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Geochemical Modelling of Low-Temperature Geothermal Fields from Bihor County, Romania

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ABSTRACT

The main geothermal zone in Romania is situated along the western border of the country, from Satu Mare in the north to Timisoara in the south. Considering the wellhead temperatures of the waters, the geothermal areas are classified as low-temperature and medium enthalpy. The Bihor County, located in the north-western side, with its high geothermal potential has supplied heating both for residential and commercial spaces, industrial processes and for balneal purposes. Chemical study for the characterization of the geothermal waters and water-rock interaction is of great significance both before the operation and during the geothermal well production. For the evaluation of the geochemical structure of the fields, fluid samples were obtained from several wells. Using the analytical data of the wellhead samples, the aquifer fluids feeding the selected wells from Bihor were modelled with the aid of speciation program WATCH. The modelled aquifer fluids assessed how closely they have reached to equilibrium conditions with respect to mineral-solution reactions that may occur in the reservoir.

1. INTRODUCTION

The exploration and research for the geothermal resources began in Romania fifty years ago. The first geothermal wells were drilled in the Western Plain, in Bihor County. Here, the Triassic aquifer Oradea and the Cretaceous aquifer Felix are hydrodynamically connected and are parts of the active natural circulation of water (Roşca, 1998). Considering the outstanding special therapeutic properties of the geothermal water in Felix, where the microclimate is ideal for recreation and the landscape is pleasant, it has become an attraction for the investments in tourism, recreation and health. Felix, situated less than 10 km southwest of Oradea city, is nowadays the most famous resort, which contains abundant treatment indoor and outdoor facilities. This thermal spa is well fit for the balneological use. Geothermal water is used in external cures for balneo-therapeutic purposes such as rheumatics and post-traumatic applications. The Felix Spa reservoir is currently exploited by six wells with depths between 50 and 450 m. The geothermal waters have wellhead temperatures in the range of 36–48°C.

The assessment of an area in terms of subsurface geothermal exploration and exploitation requires a detailed study of all surface investigation methods such as geological, geochemical and geophysical methods. Geochemical methods are relatively inexpensive and can provide valuable information about the temperature conditions in a geothermal reservoir and the source of the geothermal fluid. The use of geochemistry has a significant importance for inferring the subsurface conditions by studying the chemistry of the surface manifestations or discharged fluids that carry the signature of the deep geothermal resources.

2. APPLICATION OF GEOCHEMICAL METHODS

2.1 Classification of Thermal Waters

At the Felix Spa resort, the geothermal water is used for recreational and health bathing. Its therapeutic properties have been known for a long time. Due to the economic importance, it might be of real need to give a geochemical study correlated to geochemical modeling for delineating the change in the exploited area of Felix Spa. In this study, three geothermal wells from Felix were selected, which were monitored during their production years. Water samples were collected and analyzed in the chemical laboratory at the Oradea University, according to the standard practice of geothermal analysis. The results from each well were treated depending on their chemical properties and production properties. The analysis results of the main elements in the water samples are plotted in different classification diagrams.

The Schoeller diagram (Figure 1) utilizes the concentrations of sulfate, carbonate, chloride, magnesium, calcium, and the sum of the alkali ions, sodium and potassium on the y-axis and these elements are lined up on the x-axis in this order. Each water sample is represented by a line in the diagram. Water samples belonging to similar water groups follow the same pattern in the diagram. The studied waters are calcium-bicarbonate waters with higher sulphate concentration for the well 4011.

The Durov diagram (Figure 2) utilizes two triangular diagrams connected into a square, adding total dissolved solids and pH of the water samples in the connecting rectangles. The measured pH at water collection was 7.1 at the wellhead of the well 4003, and were slightly acidic 6.7 and 6.4 for the wells 4011 and 4012, respectively. In the triangular diagrams the proportions in equivalent concentrations of the main cations and of the main anions are plotted. It can be noticed that the analyzed waters are calcium-bicarbonated type waters, with a secondary anion as sulphate, which has higher concentration in the well 4011. The mineralization of the geothermal waters in the well 4011 is high, compared to other two wells. These diagrams were constructed using the AqQa program (2005).

The Cl-SO4-HCO3 diagram illustrates the proportions of the major anions presented in the geothermal water in the representation style of Giggenbach (1991). From the plots (Figure 3) it is shown that the samples are located within the region of high bicarbonate concentration. Waters from the well the 4003 are classified as peripheral waters, while the tendency of waters from the well 4012 is

towards the steam-heated water area and those from the well 4011 is closer to the area of steam-heated water, possibly mixed with cold groundwater.

