Interpretation of geochemical data from wells in the western geothermal field of Romania

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Abstract

The western geothermal field of Romania is a low temperature geothermal area. In this paper data from four production wells are presented. The chemical composition of these waters was analysed by standard methods and subsequently classified by the use of the Cl-SO_4-HCO_3 triangular diagram. Another basic diagram, Na-K-Mg, was used to classify waters according to the state of equilibrium at given temperatures. The geothermal waters are bicarbonated-sodium-chloride type. Chemical geothermometers were used to predict subsurface temperature. The calculated quartz geothermometer values for the geothermal well waters indicate reservoir temperatures higher than values for chalcedony geothermometers and Na/K geothermometer values are very different. The silica-enthalpy mixing model was used to try to define the source temperature of the hot water component. The results could be an evidence of mixing with cold waters in all the fields taken for study. The WATCH program was used to interpret the equilibrium state of the reservoirs and to predict scaling tendencies. The saturation index for calcite exceeds 1, which indicates that $CaCO_3$ scaling problems will occur.

Keywords: *reservoir temperature, western Romania, scaling potential.*

1 Introduction

In the present study, the chemical characteristics of geothermal waters from four wells in three geothermal fields in western Romania are described. The main emphasis is on estimating the scaling potential of the water as well as temperature of the respective reservoirs. Due to the importance of the geothermal water, it is necessary to know its chemical characteristics in order to enable the most economic way of utilizing it.

The geothermal fields of Bors, Ciumeghiu and Sacuieni are situated in the vicinity of the town of Oradea in western Romania.

- The Bors geothermal field is situated some 6 km to the northwest of Oradea. It has a surface area of 12 km^2 and the reservoir is limited or closed. Water from wells Bors-529 and Bors-4155 is used for the present study.
- The Ciumeghiu geothermal field is located south to Oradea. The reservoir consists of gritstone at an average depth of 2200 m. For the present study water from well Ciumeghiu-4668 is used.
- The Sacuieni geothermal field is located to the north of Oradea. It has seven exploration wells and four of them are production wells as well. Only well Sacuieni-4058 has been producing lately and is used for this study.

2 Characterization of geothermal waters

The analytical methods used for the determination of the main constituents of the geothermal water samples are presented in Table 1. The results of the laboratory analysis are summarized in Table 2 (Stănăşel, 2002).

For an initial classification, in terms of the major anions Cl, SO_4, and HCO_3, a triangular diagram (Giggenbach, 1991) was used.

Table 1: Methods of chemical analysis.

Constituent	Methodology	Constituent	Methodology
pH	Glass electrode pH meter	H_2S	Titration with $Hg(CH_3COO)_2$; dithizone as indicator
SiO_2	UV/VIS silico-molybdate complex	Fe	Spectrophotometric determination at λ=510 nm, using o-phenantroline
B	Spectrophotometry at 420 nm; azomethine H/ ascorbic acid reagent added	F	pH millivoltmeter and selective electrode
Na K	Flamephotometric determination λ=589; 767 nm	Cl	Titration with $AgNO_3$; K_2CrO_4 as indicator
Ca Mg	Titration with EDTA	SO_4	Titration with $Ba(ClO_4)_2$; Thorin as indicator
CO_2	Electrometric titration	TDS	Gravimetric

Table 2: Chemical Composition of Geothermal Waters, in mg/l.

Component	529	4155	4668	4058
Measured temp.of water	90	119	84	84
pH	7	7.5	7.9	8.1
CO_2	1068	1520	2045	2122
H_2S			0.7	
B	49	79.2	98.2	78.9
SiO_2	127	120.5	181	62.9
Na	4230	5200	2250	1610
K	385	218	33	21.3
Mg	13.2	25	4.5	4.1
Ca	122	130.2	45.6	13.2
F			0.7	
Cl	6320	7198	1902	911
SO_4	115	140	47	5.9
Fe	9.6	5.2	0.14	0.25
TDS	11210	12200	6574	11647

On the triangular diagram Cl-SO_4-HCO_3 (Figure 1,a) waters from Bors plot near to the chloride corner and in the field of mature geothermal waters. The waters from Ciumeghiu, well 4668 and from Sacuieni, well 4058 as shown by the ternary diagram, are peripheral geothermal waters. The bicarbonate content of waters from Sacuieni is high.

