Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Origin and Potential of Geothermal Systems in Vojvodina

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Keywords: scale, geothermometers, utilization

ABSTRACT

This paper presents a set of water geochemistry data for a better understanding of the origin, circulation of fluids, chemical evaluation, and potential of systems in Vojvodina.

The chemical studies have been undertaken for knowledge of the potential resources, optimum development conditions, and possible problems caused by scaling or corrosion processes.

The chemical compositions of geothermal waters have been used to obtain information on the original reservoir temperatures. The reservoir temperatures were obtained using empirical geothermometers.

Some examples of geothermal energy utilization are presented.

1. INTRODUCTION

Thermal waters in Vojvodina, commonly, occur mainly in the young sand and sandstone formations and belong to the Panonian basin, extending further, into Middle Europe. The location map is shown in Figure 1. The basin is an oil-bearing province and has been explored extensively. The lowest southeastern part of the basin belongs to the Autonomous Province of Vojvodina, where the exploration for oil, gas and thermal water is done by the NIS-Naftagas Company. In the fifty five years of exploration activities, almost 1,700 wells have been drilled, providing a reliable picture of the distribution of thermal waters and their physical and chemical properties.

The Autonomous Province of Vojvodina, just like the entire Panonian basin, lies in the zone of high geothermal gradients. In this region the growth of crust temperature with the depth (56 ^{o}C/1000 m) is two times higher than the world average (30 ^{o}C/1000 m). Such a high positive anomaly of the geothermal gradient allows the production of hot water from shallow wells conditions. The geothermal conditions of the southeastern part of the Panonian basin are such that it is possible to get thermal water with temperatures that are higher than 150 ^{o}C. This water, however, has not been used due to a high mineral content - over 50 g/l (Basic, et al., 1988).

2. CHEMICAL COMPOSITION OF WATER

The geochemical properties of thermal waters in Vojvodina are given in Table 1 (ions concentrations are given in mg/l) and shown in Figure 2.

Based on the total dissolved solids values (TDS) the 17 sampling sites can be divided into 3 groups:

a. TDS > 10 g/l (Sample TW8);

b. TDS between 3 and 10 g/l (Samples TW3, TW4, TW5, TW6, TW11, TW16);

c. TDS < 3 g/l (Samples TW1, TW2, TW7, TW9, TW10, TW12, TW13, TW14, TW15 and TW17).

Water of group *a* is an alkaline-chloride type. Waters of group *b* belong to the sodium-chloride and sodium-bicarbonate-chloride types. Waters of group *c* are a sodium-bicarbonate type.

2.1 Scale Formation Tendency

The formation of scale is one of the most seriously limiting factors in the use of the geothermal wells of Vojvodina. Scale is most likely to occur due to the changes in temperature, pressure, pH, velocity or mixing of different types of source waters during injection.

Water scale formation tendency was calculated by the computer program VODASS (Sevic, et al., 1994). A model is based on the prediction of scaling tendencies of barium, strontium and calcium sulfate and calcium carbonate as a function of temperature, pressure and pH. Barium, strontium and all modifications of calcium sulfate, as well as $CaCO_3$ scales were found.

Scale tendencies of four selected types of water are shown in Table 2. Water TW1 has a tendency to form gypsum scale. TW4 exhibits no scale formation tendency and is corrosive. TW9 has a tendency to form gypsum scale. TW16 has a tendency to form $BaSO_4$ scale.

3. GEOTHERMOMETRY

A number of chemical geothermometers, such as Fournier, Na/K - Furnier-Truesdel, Na-K-Ca, Na-K-Ca-Mg, Li and K-Mg geothermometer, were applied to estimate the reservoir temperature. The most serious problems with respect to the reliability of any given geothermometer is the failure of equilibrium in low enthalpy systems and the effects of local mixing. Therefore, some chemical geothermometers give different reservoir temperatures than the measured ones.

Downhole temperatures were estimated on the basis of a geothermal gradient of 5.6 ^{o}C/100m. Table 3, also, gives the temperatures obtained with some geothermometric equations applied to the chemical analyses reported in Table 1.

The results of chemical geothermometers show that temperature values cover a wide range, so it is difficult to reach reliable estimates of real temperature. Some of the geothermometers give comparable temperature values, while others give temperatures that are close to the discharge temperatures.

None of the geothermometers give appropriate reservoir temperatures for the thermal fluids TW4, TW5, TW8, TW9 and TW15.

Na-K-Ca geothermometer gives the reservoir temperatures close to the measured values for thermal fluids TW7, TW10, TW11, TW12, TW13, TW14 and TW17.

Na-K geothermometer gives the reservoir temperatures in agreement with the bottom-hole temperatures for the wells TW3, TW13, TW16 and TW 17.

