontal hydraulic conductivity of the phreatic aquifer ranges between 5*10^{-5} and 1*10^{-2} m/s (Previati & Crosta, 2021)). In 2019 the total number of installed GCHPs (Ground Coupled Heat Pumps) in the study area was 1.166 with a total power of 42 and 33 MW for heating and cooling, respectively (Regione Lombardia, 2019a). The main focus of this work is to investigate solutions that can get the exploitation of the geothermal resource more effective. The idea is to simulate the response of aquifers, stressed by possibly new installations, in hydro/thermal flow dynamics, in groundwater fluctuations, and in thermal perturbations to verify the system's efficiency and minimize short-circuiting between the existing and new system. To support the analysis it is planned to develop a research infrastructure that will enable the testing and evaluation of the heat pump system (geothermal installation). This will allow, at least at the local scale, the calibration and validation of numerical and analytical models as well as could become a paradigm case to be replicated in urban areas.

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21. Utilization of geothermal energy from massive carbonate rocks

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Keywords: carbonate rock, geothermal energy

Abstract

Geothermal energy, harnessed from the Earth's heat, has emerged as a viable and sustainable alternative to conventional energy sources. While the utilization of geothermal energy has traditionally focused on volcanic regions with permeable reservoirs, recent advancements have unveiled the potential of tapping into massive carbonate rocks for geothermal energy extraction.
Massive carbonate rocks, such as limestone and dolomite, are prevalent geological formations found worldwide. These rocks possess low permeability, making them unconventional geothermal reservoirs. However, advancements in drilling and stimulation technologies, such as hydraulic fracturing, have opened new avenues for extracting heat from these formations. By creating artificial fractures within the carbonate rocks, the permeability can be enhanced, enabling the circulation of fluids necessary for heat extraction.
The extraction process involves injecting water or a working fluid into the created fractures to capture the heat stored within the rocks. The heated fluid is then circulated to the surface, where its thermal energy can be utilized for electricity generation or direct use in heating applications. This approach allows for a sustainable and continuous supply of geothermal energy, reducing reliance on fossil fuels and minimizing greenhouse gas emissions.
Despite the potential advantages, several challenges need to be addressed when harnessing geothermal energy from massive carbonate rocks. The low permeability of these formations necessitates careful well design and stimulation techniques to create effective fracture networks. The variability in rock properties within carbonate formations also poses a challenge, requiring detailed geological characterization and monitoring to optimize energy extraction.
Furthermore, the presence of dissolved minerals and potential scaling issues in the fluid circulation system can affect the overall efficiency and longevity of geothermal operations. To mitigate these challenges, advanced fluid management techniques and geothermal reservoir modeling approaches are being developed, focusing on minimizing fluid-rock interactions and maintaining long-term sustainability.
In conclusion, the exploration of geothermal energy within massive carbonate rocks presents an opportunity to expand the utilization of this renewable resource. While significant technical and operational challenges exist, advancements in drilling, stimulation, and reservoir management techniques are paving the way for enhanced heat extraction from these unconventional reservoirs. By furthering research and development efforts, geothermal energy from massive carbonate rocks can contribute to a more sustainable and diversified energy production, reducing carbon emissions and enable a cleaner energy future.

22. Direct measurement of thermo-physical parameters along continuous cores, as a tool for characterizing shallow alluvial geothermal resources (examples from the Po Valley, Northern Italy)

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Keywords: thermo-physical properties, shallow geothermal resource, thermal conductivity, grain-size characterization, continuous cores

Abstract

The importance of understanding and determining thermo-physical properties of soils is increasing exponentially, especially as concerns feasibility studies for the harvesting of the shallow geothermal resource. The ongoing research activities are devoted to carry out direct measurements on some continuous cores for characterizing the shallow geothermal potential in the Ferrara area. Available cores have been drilled in nearby sheets in the frame of the regional geological cartographic (CARG) project. In the first step of the planned research activities, some samples of different grain size (e.g. sand, silt, clay) were collected from the cores, with the aim of realizing a grain-size characterization, with a sedigraph. At the same time, the thermal properties of these different soil types are measured in the laboratory with the use of a portable instrument based on the Linear Probe Method. At present, the most important property obtained is the thermal conductivity, from which thermal diffusivity and thermal resistance could be calculated using theoretical formulations. No GRT (Ground Response Test) or other on-field measurements were performed so far.

