Isotopic Evaluation of Savcili-Buyukoba (Kirsehir-Kaman) Geothermal Area

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ABSTRACT

Isotopic and hydrochemical characteristics of thermal waters in the Savcili-Buyukoba geothermal area are evaluated in this study. Savcili-Buyukoba geothermal area is located in Kaman province of Kirsehir city in Central Anatolia Turkey which is about 150 km southeast of Ankara and 5 km north of Hirfanlē Dam. Measured surface temperatures and specific electrical conductivity values of the thermal waters change between 30.01-34.6ºC and 513-565 µS/cm, respectively. According to ionic content, the hydrochemical facies of the thermal waters are Na-Cl and cold waters have Ca-HCO_3 type. For Savcili-Buyukoba geothermal area, the stable isotope oxygen composition of the water samples ranges from -6.39 ă to -12.93 ă ŭ^{18}O-VSMOW and Deuterium ranges from -32.62 ă to -94.47 ă ŭ^{2}H-VSMOW. Results of environmental isotopes (ŭ^{18}O and ^{2}H) and hydrochemical analysis show that the thermal waters are meteoric origin. The low tritium (0.18-0.38 TU) content of thermal waters show that the thermal aquifer of Savcili-Buyukoba geothermal area is recharged by groundwater having relatively long residence time which represents a deep groundwater circulation system. Tritium concentrations below 1 TU indicate that groundwater circulation time is at least 60 years.

1. INTRODUCTION

Environmental isotopes are commonly used in hydrologic and hydrogeologic studies to determine the origin of hot and cold waters, water rock interaction and recharge altitudes. This study is an example of using environmental isotopes such as Oxygen-18 (ŭ^{18}O) Deuterium (ŭ^{2}H) and Tritium (^{3}H) to explain low entalphy geothermal system in Savcili-Buyukoba of Central Anatolian Region (Figure 1). The arid climate of the area characterized by hot dry summers and cold winters. The mean annual temperature and rainfall at Savcili Meteorological Station are about 12ºC and 353.7 mm, respectively.

In this study, hydrochemical characteristics of thermal waters at the Savcili-Buyukoba geothermal area is evaluated with the hydrochemical and isotopic analysis.

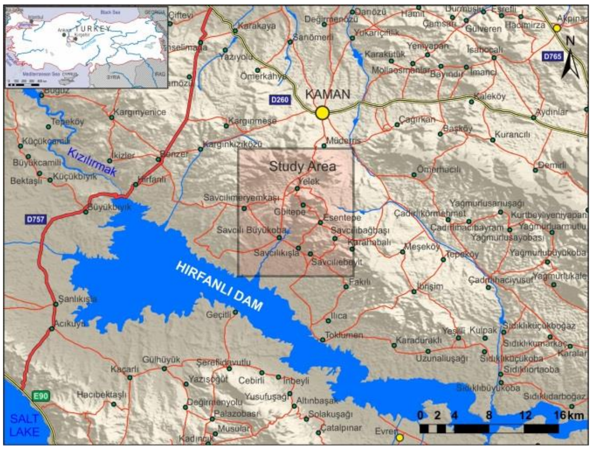


Figure 1: Location map of Savcili-Buyukoba geothermal area

2. MATERIALS AND METHODS

To compare the chemical and isotopic characteristics of water samples were collected between March 2014 -August 2014. Twenty-four water points were selected and sampled. Thermal waters and spring water samples collected from natural springs. Four water samples per spring were stored in polyethylene bottles for each sampling site. 250 ml water samples were taken to measure their anion contents, 250 ml for cation and trace element contents, 500 ml for tritium (^{3}H) analysis, 20 ml for ŭ^{18}O and ŭ^{2}H isotope analysis. The samples were kept cold until they were sent to the laboratories. Temperature, pH, and specific electrical conductivity values were measured directly in the field. Major anion-cation, trace element and tritium analysis were carried out at Hacettepe University Hydrogeological Engineering Programme Water-Chemistry Laboratory. Stable isotope analysis was performed by Hacettepe University- UKAM, Stable Isotope Laboratory.