Temperatures calculated by Na-Li geothermometer are in a close agreement with the measured reservoir temperatures for TW2, TW6 and TW 14.

Na-K-Ca-Mg geothermometer gives the appropriate reservoir temperature for the thermal fluid TW1, and K-Mg geothermometer is the appropriate one for fluid TW16.

Geothermometers using silica modification did not give reliable temperatures. The values computed by SiO_2 geothermometers indicated reservoir temperatures lower than values for other geothermometers. During geothermal water ascent it could be diluted with SiO_2 free groundwaters resulting in lower reservoir temperatures obtained by SiO_2 geothermometers

4. UTILIZATION OF GEOTHERMAL ENERGY IN VOJVODINA

A systematic exploration for geothermal waters in Vojvodina started in 1969 by the NIS Naftagas Company. By the end of 2003 this area was covered by 74 hydrothermal wells.

Based on the detailed analysis of the geological possibilities, energy potentials and economic effects for the production of low-enthalpy aquifers in Vojvodina, several possibilities for utilization have been found. (As a starting criterion, low enthalpy systems were taken to be those with surface discharge temperatures less than about 80 ^{o}C.)

The use of geothermal energy in Vojvodina includes: district heating of residential, commercial and industrial buildings, greenhouse and soil heating, swimming pools, farming.

5. CONCLUSIONS

Extensive hydrogeological and chemical studies of Vojvodina thermal fields have been undertaken for different purposes: knowledge of the potential resources, optimum development conditions, structure of the reservoir, problem caused after heat exchange or corrosion processes. This paper summarizes 17 of over 70 thermal wells in Vojvodina.

Geothermal resources presented in this paper are low enthalpy geothermal resources. Discharge temperatures range between 24-81 ^{o}C.

The chemistry of these wells indicates that there are three basic types of water: sodium-chloride, sodium-chloride-bicarbonate and sodium-bicarbonate. The geothermal fluids display TDS between 0.428 and 13.270 g/l.

Reservoir temperatures obtained by geothermometers cover a wide range. Some of the geothermometers give comparable temperature values and some are close to the discharge temperatures, reflecting complex mixing and circulation.

The use of geothermal energy in Vojvodina includes: district heating of residential, commercial and industrial buildings, greenhouse and soil heating, swimming pools, farming.

