Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

The Study of Silica Content in Geothermal Waters Function of Temperature

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Keywords: silica- enthalphy model, geothermal water, watch simulation program.

ABSTRACT

Geothermal waters have similar characteristics to their geological formations of origin. The solubility of silica in geothermal waters varies depending on temperature.

In this paper we will determine the SiO_2 content of geothermal fluids from the two geothermal reservoirs outside of Oradea city.

With silica-enthalpy model will estimate the temperatures of depth in geothermal reservoirs, and we will compare with the temperatures of depth, that found it using Watch simulation program.

1. INTRODUCTION

The geothermal wells, that were studied are presented on the map in Figure 1.



Figure 1. The map of the country Bihor.

It is known that silicon is a universal element prevalent in the earth's crust in many combinations. Its solubility in water depends on a number of factors such as what compound it is, content of minerals dissolved in the water, pH, and temperature.

The goal of this work is to investigage the connection between the content of silica in geothermal waters and temperature. Instruments were built to measure the concentration of silicon dioxide and the temperature in the well.

Bödvaesson (1960) used the contents of silica as a relative indicator of the temperature. Later, in 1966, Maleon achieve remarkable success, managing to draw a calibration curve of quartz solubility with temperature.

The results of Maleon, led to the determination of temperature by deep waters in New Zealand. Orey determined the silica concentration in waters of Yellowstone National Park (USA) colorimetrically and compared the data with the solubility curve of SiO_2.

Studying the graph in the Figure 2, which shows the solubility of amorphous silica, cristobalite, chalcedony and quartz in water under vapor pressure, we note that amorphous silica begins to dissolve at 0°C, and the solubility increases with temperature.

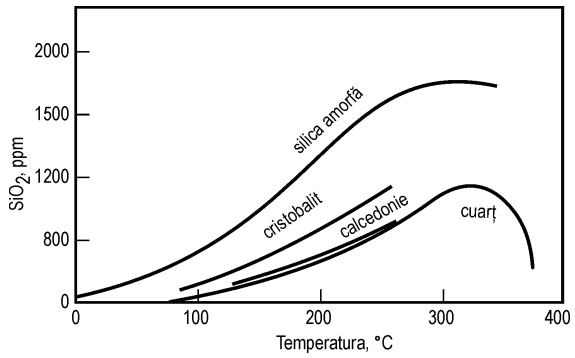

Figure 2. Solubility curves for amorphous silica, cristobalite, chalcedony, and quartz.

The content of SiO_2 in geothermal waters from wells 4797 and 4767 in Oradea were measured.

Silica content in geothermal waters were used as an indicator of temperature.

Thus, by using the silica-enthalpy model the temperatures in geothermal reservoirs were estimated. The values obtained were compared with the values for temperatures with depth, estimated using Watch software.

2. EXPERIMENTAL DATA

Flowrate, depth of drilling and drilling temperature data were provided by the hydrogeological research carried out in drillings from Oradea, correlated with the results of geological research undertaken in bordering areas (Vasilescu and Nechiti 1968, Istocescuab 1970, Bleahu et al. 1971, Mihăilă 1971, Michael 1972, Tenu 1981, COHUT 1986, Veliciu 1987, Miklos 2000). It was shown that the geological composition of Oradea area includes formations belonging to the Quaternary, Neogene, Cretaceous, Jurassic and Triassic periods. The basement consists of metamorphites.

Geothermal waters from the studied geothermal wells were analyzed using standard analytical methods. The results are presented in Tables 1 and 2.

Table 1: Content of silica in geothermal waters of the Oradea.

Source	Flow [l/s]	Depth [m]	Temperature drilling ^oC	Quantity SiO_2 [mg/l]
4797 Oradea	26	2800	103	82
4767 Oradea	8	3200	72	116

Table 2: Chemical composition of geothermal waters from the Oradea.

Well	4797 Oradea	4767 Oradea
PH	7,1	7,33
CO_2 [mg/l]	114,8	180,6
SiO_2	82	116
Na^+	17.3	33
K^+	12,7	10
Ca^{2+}	254,5	260,3
Mg^{2+}	60,9	19,2
SO_4^{2-}	744	250
HCO_3^{2-}	224	310
Cl^-	12,5	31,9
TSD	1118	913

Watch software can be used to interpret the chemical composition of the geothermal fluids and predict the behavior of the geothermal fluid under different conditions (at temperature of the reservoir and at lower temperatures that occur in the distribution system with geothermal water).

Reference temperatures can be chosen as the water temperature measured in the well or the value determined via chalcedony, quartz, or Na-K geothermometry.

Geothermometry using the Watch simulation program assumes that the geothermal fluid and minerals in reservoir rocks are at equilibrium. The chemical composition of the geothermal fluid can then be used to predict the temperature of the geothermal reservoir.

Calculation of geothermal reservoir temperatures with depth was performed using the Watch program (Bjarnason 1994). This program can be used for quartz geothermometry (Fournier and Potter 1982), for chalcedony geothermometry (Fournier 1977) and for Na / K geothermometry (Arnorsson et al., 1983). The results are shown in Table 3.

Table 3: Temperatures calculated with geothermometry

Well	T (quartz) °C	T (chalcedony) °C	T(Na/K) °C
4797 Oradea	96,5	106,0	59,2
4767 Oradea	131,5	85,6	48,9

The temperature calculated by quartz geothermometry for well 4767 Oradea (Iosia) is very close to the production temperature and the temperature calculated by chalcedony geothermometry for well Oradea 4797 (Nufarul) is close to the drilling temperature of geothermal fluids.

