PROCEEDINGS, Twenty-Fourth Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, January 25-27, 1999
SGP-TR-162

STUDIES ABOUT DEPOSITIONS THAT COULD APPEAR AT GEOTHERMAL WATER UTILIZATION

Oana Stanasel, Ludovic Gilau

University of Oradea, Romania

ABSTRACT

This paper presents the research made on the composition and structure of depositions at geothermal water utilization for heating.

First the chemical composition of geothermal water from a well was determined. Then the depositions which appear at geothermal water utilization were analysed by X-Ray method, being possible to establish the structure of these depositions.

Using a computer program, the influence of temperature on the structural and mineralogical composition of depositions was studied.

INTRODUCTION

Geothermal energy is used in many parts of the world, not only for space and process heat for residential, commercial and industrial uses, but also for electricity generation.

Thermal energy for space heating and other purposes throughout a city costs one-half that of a fossil fuel-fired heating system, a large portion of this cost being due to the distribution system.

Geothermal energy has the advantaje over other available domestic resources that is an unpolluted resource.

Using geothermal water, due to temperature decrease, depositions could appear. The composition and the mineralogical structure of these depositions depend on the chemical composition of geothermal water, the temperature of water and the composition of the distribution system material. In the same time with the scaling process could take place corrosion processes.

In order of using geothermal waters in good conditions it is necessary to know their chemical composition and the processes which could take part depending on the temperature. Therefore the purpose of the research work was to establish a relation between the chemical composition, the temperature and the type of depositions which could appear when they use geothermal water from Seltjarnarnes, Iceland.

1. STUDIES ABOUT THE CHEMICAL COMPOSITION OF GEOTHERMAL WATERS

Geothermal water was sampled and analysed by the following analytical procedures:

- total carbonate was determined by electrometric titration
- hydrogen sulphide was determined by titration using dithizone
- oxygen - colorimetric analysis
- boron - spectrophotometric determination using azomethine method; absorption was determined at 420 nm
- silica - spectrophotometric determination (λ = 410 nm)
- sodium, potassium, magnesium, calcium - atomic absorption spectroscopy, direct aspiration analysis; absorption was read at 589,6 nm; 766,5 nm; 285,2 nm and 422,7 nm
- aluminium - atomic absorption spectroscopy, graphite furnace analysis
- fluoride - selective electrode
- chloride, sulphate - ion-chromatography
- total dissolved solids - gravimetric analysis.

The analytical results are shown in table 1.

The chemical data show that Cl^-, Na^+, Ca^{2+} and SO_4^{2-} are in high concentrations. The water salinity is determined as main by the infiltration of seawater into the geothermal system.

Table 1. Chemical composition of geothermal water from Seltjarnarnes, Iceland, at the wellhead temperature 112,8^{0}C and at pH=8,49 (measured at 24,6^{0}C).

Component	Determined value
CO_2	10.9 mg/l
H_2S	0.04 mg/l
O_2	5 ppb
B^{3+}	0.23 mg/l
SiO_2	106 mg/l
Na^+	604.6 mg/l
K^+	14.41 mg/l
Mg^{2+}	0.51 mg/l
Ca^{2+}	481.9 mg/l
Al^{3+}	0.023 mg/l
F^-	0.642 mg/l
Cl^-	1581 mg/l
SO_4^{2-}	278 mg/l
TDS	3550 mg/l
cations	0.04957 mol/eq.
anions	0.04961 mol/eq.
difference	- 0.08 %

2. STUDIES ABOUT THE TEMPERATURE INFLUENCE OVER THE STRUCTURAL AND MINERALOGICAL COMPOSITION OF DEPOSITIONS

The decrease in temperature of geothermal water parallels the solubility in the system, that means a supersaturation, resulting scale depositions.
To predict the potential danger of scaling and corrosion, WATCH computer program is used. This program is commonly used for interpreting the chemical composition of geothermal fluids.

The WATCH program can be used to compute the concentrations of resulting species, activity coefficients, activity products and solubility products when the equilibrated fluid is allowed to cool conductively or by adiabatic boiling from the reference temperature to some lower temperatures. This is particularly useful in the study of scaling.