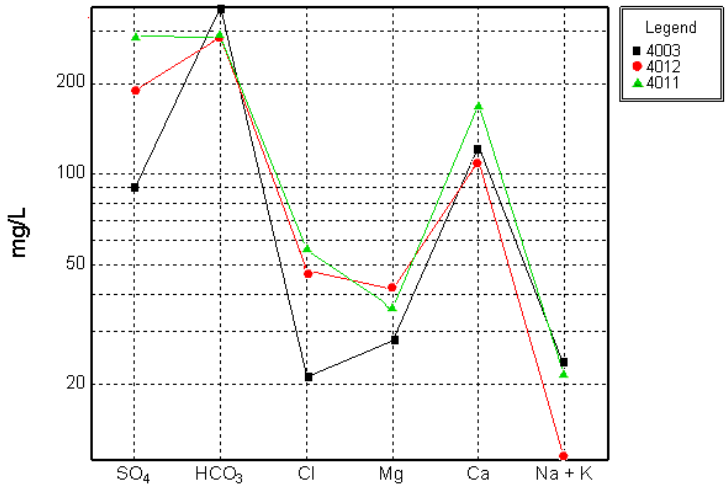

Figure 1: Schoeller diagram for the water samples.

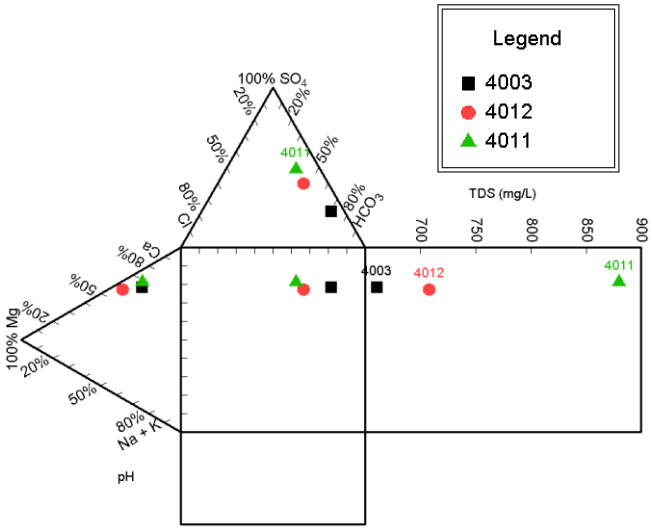

Figure 2: Durov diagram for classification of the water samples.

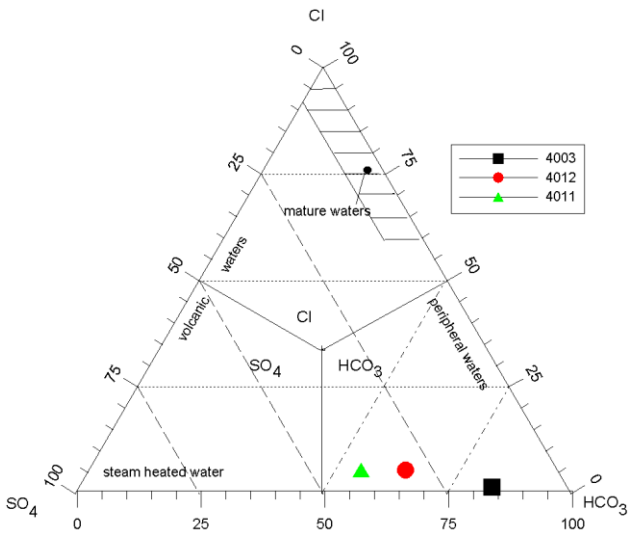

Figure 3: Classification of water samples from Felix based on the Cl-SO4-HCO3 plot.

2.2 Water Geothermometers

The Na-K-Mg triangular diagram of Giggenbach (1991) and Arnórsson et.al. (1983) is one of the most widely used cation geothermometry plots, which is a ternary diagram combining the Na-K and K-Mg geothermometers. It reveals the equilibrium temperatures of minerals containing these elements and used to identify water-rock equilibrium and to determine the deep reservoir temperature. The selected samples have high magnesium contents, plotting in the immature region (Figure 4). The water samples did not attain equilibrium between water and rock. The resulted equilibrium temperatures (Figure 4) are over 260 °C, considering the Na-K geothermometer temperature. Obtained high deep reservoir temperature values will be verified/recalculated using the WATCH program.

Estimation of reservoir temperature was done by the use of speciation program WATCH, Arnórsson and Bjarnason (2004). This program uses the functions for quartz, chalcedony, and Na/K ratio geothermometers. The results are summarized in Table 1.