The Na-K-Mg triangular diagram clarifies better the origin of the waters as shown on (Figure 1,b). According to the diagram the samples from Bors geothermal field are only partly equilibrated, whereas samples from Ciumeghiu and Sacuieni are close to equilibration. Partial equilibration may be due to reactions with wall rock during upflow from the reservoir or could result from mixing of waters of different compositions. The water from Ciumeghiu, well 4668 appears to be well equilibrated at temperatures of 100-110°C according to the Na-K-Mg ternary plots of Giggenbach (1988).

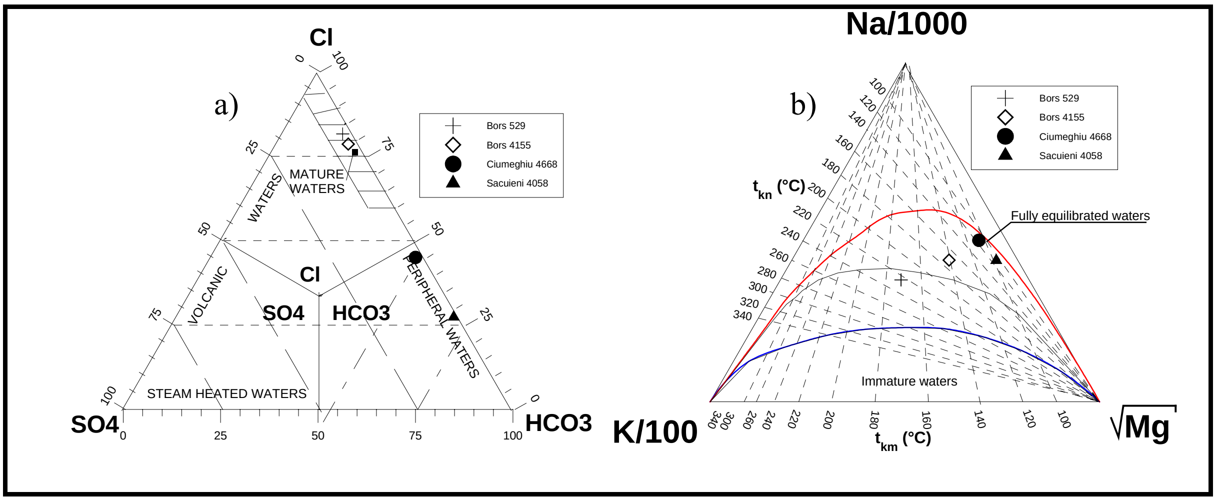


Figure 1: Classification of geotermal waters according to (a) Cl-SO4-HCO3 ternary diagram (a) and to (b) Na-K-Mg equilibrium diagram.

Geothermal waters from Bors are classified as sodium-chloride and medium bicarbonated waters, waters from Ciumeghiu are bicarbonated-sodium-chloride waters and geothermal waters from Sacuieni are bicarbonated-sodium water with a medium chloride content. These waters are partially equilibrated according to Giggenbach and Arnorsson diagrams.

3 Estimating the deep water temperature

The wellhead temperatures measured during sampling were: 90ºC at Bors-529, 119ºC at Bors-4155, 84ºC at Ciumeghiu and 84ºC at Sacuieni-4058. The ionic balances (Table 3) for the samples calculated by the Watch program (Bjarnason, 1994) gave values ranging from –3.93 -+0.69, which are acceptable and the data could be used for the interpretation. The temperatures resulting from geothermometers, which were calculated by the Watch program are presented in Table 3.