Using the WATCH program the log solubility index for different minerals was calculated. A positive value for the relative log solubility (logQ/K) of a mineral means that the solution is supersaturated with respect to that particular mineral and theoretically it would start to precipitate.

Based on data from table 1 the WATCH program was used to calculate the log solubilities for the minerals which could start to precipitate, assuming a conductive cooling in 4 steps of 20^{0}C. The results are presented in table 2.

The results which are summarized in table 2 were prelucrated by using of the GRAPHER program, so being possible to establish the saturation index (logQ/K) for many minerals at different temperatures. Figure 1 shows the dependence of saturation index on the temperature for different minerals.

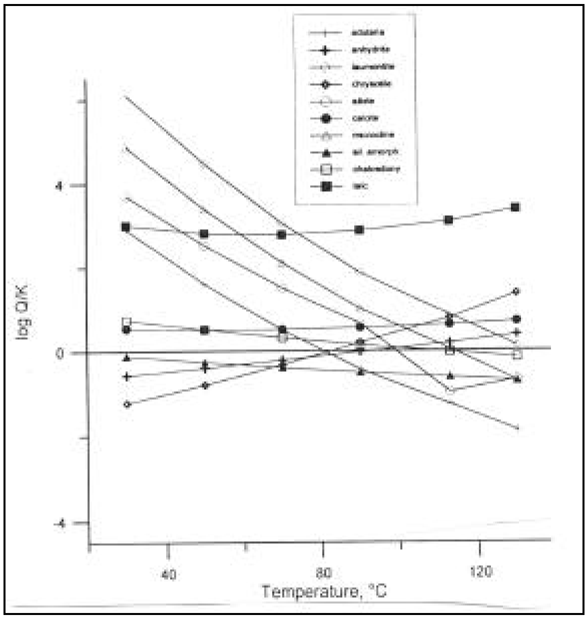

Figure 1. LogQ/K vs. temperature for selected geothermal water from Seltjarnarnes, Iceland

The diagrams are scattered and intersect mostly between 80 -110^{0}C. This can be interpreted by an increased importance of the colder 80^{0}C aquifers in the production water. At the measured temperature the minerals are undersaturated, saturated or near the saturation line. There are no scaling problems Only talc is supersaturated, but this does not create problems. Minerals are in equilibrium at different temperatures in the interval 80-120^{0}C. By cooling under 80^{0}C the supersaturation increases and could start to form depositions of: laumontite, microcline, albite and adularia.

Table 2. Log solubilities theoretic and calculated (logK, logQ) for the minerals which could form scale depositions by cooling the geothermal water at different temperatures.

112.8^{0}C		90^{0}C		70^{0}C		50^{0}C		30^{0}C	
logK	logQ	logK	logQ	logK	logQ	logK	logQ	logK	logQ
Adularia									
-16.819	-18.077	-17.632	-18.067	-18.565	-18.058	-19.664	-18.050	-20.950	-18.042
Anhydrite									
-5.762	-5.576	-5.467	-5.488	-5.205	-5.417	-4.966	-5.360	-4.757	-5.317
Laumontite									
-26.702	-25.840	-27.678	-25.806	-28.831	-25.776	-30.213	-25.751	-31.845	-25.732
Chrysotile									
22.788	23.571	24.496	24.693	26.360	26.042	28.483	27.696	30.911	29.698
Albite									
-16.117	-16.214	-16.859	-16.204	-17.711	-16.195	-18.715	-16.187	-19.889	-16.181
Calcite									
-9.629	-9.007	-9.272	-8.716	-8.971	-8.454	-8.720	-8.208	-8.528	-7.979
Microcline									
-18.121	-18.077	-19.081	-18.067	-20.171	-18.058	-21.446	-18.050	-22.925	-18.042
Sil. amorph.									
-2.163	-2.777	-2.272	-2.778	-2.389	-2.778	-2.521	-2.778	-2.670	-2.778
Chalcedony									
-2.758	-2.777	-2.922	-2.778	-3.099	-2.778	-3.297	-2.778	-3.522	-2.778
Talc									
14.935	18.017	16.269	19.138	17.709	20.486	19.326	22.139	21.138	24.142

3. STUDIES ABOUT SOLID DEPOSITIONS

A thermowell which had been within the pipeline for about two years, acted as a corrosion / scaling monitoring device, was removed. This thermowell was consequently inspected and analysed.

