An overview of chemical methods in geothermal reservoir exploration

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Abstract

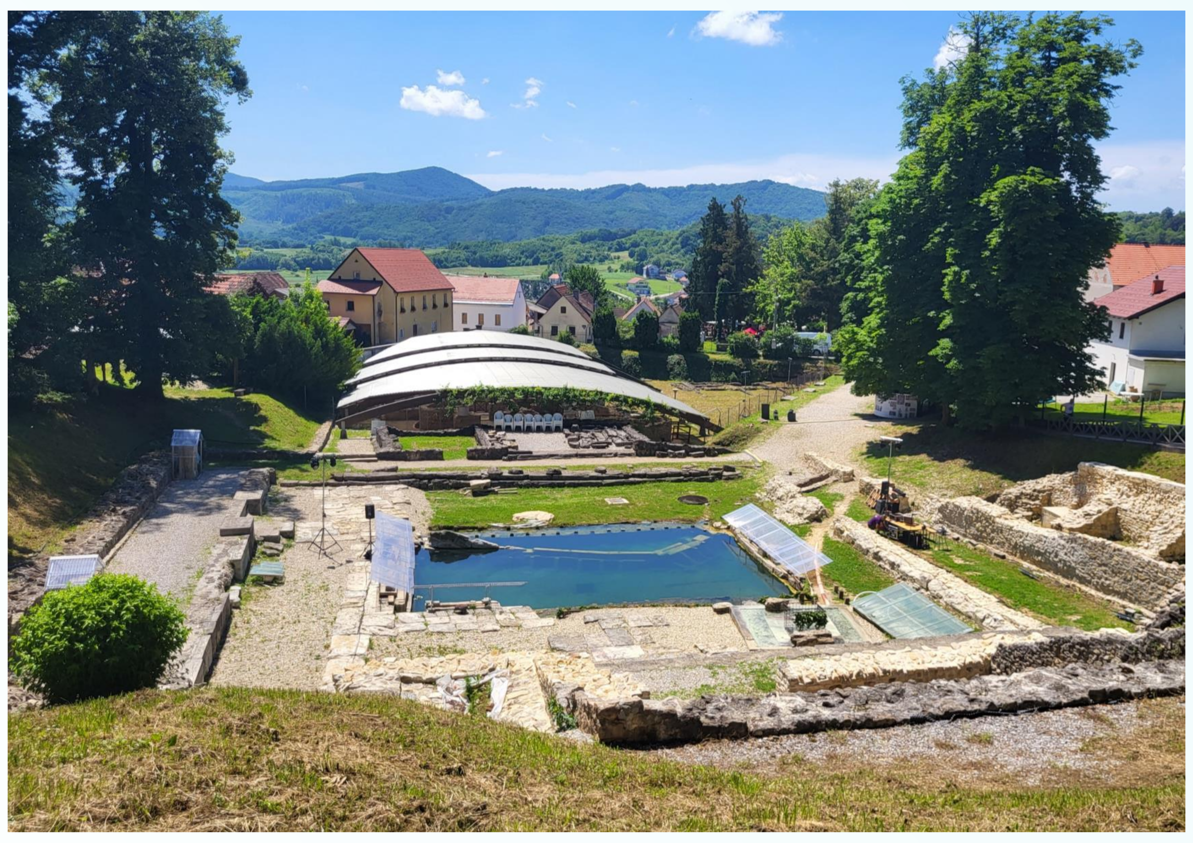
During the exploration of geothermal resources, the examination of the chemical composition of geothermal fluids plays an important role. The use of different chemical methods begins during the prospecting of a potential deposit, continues through all stages of preparation for exploitation, and plays an important role throughout the exploitation of the geothermal resource through the monitoring and management of the deposit. The chemical composition of water is the result of a series of processes, such as interaction with aquifer rocks, mixing with cold water from shallower aquifers, etc. Certain chemical elements can also be used as geothermometers and indicate the temperature of the water in the aquifer, and the presence of certain mineral species in the samples of wells may indicate potential cooling or heating of the geothermal system. The chemical composition and properties of the hot fluid are important when designing the well as well as the entire system for utilising the stored heat, whether it is a heated greenhouse or a geothermal power plant. Ultimately, understanding the chemistry of the fluid is also important when finding the best solution for the used geothermal fluid, which directly contributes to reducing the impact on the environment.

