INTERNATIONAL AEGEAN SYMPOSIUM ON INNOVATIVE INTERDISCIPLINARY SCIENTIFIC RESEARCHES - II

PROCEEDING BOOK

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ISBN-978-605-7811-35-6
BY ISPEC PUBLISHING HOUSE

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EVALUATION OF HYDROGEOCHEMICAL PROPERTIES AND RESERVOIR TEMPERATURES OF THERMAL WATER RESOURCES IN KAVAK (SEYDIŞEHIR - KONYA) REGION

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ABSTRACT
The study area including Kavak village and its vicinity is located 13 km north of Seydişehir County, approximately 90 km southwest of Konya Province, Central Anatolia, and is one of the important geothermal resource areas. The main purposes of this study are to evaluate the hydrochemical characteristics of thermal water resources in the study area and to investigate reservoir temperatures. For this purpose, the pH, the electrical conductivity (EC), the temperature, the main anion-cation composition (Ca, Mg, Na, K, HCO_3, CO_3, SO_4 and Cl) and SiO_2 contents of the water samples taken from the study area were determined.

The thermal spring and wells in the study area show neutral to slightly acidic with a pH of 6.44 to 6.78. A total discharge rate of the springs and wells varies between 0.1 and 185 l/s, electrical conductivity values vary from 2530 to 4150 µS/cm and the measured temperatures range from 21.5 to 45.80 °C. The thermal waters are of Ca-Na-HCO_3 types. The carbonates within the Çaltepe formation are highly fractured and karstified and are assumed to be the main aquifer for thermal waters. In addition, fractured quartzite and marble units within the Seydişehir formation also act as aquifers for thermal and cold ground waters. Fine grained metasandstone, metasiltstone, and phyllite within the Seydişehir formation act as the cap rock, and the heat source of the thermal waters can be related to the high geothermal gradient of the Late Miocene- Pliocene aged Erenlerdağ volcanic rocks located in the east of study area. According to the various geothermometry results used in the study, reservoir temperature for the thermal water in the study area is ranging from 68 to 98 °C with low enthalpy.

Keywords: Thermal water, Reservoir temperature, Hydrogeochemistry, Kavak, Seydişehir

INTRODUCTION
Geothermal heat has also the advantage over other renewable energies of being available all day and in all seasons. This and its large resource make geothermal energy an attractive option for a sustainable supply of energy in the future [1]. The Kavak geothermal area is located 13 km north of Seydişehir town, about 90 km southwest of Konya Province in the Central Anatolia, Turkey (Figure 1), and is one of the important geothermal areas in Central Anatolia.

There are five thermal water springs and three deep wells in the Kavak geothermal area. The Directorate General of Mineral Research and Exploration of Turkey (MTA) drilled the two wells and third well was drilled by private companies (Figure 2). Thermal water springs in the study area discharge along NW-SE trending Beysehir-Seydişehir Fault Zone (BSFZ) and along minor faults parallel to the BSFZ. The temperature of the thermal waters from all springs and wells varies between 21.6 and 45.8 ^oC and a total discharge rate varies between 0.1 and 185 l/s ([2], [3]).