23. Atlas of geothermal energy resources of Egypt

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Keywords: geothermal energy, gulf of Suez rift, Red Sea, hot dry rock, Nubian aquifer system

Abstract

Geothermal energy “the vast amount of heat beneath our feet” is gaining worldwide interest nowadays as an alternative clean and sustainable energy source. Egypt is situated in a geotectonic setting that enriches its geothermal resources, surrounded by two types of present-day plate boundaries: a convergent one in the Mediterranean and a divergent one of the Red Sea -Gulf of Suez rift system. However, geothermal energy in Egypt "till now" is not included either on the renewable energy map of Egypt or on the geothermal energy map of the world, only direct uses are being developed.

This study systematically surveys different geothermal studies on Egypt's deep geothermal resources. Furthermore, the most promising sites for geothermal drilling in Egypt are suggested based on the main important data available in the literature. The data available are geologic maps, geothermal gradient, heat flow, geochemical data including geothermometry, reservoir temperature, depth to the geothermal reservoir, and geophysical data.

The data are collected and compiled in a representative atlas. Moreover, suitable geothermal production technology for each site is suggested, aiming at facilitating and encouraging geothermal energy development in Egypt.

The Egyptian territory could be divided into four main revealed geothermal provinces, The Gulf of Suez province, the Red Sea province, the radiogenic hot dry basement province, and the western desert province.

Four promising geothermal sites are representative of the four geothermal provinces, that might represent the first sites for the construction of geothermal power plants in Egypt. These sites are Hammam Faraun and Sudr field (Gulf of Suez province), El Gouna (Red Sea province), Abu Dabbab and Wadi Ghadir (Radiogenic hot basement province), and Bahariya and Qara oases (Western Desert province).

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24. Evaluation of deep borehole heat exchanger potential in the South Slave Region, Northwest Territories, Canada

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Keywords: geothermal, low temperature, heating, north

Abstract

Heating is crucial in cold and harsh climates. For instance, in Canada, it accounts for more than 80% of household energy consumption, and the majority of its northern communities depend on fossil fuels for space and water heating. Energy cost in the Northwest Territories (NWT), enclosing several indigenous communities, is over two times higher than the national mean. South Slave region communities, like many others, need to rely on carbon-intensive fossil fuels, such as heating oil, to provide them with space and water heating.

However, the sedimentary rocks in the area appear to have low permeability. Additionally, the sedimentary basin cover under the communities is relatively thin, ranging from around 500 to 730 m as shown on the stratigraphic logs in Figure 4. These represent potential limitations for conventional geothermal energy production methods. Deep borehole heat exchanger (DBHE) could be a promising heat-producing technology. Energy needs are especially important for heating and since there is some hydraulic electricity production in the region, DBHE coupled with heat pumps could thus be an interesting alternative. However, the thermal output is unknown. To pave the way for demonstration projects, it is necessary to model the operation of such a system.

The objective of this project consists of evaluating the potential of DBHE in the South Slave Region for heating applications for communities of Hay River, Fort Providence, Enterprise and Kakisa.

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25. Two at one blow: subsurface rainwater recharge as a potential heat storage?

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Keywords: ATES, MAR, Renewable Energy, Climate change, Heat storage

Abstract

The main question raised by my study is: is it possible to combine the ATES (Aquifer Thermal Energy Storage) and the MAR (Managed Aquifer Recharge) systems? The data required for this work (water level and temperature time series) were provided by a shallow MAR pilot system established in the Danube-Tisza area where rainwater replenishment is performed through a shallow well. The temperature of the rainwater is different from that of the well water, which can create the potential for heat storage. Two different cases were investigated to reveal the natural reasons of the measured temperature data: (1) the theoretical changes in temperature data where I did not take into account the effect of water replenishment, just the conduction effects and (2) the measured effect of water recharge. The calculations concluded that the conductive model ignoring the precipitation water is a good approximation of the temperature time series recorded at the depth of the observation wells (6,7 meters) which indicates that the temperature impact of the replenishment is small. Further calculations showed that the thermal effect of the precipitation water infiltration is small at the point of water replenishment, too. However, the feasibility of interconnecting non-individual and deeper systems should also be explored which may have the potential to increase efficiency.