Introduction

Geothermal energy is becoming more and more popular as an environmentally friendly form of energy due to its low carbon footprint and great efficiency. Geothermal exploration is the complex process of finding and locating geothermal resources. One of the most important techniques applied to geothermal exploration is geochemical data analysis. Geochemical data analysis involves the collecting of fluid samples from geothermal wells or springs and their subsequent laboratory analysis. The basic premise for using geochemical methods in geothermal exploration is that fluids on the surface, be it aqueous solutions or gas mixtures, reflect physico-chemical and thermal conditions in the underground geothermal reservoir. During surface exploration and exploratory drilling of potential geothermal reservoir, it is crucial to identify water's chemical composition, estimate underground temperature, and assess geothermal water's origin, recharge areas, and underground fluid flows. On the basis of these data, it is also possible to assess the environmental impact. During the phase of exploratory drilling and pumping, the changes in the chemical composition of the geothermal fluid must be constantly monitored along with the assessment of the fluid's impact on the equipment (in the form of corrosion and scaling). During the exploitation and monitoring phase, it is important to check the chemical composition of the used fluid and its impact on the environment, as well as recharge and potential cooling of the reservoir.

Geochemical sampling and analysis

In geothermal systems, many reactions depend on temperature. Even though the waters rise to the surface and cool down, their equilibrium properties are maintained since their kinetics are not as quick at lower temperatures.
Geochemical studies of geothermal fluids consist of three steps: collection of samples, chemical analyses, and interpretation of the results. Effective sample collection demands thorough comprehension of chemical analysis and interpretation. It includes taking measurements at the site and properly handling the sample.



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On-site measurements

Once the sampling location has been chosen, it must be accurately described, and measurements should be conducted on site, primarily temperature, flow rate, and geographical coordinates. Certain measurements, like dissolved oxygen (O_2) and hydrogen sulphide (H_2S), are most accurately conducted in the field. Also, pH and total carbonate levels can be determined at the location as well. It is important to remember that precise pH measurement is crucial for subsequent calculations as it plays a role in nearly all chemical reactions.

Laboratory analysis

While in storage, the sample's chemical composition can potentially undergo alterations, especially in terms of certain elements. Laboratory analysis typically follows established and validated methods. Even if analysis in the lab is done perfectly, it will not provide accurate data on the water's chemical composition at the sampling location if the collection and sample treatment are not done correctly.
Main components measured in the laboratory are Na, K, Mg, Ca, bicarbonates, sulphates and chlorides. Trace elements can give valuable information about recharge areas, temperature, etc., and elements such as B, Br, Sr, nitrates, Li, and fluoride are also measured. Isotopes can give valuable info too, such as the origin of the waters, their age, reservoir temperatures, origin of sulphur, nitrogen, etc. Isotope analysis usually involves $\delta^{18}O$ and $\delta^{2}H$ in water an $\delta^{13}C$ in dissolved inorganic carbon. Components usually analysed in the gaseous phase are CO_2, H_2S, CH_4, N_2, O_2, Ar, He, Ne, $\delta^{13}C$ in CO_2 and the $^{3}He/^{4}He$ ratio. Gaseous phase can be either exolved from water or measured in the form of dry emissions. Analyses of geothermal fluids can prove to be more demanding than analyses of ordinary underground water due to their more complex composition and greater number of possible interferences. Laboratories in charge of geochemical analyses must have modern analytical equipment and use certified methods and materials in order to ensure the traceability of the results over a long period of years.

Conclusion

The chemical composition of the fluid samples may reveal a great deal about the geothermal system, including the temperature, pressure, and mineral content of the reservoir. Geochemical studies of geothermal fluids consist of three steps: collection of samples, chemical analyses, and interpretation of the results. Work regarding geochemical exploration can be divided into two stages: on-site measurements and laboratory analysis. Geochemical research plays an important role from the very beginning of the research of a geothermal phenomenon and does not stop during the entire time of its exploitation.

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