Table 3: Data resulted by Watch program calculations.

Well	Wellhead temperature,ºC	Ionic balance	Chemical geothermometers,ºC		
			Quartz	Chalc.	Na/K
Bors-529	90	-0.03	148.5	122.9	189.4
Bors-4155	119	0.69	142.0	115.7	117.9
Cium-4668	84	0.35	161.6	137.5	57.1
Sac-4058	84	-3.93	108.3	78.5	52.9

The reservoirs temperatures indicated by the calculated chalcedony geothermometer are closer to the production temperatures of the waters than the values given by the other geothermometers. At Sacuieni-4058 the calculated temperature based on the chalcedony geothermometer almost correspond to the wellhead temperature.

In order to estimate the reservoir temperature the silica enthalpy mixing model (Truesdell and Fournier, 1977) was also used for comparision and further classification. The cold water point is assumed to represent the hypothetical cold water (temperature: 10ºC and SiO_2 20ppm) in the study area. The intersection point with the solubility curve for chalcedony gives the silica content and the enthalpy of the deep hot water component and its temperature is obtained from steam tables.

Based on the silica-enthalpy mixing model a reservoir temperature of 180ºC for well Bors-529 and 145ºC for well Bors-4155 was obtained. This temperature is higher than the reservoir temperatures obtained by the geothermometers (Table 3), indicating probable mixing in the upflow zones. These two wells are situated close to each other and there might be some mixing of deep water in the reservoir.

The temperature of the geothermal reservoir at Ciumeghiu (Figure 3,b) was found to be 175ºC assuming a steam loss before mixing, and about 160ºC if there is no steam loss. The wellhead temperature is lower probably due to mixing with cold water during infiltration.

At Sacuieni-4058 the temperature calculated for the hot water by mixing model is 104°C. The plot is very close to the solubility curve of chalcedony. The difference is assumed to be due to the contact of the hot water with the rocks.

For all the studied wells the source temperature of the hot water component is higher than the measured wellhead temperature. The difference in temperature is due to mixing with cold water in the upper layers or only due to contact by the cold rocks. When the temperature calculated by the chalcedony geothermometer and by the mixing model is close to the temperature measured at the wellhead (as for well Sacuieni-4058) the wellhead temperature has kept the same value in time (Stănăşel, 2002).