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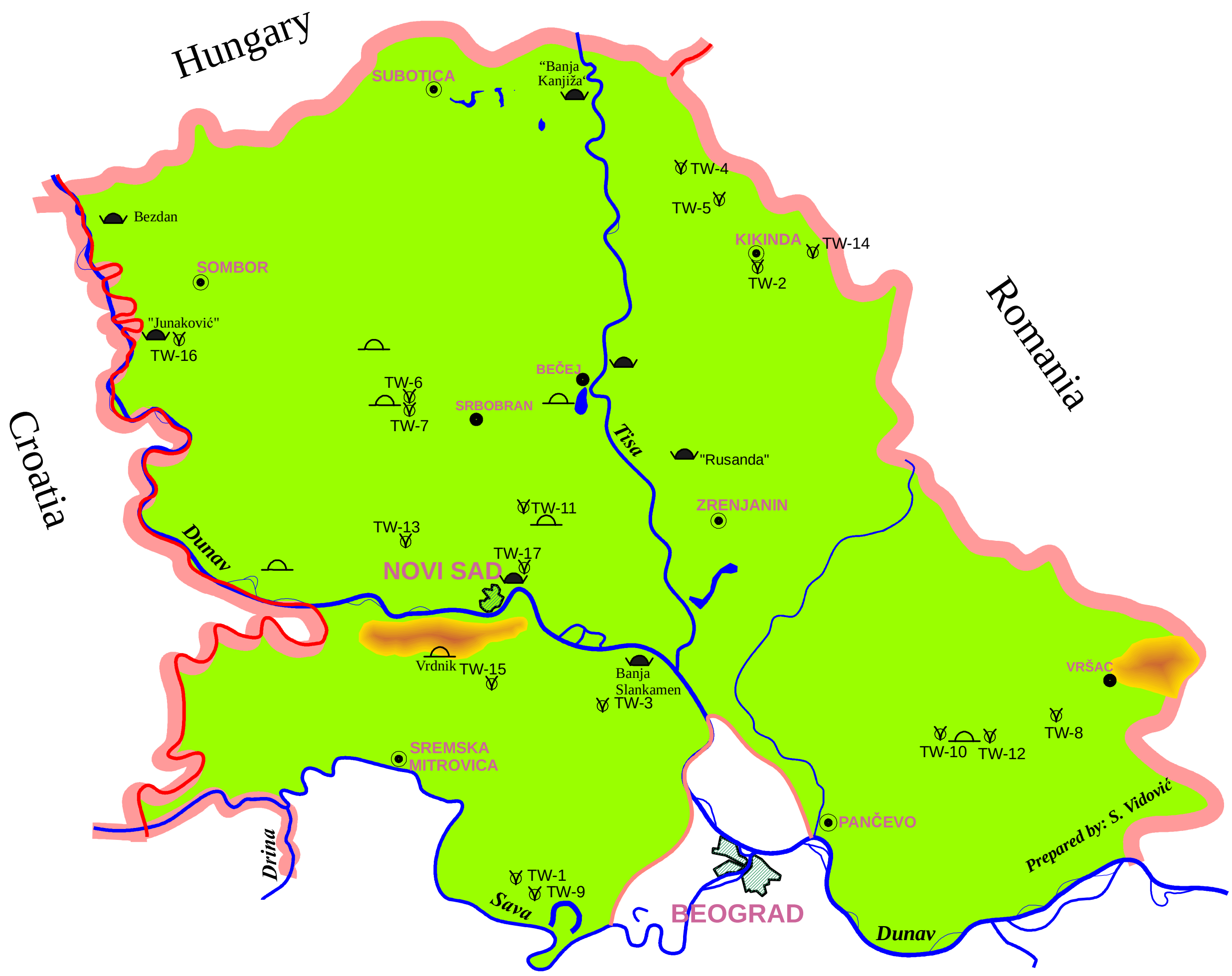
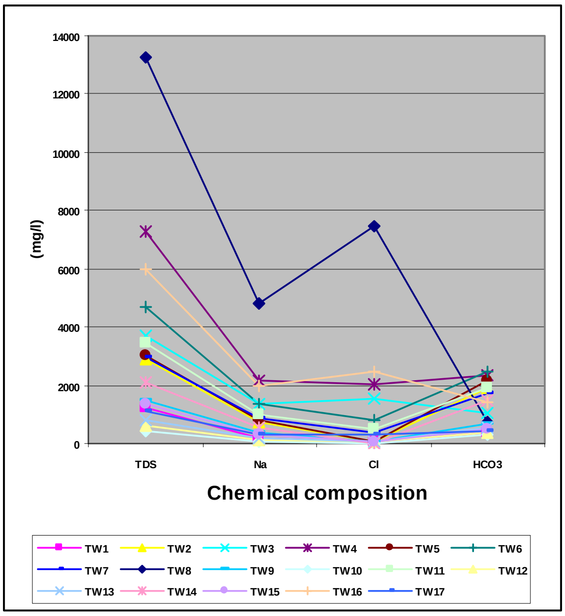


Figure 1 - Location map

Table 1 - Physical and chemical properties of waters studied

No	Sample	t (°C)	pH	TDS	Li	Na	K	Ca	Mg	Cl	SiO_2	HCO_3
1	TW1	50	7.3	1.229	0.40	170	7	15	14	53		370
2	TW2	51	7.9	2.926	0.03	750	6.8	5	4.25	39	0.6	1922
3	TW3	55	7.9	3.780	0.40	1330	27	6	9	1525		1037
4	TW4	81	7.8	7.270	0.47	2140	32	16	8.87	2056		2332
5	TW5	51	7.8	3.048	0.02	800	5.5	9	10.5	40	4.8	2162.5
6	TW6	39	7.7	4.670	0.10	1343	7	28	37	816		2440
7	TW7	55	7.9	2.941	0.15	865	6.1	2	5.62	355	3	1708
8	TW8	68	7.0	13.27	0.50	4840	59	158	25.62	7447		732
9	TW9	45	7.0	1.471	0.45	356	12	50	10	78		671
10	TW10	24	8.0	0.428	0.02	91	1.8	12	6.25	7.09	6	305
11	TW11	40	7.7	3.450	0.05	995	5.6	8.4	21.75	514	7	1910
12	TW12	26	7.0	0.607	0.01	120	2.9	27	13.25	46	6	390.5
13	TW13	46	7.9	0.795	0.01	200	3	5.7	0.67	35	1.8	549
14	TW14	43	7.9	2.072	0.02	539	4.1	2.3	7	3.54	3.6	1488.4
15	TW15	31	8.5	1.348	0.10	298	4	5	1.25	53		494.1
16	TW16	56	7.8	5.953	0.96	2000	25	3	12.5	2482	2.4	1403
17	TW17	36	7.8	1.092	0.02	300	4	18	20	319		427