3. GEOLOGIC AND HYDROGEOLOGIC OUTLINE

Basement rock outcrops in the study area is Paleozoic Metamorphics, also called Kirsehir Massif. The metamorphic rocks of Kērsehir massif is overlain tectonically by ophiolitic melange units which are consisting of basic volcanoclastic rocks intercalated with pelagic deposits of Late Cretaceous age. These units have been intruded by Baranadag Granitoids which are Mesozoic (Late Cretaceous-Paleocene) age (Seymen, 1981). The Eocene units which consists of terrestrial sediments (alternating conglomerate and sandstone) and Miocene-Pliocene Kizilirmak Formation unconformably overlie Mesozoic units. Quaternary alluvium unconformably overlie older formations which is the youngest unit in the study area and located along the Hamamozu stream in the middle of the area (Urgun, 1979). Savcili-Buyukoba geothermal area is controlled by mainly NE-SW and NW-SE faults. Thermal waters emerged along the intersection of the faults. Paleozoic metamorphics of the Kirsehir Massif which are the basement rocks of the study area are impermeable (Figure 2). However, because of the secondary porosity developed due to active tectonics, faults and joints of marbles and granitoids are permeable and show local aquifer character in the study area. Eocene and Miocene-Pliocene sediments exhibit cap rock properties and terrestrial units of formations which are consisted of conglomerates and local limestones may have local importance as an aquifer. Alluvium in the Hamamozu stream is part of the Savcili-Buyukoba geothermal area which forms the main groundwater aquifers (Tekin and Tekin, 1986).

ISOTOPIC EVALUATIONS

For evaluation of the hydrochemical and isotopic characteristics of water samples were collected between March 2014-August 2014. Twenty-four water points were selected and sampled. According to the stable isotope (ŭ^{18}O and ŭ^{2}H) analysis of the water samples from the study area values change between -5.98ă to -12.93ă for ŭ^{18}O and from -50.25ă to 94.47ă for ŭ^{2}H (Table 1 and Table 2). Relation between ^{18}O and ^{2}H in precipitation is linear. Most of the water samples plot close to the GMWL (Figure 3). The stable isotope contents of water samples indicate that the geothermal waters of a meteoric origin in the area. Some of the water samples (KSBO-6, KSBO-8) exhibits slight shift from the Global Meteoric Water Line (GMWL). This shows that water-rock interaction process occur in the Savcili-Buyukoba geothermal system. Stable isotope analysis was carried to determine the origin of thermal waters and the geothermal reservoir possible recharge areas (Clark and Fritz, 1997). The elevations of the thermal reservoir recharge areas are estimated using the stable isotopic composition-elavation relationship.

Samples	Type	Date	T (°C)	EC (25°C) (µS/cm)	δ^{18} O (‰)	δ^{2}H (‰)	^{3}H (TU)
KSBO-1	Cold Spring	14.03.2014	8.23	179	-10.7	-72.38	5.57
KSBO-2	ColdSpring	14.03.2014	10.38	274	-11.16	-74.91	7.16
KSBO-3	Cold Spring	14.03.2014	7.49	267	-11.33	-76.58	6.87
KSBO-4	Cold Spring	14.03.2014	11.96	454	-10.11	-72.09	6.52
KSBO-5	Degirmenözü Stream	14.03.2014	7.25	576	-10.02	-71.4	6.17
KSBO-6	HirfanlēDam	14.03.2014	8.04	1449	-7.84	-58.76	6.28
KSBO-7	Cold Spring	15.03.2014	13.61	796	-9.61	-69.66	7.27
KSBO-8	Savcili Pond	15.03.2014	8.52	409	-7.13	-55.77	7.04
KSBO-9a	Thermal Water	15.03.2014	30.01	513	-12.07	-88.37	0.28
KSBO-9b	Thermal Water	15.03.2014	33.58	527	-12.27	-88.4	0.18
KSBO-10	Cold Spring	15.03.2014	12.62	535	-7.74	-58.38	8.49
KSBO-11	Rain+Snow	15.03.2014	16.52	289	-7.79	-56.71	7.9

Table 1. Environmental isotopic analysis results for Savcili-Buyukoba geothermal area (March 2014)

Samples	Type	Date	T (°C)	EC (25°C) (µS/cm)	δ^{18} O (‰)	δ^{2}H (‰)	^{3}H (TU)
KSBO-1	Cold Spring	16.08.2014	22.8	196	-11.41	-79.36	7.04
KSBO-2	ColdSpring	16.08.2014	18.6	332	-12.14	-79.21	6.38
KSBO-3	Cold Spring	16.08.2014	25.3	306	-12.06	-82.66	5.61
KSBO-4	Cold Spring	16.08.2014	20.6	507	-11.3	-78.24	6.69
KSBO-6	HirfanlēDam	16.08.2014	32.1	1628	-8.03	-60.04	7.91
KSBO-7	Cold Spring	16.08.2014	18	890	-10.19	-69.22	8.22
KSBO-8	Savcili Pond	16.08.2014	26	452	-5.91	-50.25	7.88
KSBO-9a	Thermal Water	16.08.2014	34.3	565	-12.93	-91.76	0.28
KSBO-9b	Thermal Water	16.08.2014	34.6	562	-12.91	-94.47	0.38
KSBO-10	Cold Spring	16.08.2014	20.2	721	-8.89	-67.25	7.48
KSBO-12	Cold Spring	16.08.2014	20.3	865	-8.47	-64.53	7.87
KSBO-13	Hamamözü Stream	17.08.2014	16.3	623	-9.27	-67.12	7.2