First it was analysed by microscope. The tube was covered by deposition and was also somewhat corroded. It was of a brown colour, which, when appearing indicated that corrosion had started. A few crystals of white coloured deposited minerals could be observed. Depositions of metalic colour could be also seen. Microscopic identification was difficult, because the mineral was alterated. The result of this inspection was that some scaling and corrosion were present on the tube.

After this preliminary inspection the tube was analyse by X-Ray diffraction, giving information about the existence of crystals in a solid sample. The XRD study was made using K_αCu radiations. The diagram obtained, figure 2, shows that there are magnetite crystals in the sample.

After this the elements in the solid sample were analysed by X-Ray fluorescence. A qualitative analysis was made to determine which elements were present in a specimen and also an analysis to gain a semiquantitative appraisal of their concentration. The XRF diagram is shown in figure 3.

The XRF diagram, figure 3a showed the presence of Si in a big amount and Fe. The XRF diagram, figure 3b indicated the presence of Fe, Cr, Ca, Ti, Cu and Zn. The presence of Fe, Cr, Ti, Cu, Zn in depositions means that there are corrosion processes of the pipe. The other elements are from geothermal water.

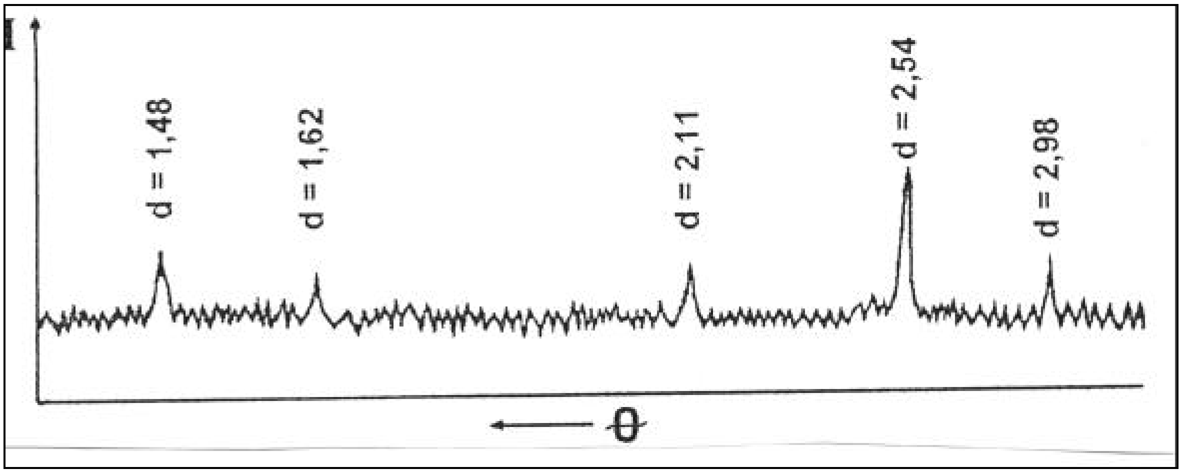

Figure 2. The XRD diagram for depositions.