Table 1. Geothermometry calculations

Well no.	Wellhead temperatures, ºC	Chemical geothermometers, ºC		
		Quartz	Chalcedony	Na/K
4003	45	54.3	22.2	312.2
4012	43	66.8	34.6	313.0
4011	45	69.5	37.2	316.0

The temperatures of the reservoirs indicated by the calculated chalcedony geothermometer are close to the production temperatures of the waters from the wells 4012 and 4011 (Table 1). For the well 4003, it seems that the quartz geothermometer controls better the temperature of silica equilibrium in the reservoir. The Na/K geothermometer yields higher values compared to the silica geothermometers for all the cases. This geothermometer does not give good results for the low-temperature geothermal waters, probably due to a specific mineral, which controls the mineral-fluid equilibration.

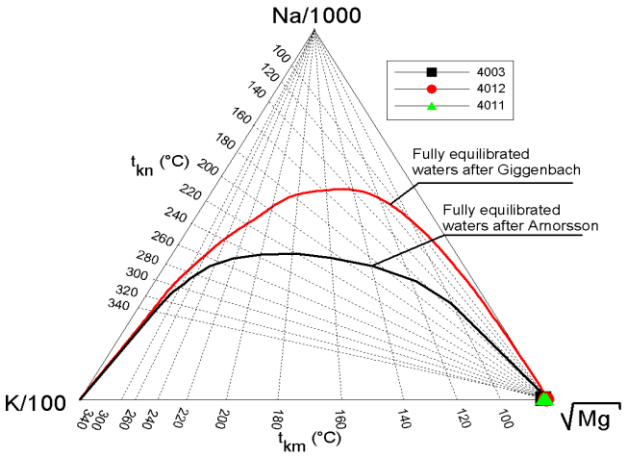

Figure 4: Na-K-Mg equilibrium diagram.

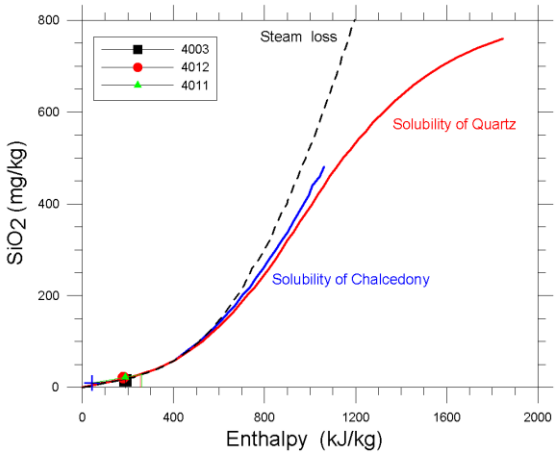

Figure 5: Dissolved silica-enthalpy diagram.

The silica-enthalpy mixing model (Truesdell and Fournier, 1977) was applied in order to estimate the temperature of the hot water component feeding the wells in the reservoir. The analyzed silica contents of the geothermal waters from wells 4003, 4012 and 4011 were 15.7, 21.7, 23.2 mg/L. The diagram (Figure 5) plots silica versus the enthalpy of water, giving the temperature of the deep hot water component. It fits well when a mass flow rate is high enough to allow for a little conductive cooling. The cold water point was assumed to represent the hypothetical cold groundwater from the upper aquifer in the study area (temperature of 10°C and silica content of 10 mg/L). The intersection points of the "cold water - geothermal water" line with the solubility of chalcedony curve give the silica content and the enthalpy of the deep hot water component (190, 260, 270 kJ/kg for the wells 4003, 4012, 4011). Deep water temperatures are obtained from the steam tables. Based on this model, a temperature of 46 ºC was obtained for the deep geothermal water from well the 4003, 59 ºC from well the 4012, and 63 ºC from the well 4011. These temperatures are close to the results of silica geothermometers calculated by Watch program and indicate a shallow feed reservoir, based on the fact that the depths of the wells is low and well-sustained the reservoir pressure.

2.3 Prediction of Scales

Changes in water temperature, pressure, pH and mineral saturation occur when the fluid is tapped from geothermal reservoir by production wells. As a consequence, minerals may deposit within the wells, in pipelines and other surface equipments. The most common scales consist of calcium carbonate and silica, but scales of various oxides, sulphides, and silicates are also known. Calcite solubility decreases by increasing temperature, but the pH modification due to degassing of water may also lead to supersaturation. Silica solubility is proportional to the temperature, but the formation of silica scales depend on various factors including pH, hydrodynamic conditions in flow and rate of the interaction among siliceous groups.

The saturation index (log Q/K) is an indicator of the degree of saturation of water with respect to a mineral. When the ionic activity has a lower value than the theoretical solubility (Q<K), the saturation index is negative, giving rise to an undersaturated solution with respect to a particular mineral considered. If saturation index is positive (Q>K), the solution is supersaturated with respect to that mineral. When Q=K, geothermal water is in equilibrium with the mineral in respect. Figures 6, 7 and 8 show the results for the saturation indexes of calcite, chalcedony, and quartz, respectively. They are calculated for each well using the wellhead temperature and also using lower temperatures, which can be reached after utilization of geothermal waters.