Table 2. Environmental isotopic analysis results for Savcili-Buyukoba geothermal area (August 2014)

Average estimated recharge elevations for the thermal waters computed by using isotopic equations. The elevation of the thermal reservoir recharge areas are estimated using the stable isotopic composition-elevation relationship between samples of cold waters (KSBO-1, KSBO-2, KSBO-3, KSBO-4 and KSBO-7).

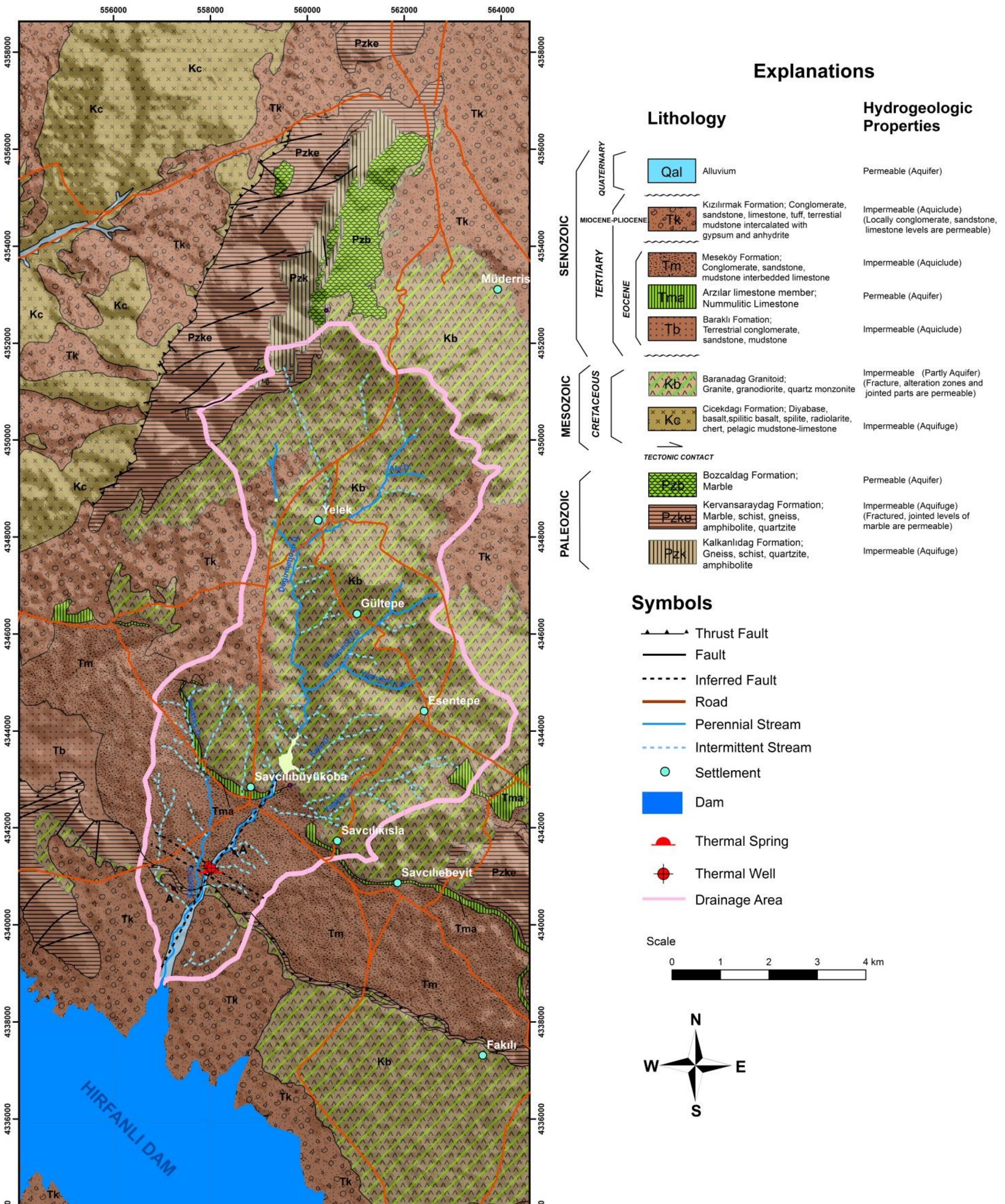


Figure 2. Hydrogeological map of the Savcili-Buyukoba Geothermal Area (After MTA, 1991)