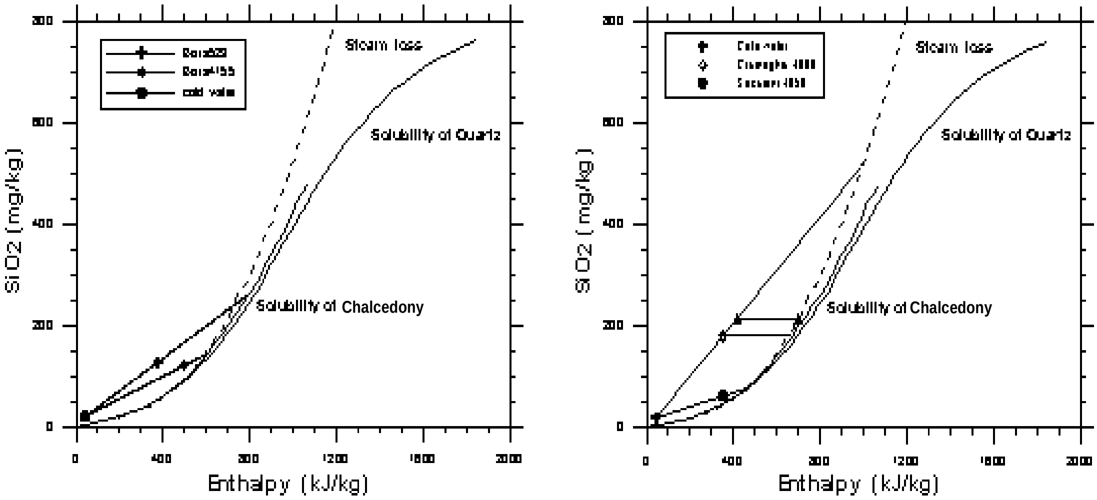
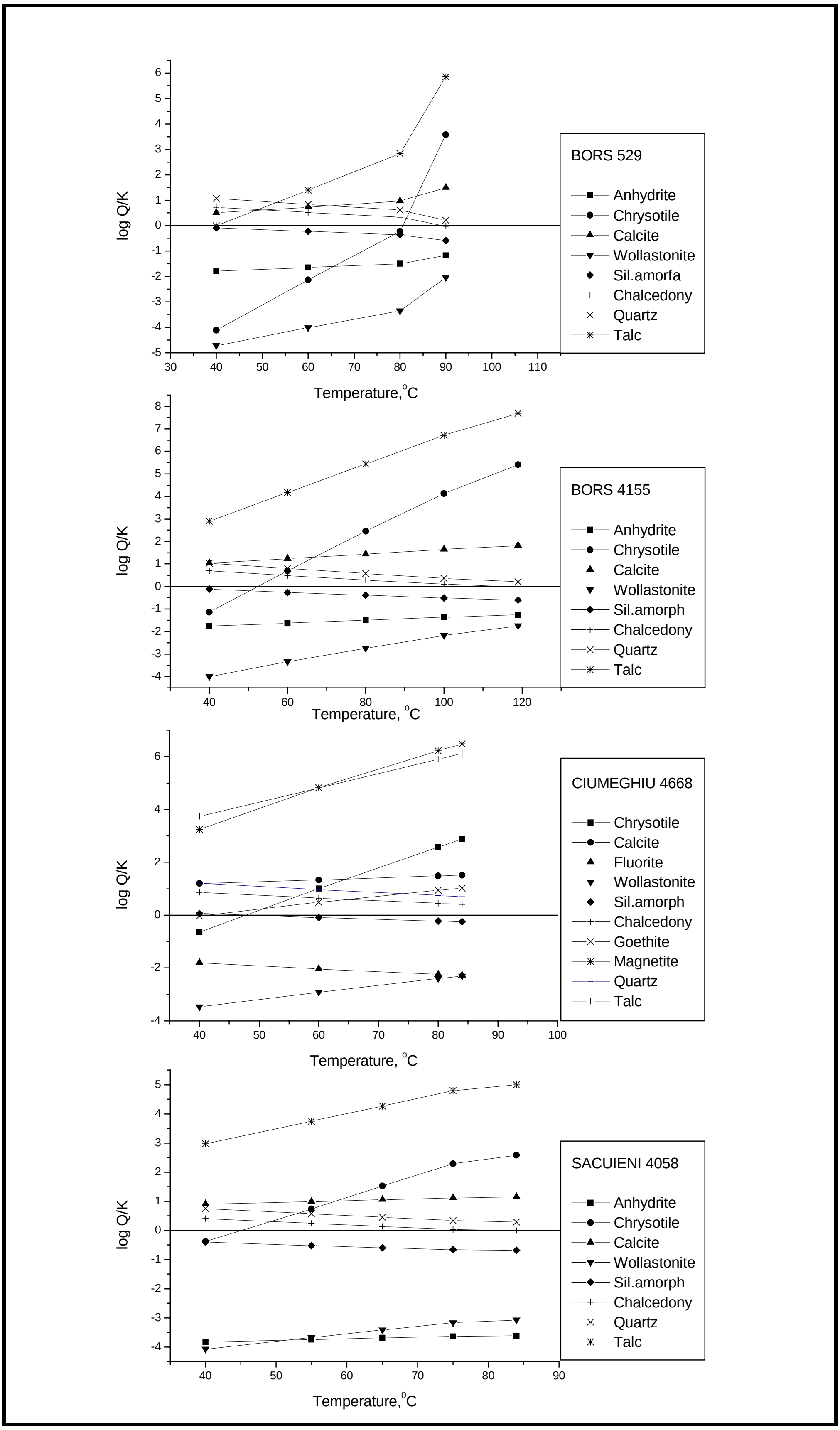


Figure 2: Dissolved silica-enthalpy diagrams, (a)-(b).