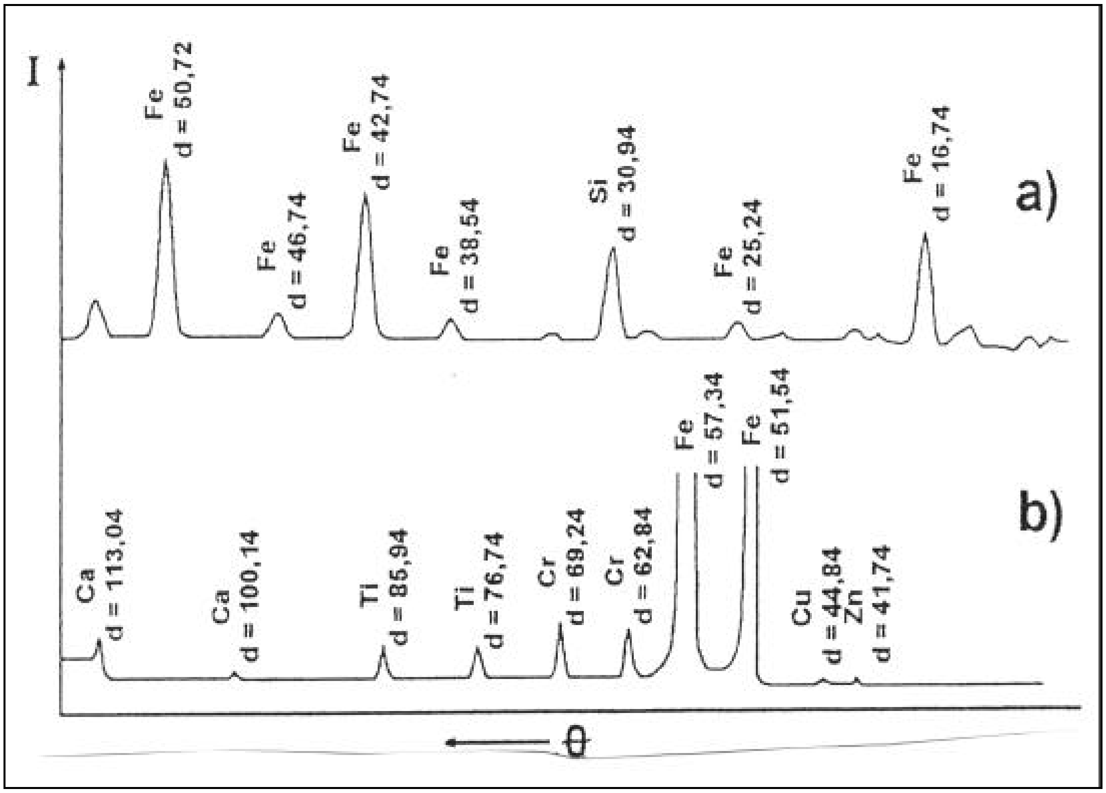

Figure 3. The XRF diagram.a) mixture with HOOC-C6H4-COOK. b) mixture with LiF.

At the wellhead temperature the amorphous depositions are probably formed by complex silicates, calcium carbonate and metals sulphide in small amounts and the crystaline phase is magnetite, a corrosion product.

CONCLUSIONS

The geothermal waters have a complex chemical composition, which depends on the aquifer.

The chemical composition was interpreted by using the WATCH program that calculates the saturation index for many different minerals, establishing the minerals which would form depositions by cooling the geothermal water.

The structural analysis of depositions show that at the wellhead temperature the depositions are formed by an amorphous phase (complex silicates, carbonates and metals sulphide) and a crystaline phase (magnetite). The depositions result from geothermal water and from the corrosion process of the distribution system.

REFERENCES

1. Azaroff, L.V., Buerger, M.J.: *The powder method in X-ray crystallography*, Mc Grew-Hill Book Company, New York, 1958, p. 342.

2. Becherescu, D., Cristea, V., Marx, Fr., Menessy, I., Winter, Fr.: *Metode fizice in chimia silicatilor*, Ed. Stiintifica si Enciclopedica, Bucuresti, 1977, p. 124.

3. Bjarnason, J.O.: *The speciation program WATCH, version 2.1*. Orkustofnun, Reykjavik, 1994, 7pp.

4. Trujillo, P.E., Counce, D., Grigsby, C.O., Goff, F. and Shevenell, l.: *Chemical analysis and sampling techniques for geothermal fluids and gases at the Fenton Hill Laboratory*, Los Alamos National Laboratory, New Mexico, report LA-11006-MS, 84 pp.

5. ****Mineral Powder Diffraction File. Data book.* International Centre for Diffraction Data 1601 Park Lane. Swarthmore, PA 19081, USA, 1986.