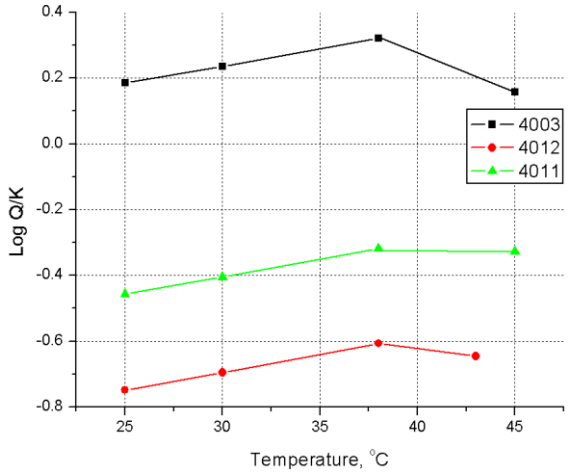

Figure 6. Prediction of saturation state of calcite for selected wells.

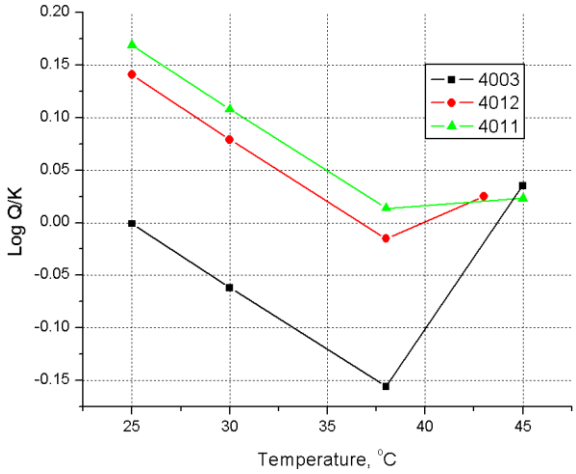

Figure 7: The Prediction of saturation state of chalcedony for selected wells.

The sample from well the 4003 is supersaturated with respect to calcite, the saturation indexes are in the range of 0.15 to 0.3 at measured wellhead temperature and at lower temperatures. For the other wells, calcite is undersaturated. There is an equilibrium with chalcedony at the wellhead temperature for all the studied wells. There is recorded a slight supersaturation with respect to quartz at the measured temperatures, the saturation indexes having values more than 0.35.

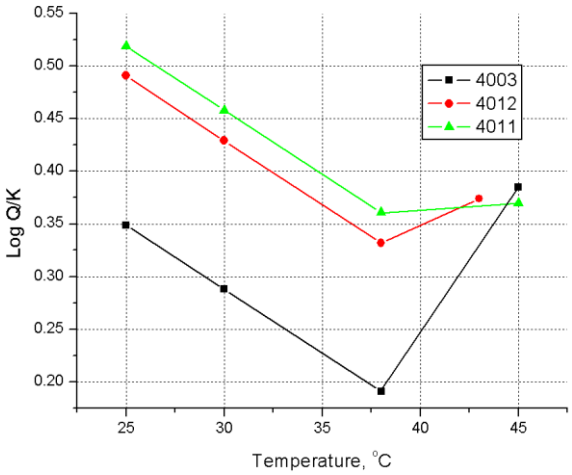

Figure 8: Prediction of saturation state of quartz for selected wells.

3. CONCLUSIONS

The Felix geothermal field from Bihor County, Romania was chosen for the study due to its high exploitation for tourism, recreation and health. By interpreting the results of the laboratory analysis using various geochemical tools, it was concluded the type of waters are calcium-bicarbonate, peripheral to steam-heated waters.

The chemical composition of the waters were also interpreted by using WATCH program, which gives information about the mineral equilibrium and a basis to assess any possible scaling problem. The simulation results indicate the possibility of calcite precipitation for the geothermal water of the well 4003. In such low-enthalpy wells considered for this study, the main scaling problems are due to calcium carbonate precipitation. Considering the predicted results of saturation indexes of quartz, it is assumed that the silica scaling would occur during the production.

The solubility of silica minerals has been shown to be positively related to temperature, specifically chalcedony and quartz geothermometers yielded good results for temperature. Understanding the chemical equilibrium of the water-rock interaction has a key role in application of chemical geothermometers. It is proved that the silica geothermometers were suitable for the studied geothermal systems.

A continuous geochemical approach of the geothermal waters is needed for maintaining a proper well production without drawdown.

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