4 Scaling prediction

The potential scaling problems when utilizing geothermal water depends on the type of water as well as the temperature and the changes the water undergoes in the installations. Therefore, a reliable analysis of the water and a simulation of the changes occuring during the utilization are needed to predict possible scaling. In this paper the WATCH program was used to calculate the concentrations of resulting species, activity products and solubility products when the equilibrated fluid is allowed to cool conductively from the reference temperature to some lower temperatures. The scaling potential is estimated by calculating logQ/K, where Q means the ionic activity corresponding to different minerals in the brine and K the theoretical solubility of the respective minerals. Figure 3 presents the mineral equilibrium diagrams for the selected wells.

Figure 3: Log Q/K vs. temperature for selected geothermal waters.



At wellhead temperature, the water from well Bors-529 is supersaturated with respect to chrysotile and talc, and quartz is close to saturation. Calcite is supersaturated at all temperatures. Amorphous silica, anhydrite and wollastonite have negative saturation indexes and can not possibly precipitate. The system is in equilibrium with chalcedony at the wellhead temperature

The diagram for Bors 4155 shows that logQ/K for calcite exceeds 1 at the wellhead temperature, which is considered to be very dangerous with respect to scaling. Anhydrite, amorphous silica, and wollastonite are undersaturated and there is an equilibrium with chalcedony at the measured temperature. Quartz is slightly supersaturated at the wellhead temperature. Chalcedony and quartz become supersaturated at lower temperatures. A potential chrysotile scaling could be expected. Talc is supersaturated, but this does not create problems.

At Ciumeghiu, the precipitation of calcite seems to be inevitable at the wellhead temperature and at lower temperatures. Chrysotile, goethite, quartz, chalcedony and magnetite are also supersaturated at the measured temperature, but at low temperatures chrysotile and goethite become undersaturated.

The diagram for Sacuieni 4058 shows that anhydrite, amorphous silica and wollastonite are undersaturated. The equilibrium temperature for chalcedony is very close to the measured temperature. The water is close to saturation with quartz and it is saturated with chrysotile and talc at the wellhead temperature. Calcite is supersaturated at 84ºC. If the temperature of geothermal water were to decrease calcite would still remain supersaturated and chrysotile become undersaturated; chalcedony and quartz lie close to the saturation line.

5 Conclusions

The geothermal waters from the studied area could by geochemical studies be classified as sodium-chloride-bicarbonated waters with a high mineralisation, that reaches maximum for the wells from Bors.

Considering the major anions, the waters from Bors are classified as mature waters, whereas those from Ciumeghiu and Sacuieni are classified as peripheral. Taking into account the major cations the geothermal waters are classified as partially equilibrated, with the Ciumeghiu and Sacuieni waters falling near to Giggenbach's (1988) line for fully equilibrated waters and the water from Bors is almost equilibrated after Arnorsson's (1991) line.

The chalcedony geothermometer gives the best values at low temperature as compared to the quartz and Na/K geothermometers. The dissolved silica-enthalpy diagrams for determining the temperatures of hot water components mixed with cold water, indicate higher temperatures than the results given by the chalcedony geothermometer, which indicates a mixing of the hot water from the reservoir with the infiltrated cold water in the upper layers.

Knowing the chemical composition one can estimate the scaling potential during geothermal utilization by computer simulation. The results can be used to make changes in the production cycle. In this way it is possible to interfere to prevent the scale before it occurs.

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