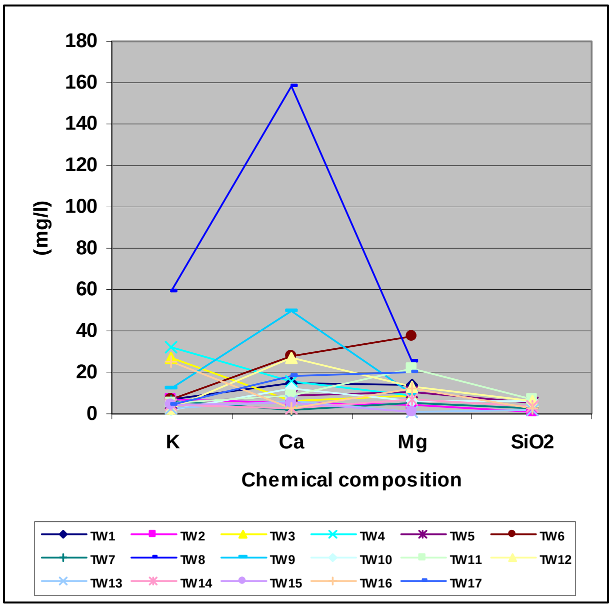


Figure 2 - Chemical composition of geothermal waters

Table 2 - Scale Tendency

No	Sample	Sulphate scales Saturation index $_{\text{type of scale/temperature}}$			$CaCO_3$ & corrosivity
1	TW1	No $BaSO_4$ scale formation tendency. No $SrSO_4$ scale formation tendency. Gypsum scale formation tendency. $Si_{gyps/50}$=1.211	No $BaSO_4$ scale formation tendency. No $SrSO_4$ scale formation tendency. Gypsum scale formation tendency. $SI_{gyps/30}$=1.167	No $BaSO_4$ scale formation tendency. No $SrSO_4$ scale formation tendency. Gypsum scale formation tendency. $Si_{gyps/15}$=1.136	No $CaCO_3$ scale formation tendency. Ryznar stability index indicates corrosion if dissolved oxygen is present (SI_{Rz}> 6.5).
2	TW4	No scale formation tendency.	No scale formation tendency.	No scale formation tendency.	$CaCO_3$ scale formation tendency.
3	TW9	No $BaSO_4$ scale formation tendency. No $SrSO_4$ scale formation tendency. Gypsum scale formation tendency. $Si_{gyps/45}$=1.785	No $BaSO_4$ scale formation tendency. No $SrSO_4$ scale formation tendency. Gypsum scale formation tendency. $SI_{gyps/30}$=1.736	No $BaSO_4$ scale formation tendency. No $SrSO_4$ scale formation tendency. Gypsum scale formation tendency. $Si_{gyps/15}$=1.691	$CaCO_3$ scale formation tendency.
4	TW16	No $CaSO_4$ scale formation tendency. No $SrSO_4$ scale formation tendency. $BaSO_4$ scale formation tendency. $SI_{BaSO4/56}$=1.35	No $CaSO_4$ scale formation tendency. No $SrSO_4$ scale formation tendency. $BaSO_4$ scale formation tendency. $SI_{BaSO4/30}$=1.746	No $CaSO_4$ scale formation tendency. No $SrSO_4$ scale formation tendency. $BaSO_4$ scale formation tendency. $SI_{BaSO4/15}$=2.20	No $CaCO_3$ scale formation tendency. Ryznar stability index indicates corrosion if dissolved oxygen is present (SI_{Rz}> 6.5).

Table 3 - Temperatures computed by selected geothermometers

NO.	Sample	Reservoir temperature	Reservoir temperatures computed by geothermometers					
			TNK1	TNK2	TNKC	TNKCM	TL	TKM
1	TW1	87	151	113	97	97	121	55
2	TW2	118	72	83	105	32	116	68
3	TW3	111	109	118	144	28	124	93
4	TW4	223	95	107	121	73	112	94
5	TW5	104	61	72	92		50	54
6	TW6	97	50	63	82		86	46
7	TW7	107	62	81	103		97	63
8	TW8	148	85	95	118	89	29	100
9	TW9	82	136	106	147		57	72
10	TW10	59	107	80	54		11	36
11	TW11	91	53	68	88		70	47
12	TW12	55	119	86	55		37	38
13	TW13	91	95	84	95	105	37	46
14	TW14	95	65	78	99		104	52
15	TW15	65	90	86	122	35	153	87
16	TW16	93	86	109	122	35	153	87
17	TW17	82	89	79	83		50	41

Note: Where TNK1 represents Na/K - Fournier- thermometer; TNK2 Na/K - Furnier-Truesdel- thermometer; TNKC presents Na-K-Ca thermometer; TNKCM is Na-K-Ca-Mg thermometer; TL is Li geothermometer; TKM is K-Mg geothermometer.