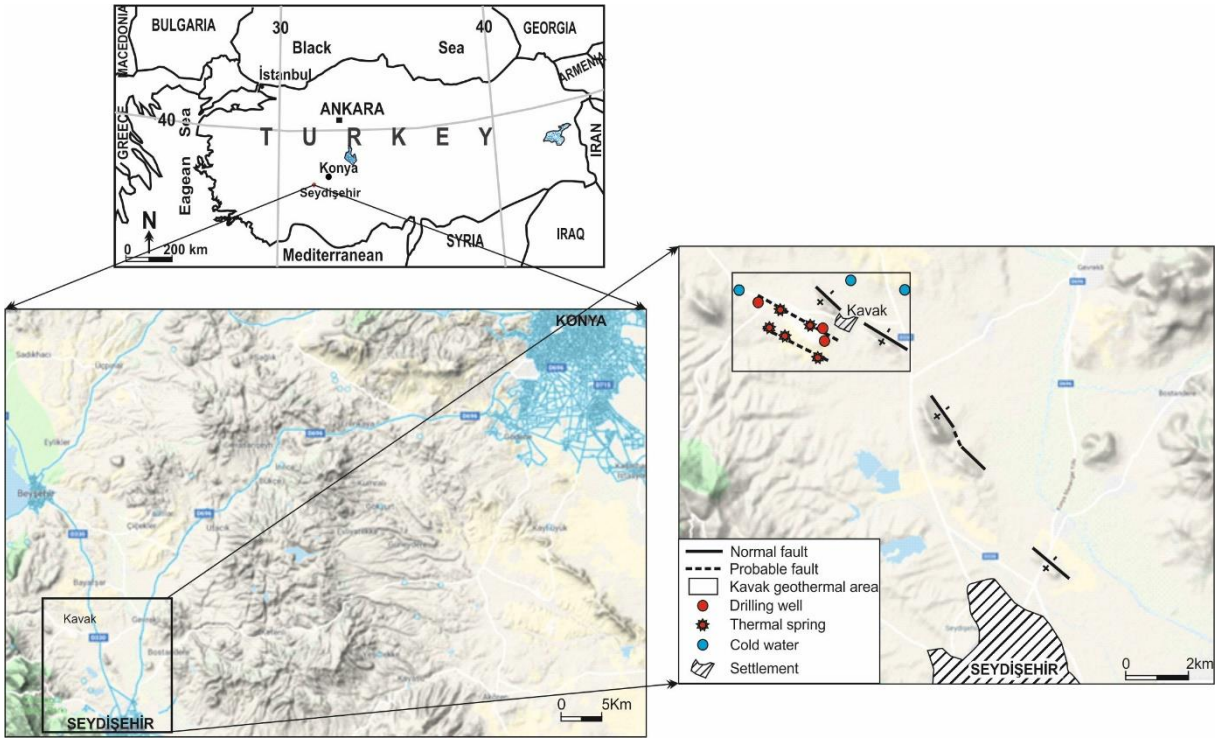

Figure 1. Location map of the study area and thermal and cold water sampling locations.

Figure 2. A view of thermal wells opened by MTA in the study area.

GEOLOGY OF STUDY AREA

The Early(?)-Middle Cambrian-Early Ordovician aged Çaltepe formation, which is consist of crystalline limestone, dolomite, and dolomitic limestone, is the oldest unit of the study area. The unit is conformably overlain by the Late Cambrian-Early Ordovician aged Seydişehir formation which is composed of shale, metasandstone and limestone and quartzite lenses [4] (Figure 3).

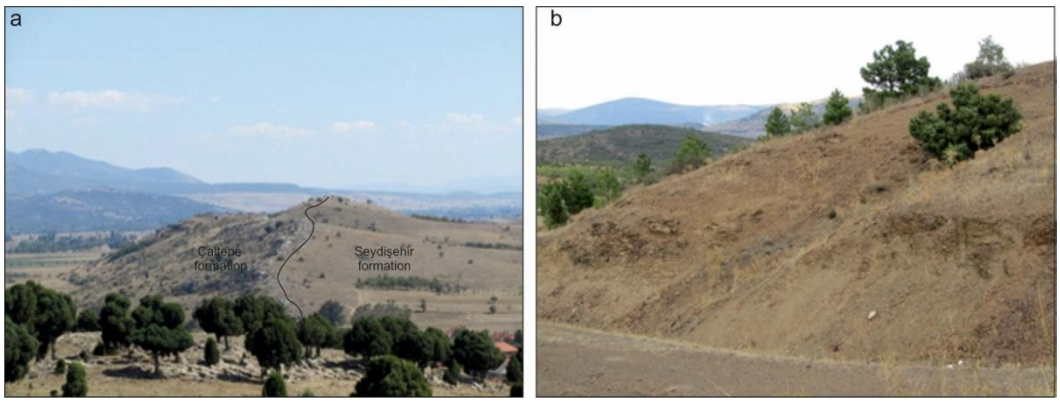

Figure 3 a) A view of Çaltepe formation and b) Seydişehir formation

The Middle-Late Triassic aged Taraşçı formation represented by blackish colored limestones overlies the Seydişehir formation with an angular unconformity. The Late Miocene-Pliocene aged İnsuyu formation forming from lacustrine deposits, which covers unconformably all of the older units, has transgressive contact with the Erenlerdağ volcanics cropping out at the higher elevation in the east of the region (Figure 4). All these units are covered unconformably by Quaternary-Recent aged alluvial deposits and travertine ([4], [5], [6]).

The Northwest-southeast trending Beyşehir-Seydişehir Fault Zone [7] is the most important tectonic structure in the study area (Figure 1).