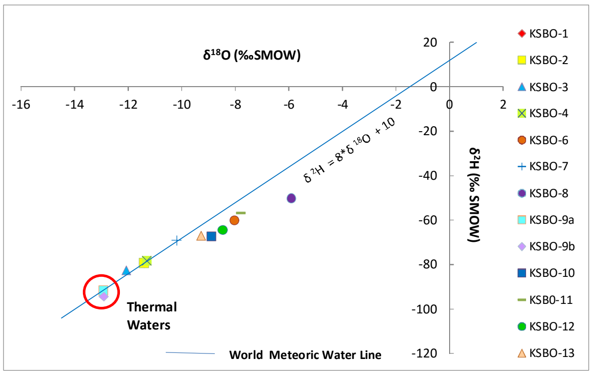


Figure 3. δ^2H-δ^{18}O relationship for Savcili Büyükoba geothermal area

The regression equations computed from ŭ^{18}O and ŭ^{2}H versus elevation are.

Elevation (m)= -211.48*ŭ^{18}O - 1127.4 (R^2=0.99) [1]

Elevation (m)= -41.103*ŭ^{2}H - 1857 (R^2=0.91) [2]

These equations [[1],[2]] show an apparent elevation effect on ŭ^{18}O and ŭ^{2}H of the order -0.47 and -2.43 ă per 100 m increase in elevation, respectively. As a result of these equations, Savcili-Buyukoba hot springs are recharged mainly from the Baranadag Mountain whose peak elevations range from 1561-1568 m is located northeast of the study area.

Tritium values for thermal waters vary from 0.18 TU to 0.38 TU. For cold water samples the tritium values changed between 5.61 TU to 8.49 TU. Thermal waters that have almost no tritium contents reveal that thermal fluids in the study area are older than 70 years. The relationship between tritium (^{3}H) and ŭ^{18}O values suggests that the thermal waters recharge from higher altitudes than cold water samples and also they have deeper circulation and low TU contents (Figure 4).