On the basis of silica content in geothermal waters studied and the surface temperature, the enthalpy of geothermal fluids was measured. The results are presented in Table 4.

Table 4: Temperatures, enthalpy of surface and concentration SiO2, for wells from Oradea.

Well	SiO_2 (mg/l)	Temperature to surface,°C	Enthalpy [kj/kg]
4797 Oradea	82	103	432.6
4767 Oradea	116	72	302.4
Cold water	20	10	42

The simplest method of determining the temperature of the water with depth in the geothermal reservoir is the graphical representation of the concentration of silica based on the enthalpy for the geothermal liquid.

Although temperature is a quantity that can be measured and the enthalpy is a property derived obtained from thermodynamic tables (Keenan et al., 1969) depending of the temperature, the Silica - Enthalpy model is preferred.

The silica-enthalpy model for the studied wells in Oradea are presented in Figures 3 and 4.

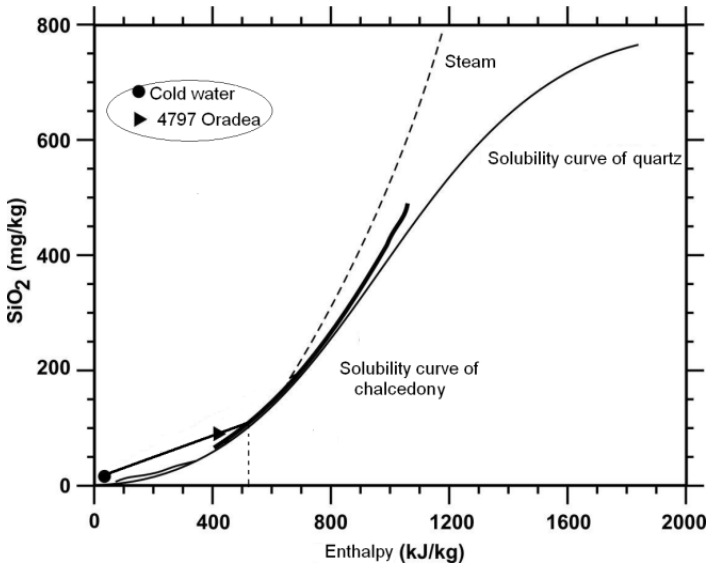

Figure 3: Diagram of dissolved silica-enthalpy for drilling 4797 Oradea.

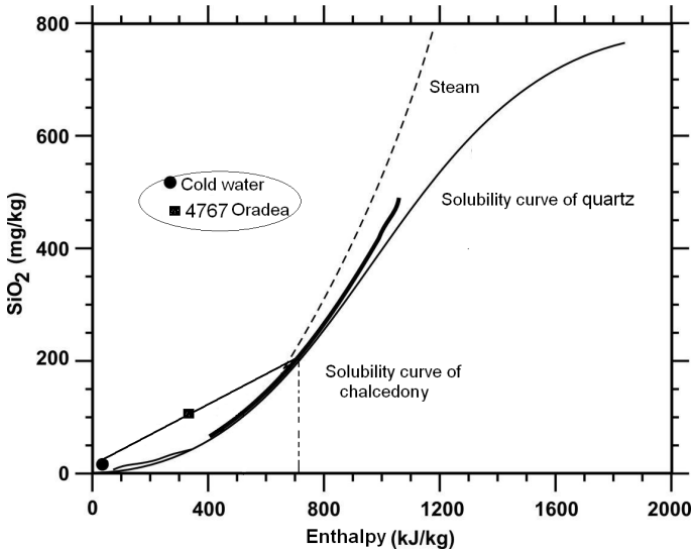

Figure 4. Diagram of dissolved silica-enthalpy for drilling 4767 Oradea

2.1 Results and discussion

Temperatures in the geothermal reservoirs calculated using the silica-enthalpy model for studied wells are shown in Table 5.

Table 5.Temperatures resulted by silica-enthalpy model calculations.

Well	SiO_2 (mg/l)	Enthalpy in reservoir, [kj/kg]	Hot water temperature in reservoir, °C
4797 Oradea	82	520,2	123,9
4767 Oradea	116	709,5	168,9
Cold water	20	42	10

Analyzing the values obtained with the silica - enthalpy model for temperatures of geothermal fluids in the interiors of reservoirs , it was found that they result in significantly higher values than those measured at the surface.

Therefore, it is assumed that mixing occurs geothermal hot water with cold water in the upper region, causing the cooling of the surface geothermal water surface.

For well 4797 Oradea, using silica - enthalpy model resulted in a temperature of 123.9 ° C (Figure 3), Which could lead us to the conclusion that higher temperature geothermal water is mixing with cold water.

At well 4767 Oradea, the temperature in reservoir calculated using quartz geothermometry is 131.5˚C. On route to the surface, this geothermal water is cooled due to mixing with cold water or contact with rocks of lower temperature.

The temperature of the geothermal source with hot water calculated using the Silica - Enthalpy model (Figure 4.) is about 168.9°C.

2.2 Conclusions

The temperatures of geothermal reservoirs were estimated using Watch software. We established that temperature calculated by chalcedony geothermometry is very close to the temperature measured at the outlet of the well for geothermal waters studied.

Therefore, this type of geothermometry can be used to estimate the temperature in the depth in the geothermal reservoirs. Also, the average water temperature is indicated using chalcedony geothermometry .

The temperatures of geothermal reservoirs were were also calculated using the silica-enthalpy model, which is based on the graphical representation of the concentration of silica based on the enthalpy of the liquid.

For all the wells in the study it was found that the temperature of the geothermal water in the tank is higher than at the wellhead. This is explained by mixing with cold water in upper layers and by the contact with rocks..

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