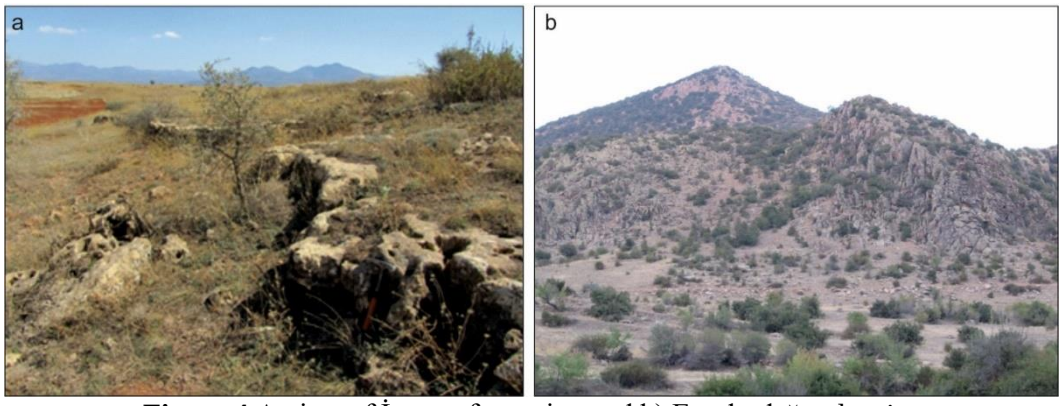

Figure 4 A view of İnsuyu formation and b) Erenlerdağ volcanics

CHEMISTRY OF THERMAL WATERS

The result of the physicochemical analyses of the thermal waters and cold water from Kavak geothermal area are given in Table1.

The pH values of the thermal waters range from 6.54 to 6.99 with an average 6.66 indicating that thermal waters are neutral to slightly acidic characteristic. However, the pH value of the cold water vary between 7.20 and 7.80 with an average 7.53 showing that the cold waters are neutral to slightly basic characteristic. The electrical conductivity values of the thermal waters ranging from 2750 to 4150 µS/cm. The temperature of the thermal waters varies from 21.58 to 45.80 ºC while the temperature of the cold waters ranges between 15.20 and 18 ºC ([2], [3]).

Table 1 Physico-chemical analyses results of the Kavak (Seydişehir, Konya) thermal waters (date: September 2015. Values are in mg/l. EC: electrical conductivity-(µS/cm). TDS: total dissolved solids-(mg/l). *April 2015).

Parameters	Thermal Water				Cold water			
	Maximum	Minimum	Average	Std.Dev.	Maximum	Minimum	Average	Std.Dev.
pH	6.99	6.54	6.66	0.15	7.80	7.20	7.53	0.25
EC	4150	2750	3492.90	575.50	668	320	511	127
T (ºC)	45	21.58	28.55	9.03	18	15.20	17.10	1.10
Ca	549.38	329.20	438.42	92.83	117.50	61.00	98.90	22.5
Mg	104.38	52.34	75.72	20.66	20.75	3.80	8.59	7.13
Na	387.45	267.70	324.63	47.09	10.37	1.80	4.39	3.42
K	103.69	69.10	83.90	10.39	1.01	0.00	0.47	0.41
HCO_3	2686.71	1506	2114.70	469.90	427.80	194	315	85.30
Cl	306.28	180.50	240.26	50.39	12.25	2.79	8.11	3.39
SO_4	88.80	73.07	79.76	5.26	18.67	14.10	16.80	2.29
SiO_2*	43.65	22.5	34.49	9.79	11.24	10.10	10.70	0.58

The dominance of ions is in order of Ca > Na > Mg > K and HCO_3 > Cl > SO_4 for thermal waters; Ca > Mg > Na > K and HCO_3 > SO_4 > Cl for the cold water. The thermal waters in the study area are of Ca-Na-HCO_3 water type while the cold waters are of Ca- HCO_3 and/or Ca-Mg- HCO_3 water type.

Calcium and bicarbonate ions are the dominant in thermal waters indicating that carbonate rocks are the main reservoir rocks. The carbonates belonging to the Early(?)-Middle Cambrian-Early Ordovician aged Çaltepe formation are highly fractured and karstified, and is the main aquifer of the thermal waters. Fractured marbles and quartzites within the Late Cambrian-Early Ordovician aged Seydişehir formation also act as aquifers for thermal and cold groundwaters. Fine grained metasandstone, metasiltstone, and phyllite within the Seydişehir formation are the cap rock of the thermal waters. Sodium in the thermal waters is derived from alteration of Na-rich feldspars in schists belonging to the Seydişehir formation. The heat source for the Seydişehir geothermal field is related to the high geothermal gradient of the volcanic rocks in the east of study area ([2], [3]).