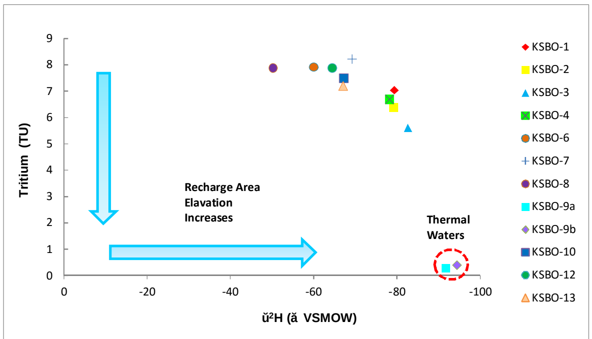


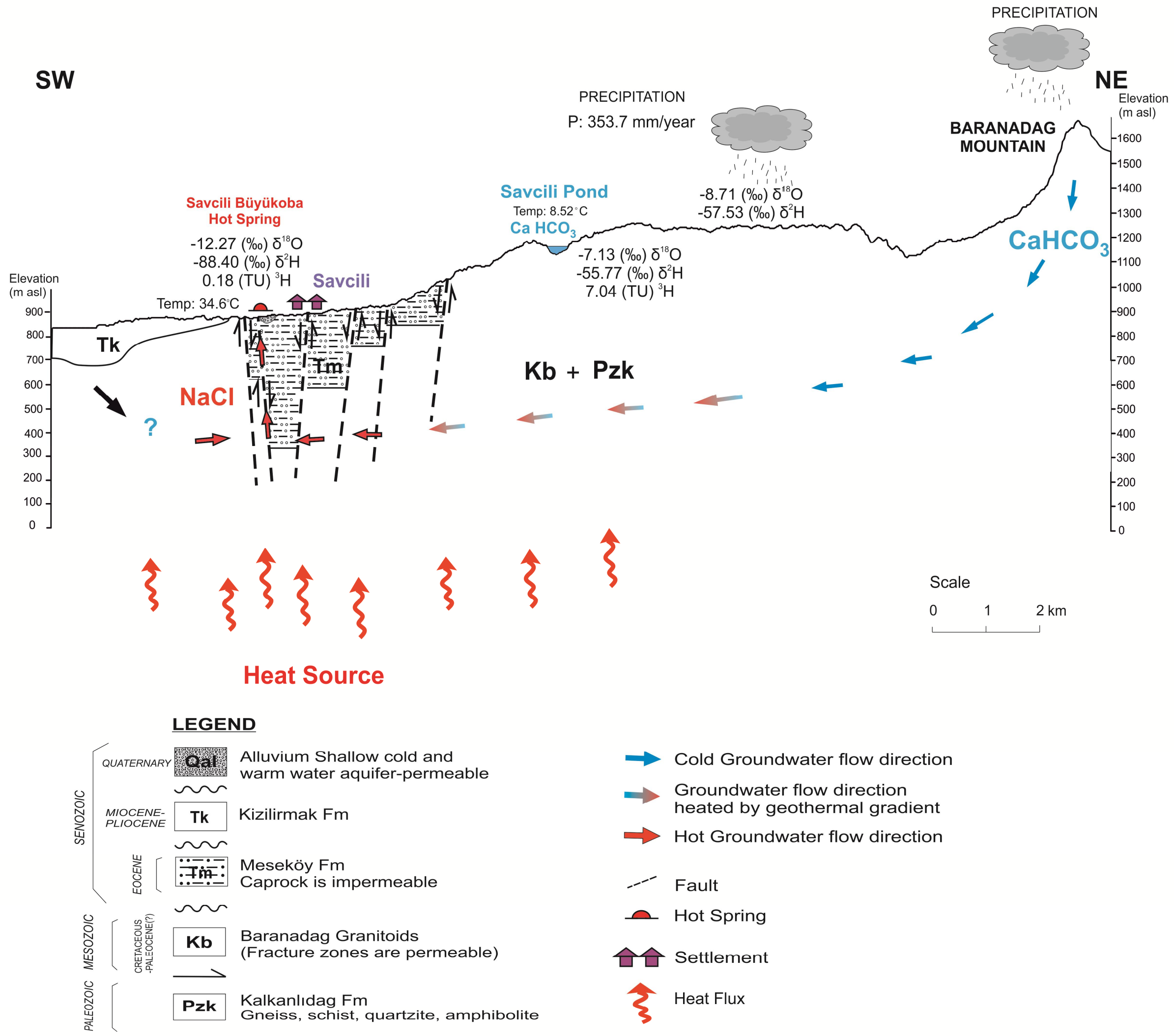
Figure 4. Tritium (^{3}H) - δ^{18}O relationship (August 2014)

According to the isotopic conceptual model; Savcili-Buyukoba hydrothermal model shows two different types of aquifer systems which are shallow and deep. Shallow waters (cold water samples) are chemically dominated by the Ca-HCO_3 type.

Deep waters are chemically dominated by the Na-Cl type. According to the isotopic schematic model, thermal waters in Savcili-Buyukoba area are formed by rain and snow precipitation filtered through a faulted and fractured zone, then heated by the geothermal gradient and returned to the surface through permeable rock (Figure 5). Savcili-Buyukoba thermal waters are recharged mainly from the Baranadag Mountain whose peak elevations range from 1561-1568 m is located northeast of the study area.

CONCLUSIONS

The results of hydrochemical and isotope analysis performed for determining hydrochemical and isotopic characteristics of Savcili-Buyukoba geothermal area are listed below: Savcili-Buyukoba geothermal waters discharge in a low-temperature geothermal system at Central Anatolian region. Temperature of the thermal waters vary between 30.01-34.6°C and electrical conductivity values change between 513-565 µS/cm. According to ionic content, the hydrochemical facies of the thermal waters are Na-Cl and cold waters are Ca-HCO_3 type. ŭ^{18}O, ŭ^{2}H and ^{3}H values are investigated in the study area to determine the origin and recharge elevation of Savcili-Buyukoba geothermal field. The isotopic composition (ŭ^{18}O, ŭ^{2}H isotopes) of the thermal waters in the Savcili-Buyukoba geothermal area shows that they are meteoric origin. Isotopic compositions about ŭ^{18}O and ŭ^{2}H for the water samples from the study area range from -5.98ă to -12.93ă for ŭ^{18}O and from -50.25ă to 94.47ă for ŭ^{2}H. Tritium values for thermal waters vary from 0.18 TU to 0.38 TU. For cold water samples the tritium values changed between 5.61 TU to 8.49 TU. The thermal waters recharge from higher altitudes than cold water samples and also they have deeper circulation and low TU contents. The circulation of thermal waters are mainly controlled by local tectonic structures and the major NE-SW and NW-SE faults zone. Thermal waters emerged along the intersection of the faults. The discharge rate of the thermal waters are limited and exploratory drilling is needed for further development of the Savcili-Buyukoba geothermal area.



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