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26. The Use of Low Enthalpy Geothermal Energy Through the Installation of Micropiles

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Keywords: Energy micropiles, thermo-mechanical behaviour

Abstract

Since the first application of piles as energy geostructures in Austria in the 1980, the use of geostructures has steadily increased worldwide. Energy geostructures are complex systems that combine structural, geotechnical, and thermal performance. They harness the soil thermal energy by exchanging heat between the ground and the building, through a heat carrier fluid circulating in closed loop of plastic pipes which are inserted in the geostructure. In the context of building rehabilitation and underpinning of existing structures, energy micropiles (EMPs) stand frequently as the best solution over other energy piles (EPs). Micropiles are small, drilled, and grouted-in-place piles having a diameter between 90-300 mm and a length up to 20 m (Ischebeck, 2015). Their thermal performance in terms of specific heat flux (about 50 W/m) show that EPs are a promising technology for heating/cooling systems. The TITAN 73/53 EMPs have an extraction capacity between 60 and 100 W/m depending on the soil thermal properties. Although very similar, the behaviour of other EPs and EMPs differ both mechanically and thermally, mainly due to the differences in size and spacing. To date, several studies are dealing with the thermo-mechanical behaviour of other EPs. Thermal performance of EMPs has also been looked at to an extent by various researchers. However, the coupled thermo-mechanical behaviour of EMPs is not well understood. This study investigates the thermo-mechanical behaviour of an energy micropile with the aim of identifying suitable evaluation criteria and design parameter for optimizing the performance of EMPs.

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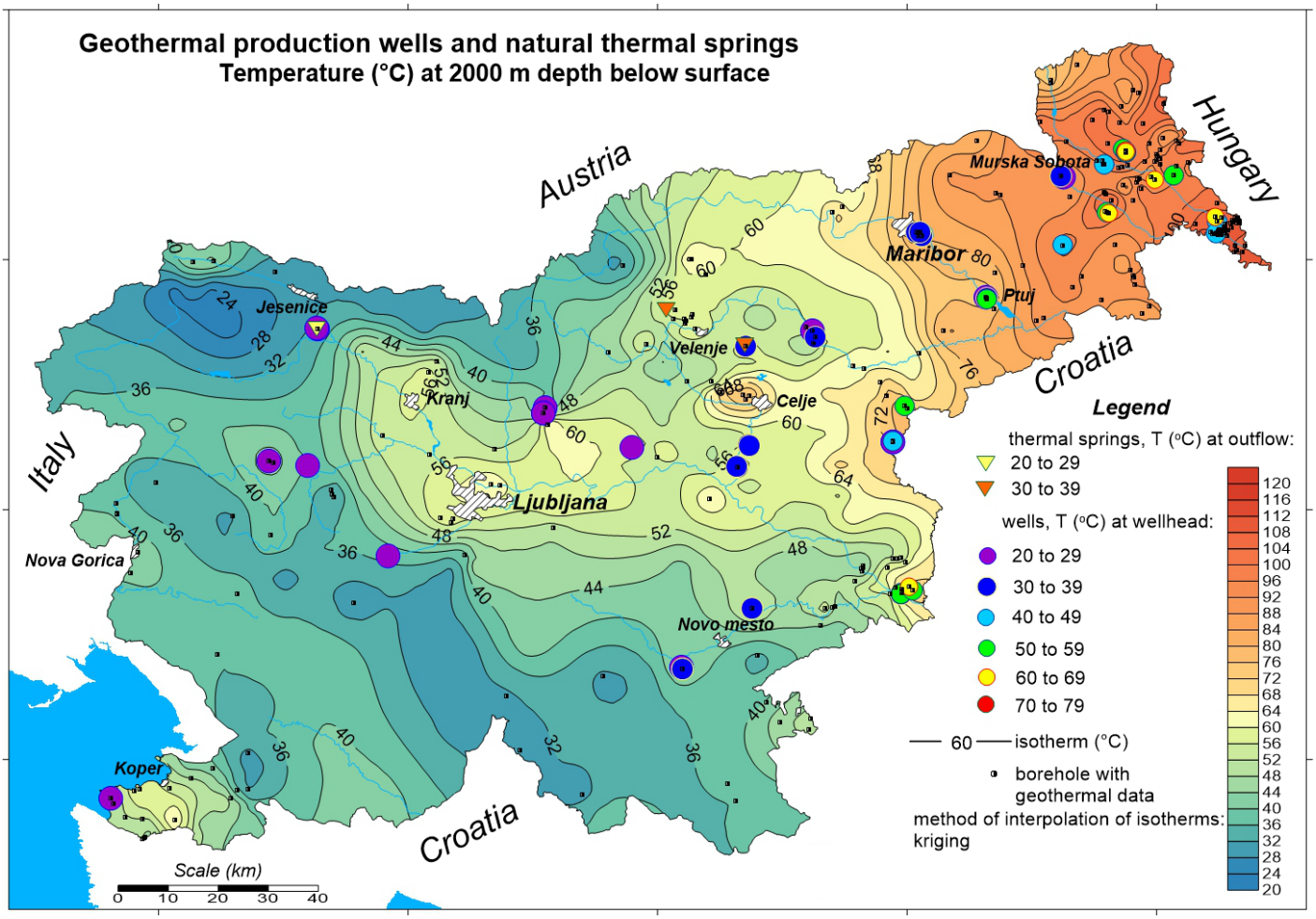