Assessment of Reservoir Temperatures of Thermal Water Resources

The silica and cation geothermometers were used to estimate the reservoir temperatures of the thermal waters in the Kavak geothermal area and their results are given in Table 2.

The reservoir rock temperatures calculated by using quartz geothermometers for thermal springs and wells vary between about 68 and 98 ºC. The temperatures calculated by using chalcedony geothermometers range between 36 and 69.50 ºC. The results of chalcedony geothermometers are lower than temperatures calculated by quartz geothermometry and even lower from measured temperature in the exracting points for some springs. Bozdağ [2] stated that quartz is a common silica species in the Kavak reservoir. Therefore, it can be accepted that quartz geothermometers gave more reliable results than chalcedony geothermometers for Kavak geothermal area.

Table 2 Geothermometer results (ºC) of the thermal waters in the study area (**[a]**[8], **[b]**[9]; **[c]**[10]; **[d]**[11], **[e]**[12])

Geothermometer (ºC)	Thermal Springs		Thermal Wells	
	Maximum	Minimum	Maximum	Minimum
T (ºC) (Measured)	26.00	22.00	45.80	30.00
[a]Quarts No stream loss	91.30	67.90	95.60	94.50
[a]Quarts Max. stream loss	93.40	72.90	97.20	96.30
[b]Chalcedony No stream loss	60.60	36.00	65.20	64.10
[b]Chalcedony Max. stream loss	65.40	43.10	69.50	68.50
[c]Na-K	343	319	326	307
[d]K-Mg	99.40	95.90	97.80	94.50
[e]Na-K-Ca	121	116	121	112

The reservoir temperatures calculated from Na-K geothermometer is too high. The application of this geothermometer, for diluted water or system below 150 °C, can result in overestimated calculated temperatures ([13], [14]). Na-K-Ca geothermometer results range from 112 to 121 °C. Reservoir temperatures estimated by K-Mg geothermometry vary between 94.50 and 99.40 °C.

Giggenbach [11] suggested a method used to discriminate mature waters which have attained equilibrium with the host lithology and waters affected by mixing and/or re-equilibration at low temperatures along their circulation path. Based on the Giggenbach diagram [12], it is detected that all the thermal water in the study area are immature water, reflecting conductive cooling or mixing with colder meteoric waters during the rise towards the springs and the cation geothermometres are not likely to yield meaningful equilibration temperatures [2]. Therefore, it is concluded that silica geothermometers may provide more reliable results than cation geothermometers because of the nonequilibrium conditions for the Kavak geothermal area. Based on the geothermaometer applications, it was determinate that the reservoir temperature for the thermal water in the Kavak geothermal area is ranging from 68 to 98 °C.

CONCLUSION

The pH values of the thermal waters in the Kavak geothermal area (Seydişehir-Konya) range from 6.54 to 6.99 with an average 6.66 indicating neutral to slightly acidic characteristic. Their discharge rate varies between 0.1 and 100 l/s and electrical conductivity values vary from 2530 to 4150 µS/cm. The measured temperatures of the thermal water range from 21.5 to 45.80 °C. A total discharge rate of the springs and wells varies between 0.1 and 185 l/s. The dominance of ions in the thermal waters is in order of Ca > Na > Mg > K and HCO_3 > Cl > SO_4 and they are of Ca-Na-HCO_3 water type. Calcium and bicarbonate ions are the dominant in thermal waters indicating that carbonate rocks of the Çaltepe formation are the main reservoir rocks for thermal waters. Fractured marbles and quartzites within the Şeydişehir formation also act as aquifers for thermal and cold groundwaters. Fine grained metasandstone, metasiltstone, and phyllite within the Palaeozoic metamorphics are the cap rock of the thermal waters. The heat source for the Seydişehir geothermal field is related to the high geothermal gradient of the volcanic rocks in the east of study area.

The silica and cation geothermometer applications for Kavak geothermal area show that silica geothermometers may provide more reliable results than cation geothermometers because of the nonequilibrium conditions. Based on the geothermaometer applications, it was determinate that the reservoir temperature for the thermal water in the Kavak geothermal area is ranging from 68 to 98 °C.

Acknowledgment: This study was financially supported by Selcuk University Scientific Research Projects (BAP) (Project no. 15401019) (Konya, Turkey).

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