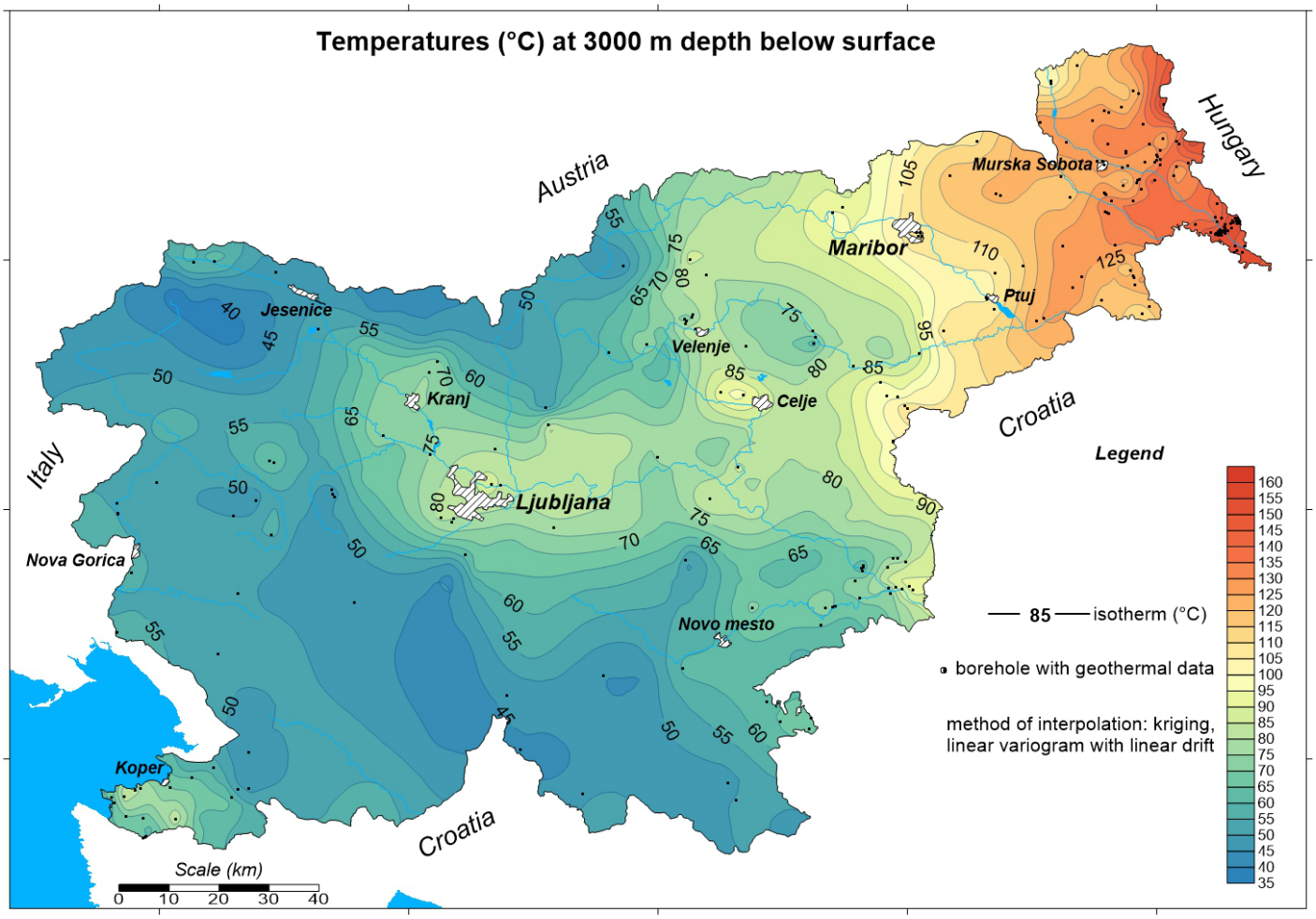

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