Hydrogeochemical characteristics and the geothermal model of the Altinoluk-Narli area, in the Gulf of Edremit, Aegean Sea

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Abstract The Altınoluk-Gure region is at the foot of Mount Kazdag. There are many thermal springs to the east of the area (Gure ande Kucukcetmi). Because of the geologic and tectonic settings, it is considered that the Altınoluk-Gure-Narlı area may have a geothermal potential as well. In this study the hydrochemical data were mapped out by sampling from the existing springs and, in order to determine the geothermal potentiality of the region, the relationship between volcanism, tectonics and springs were investigated.

1 Introduction

The Altınoluk-Gure region is an area that potentially has geothermal energy at foot of Mount Kazdag (Ida Mountain). There are many thermal springs to the east of the area (Gure and west Kucukcetmi). Due to its the geologic and tectonic settings, it is thought that the Altınoluk-Gure-Narlı area may also have a geothermal potential. This study is aimed at mapping out the hydrochemical data by sampling from the existing springs and, in order to determine the geothermal potentiality of the region, an investigation was performed into the relationship between volcanism, tectonics and springs. The results of chemical and isotopic analyses were used to correlate the relation between thermal and cold waters and establish a geothermal model.

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2 Geologic and Tectonic Outline

In the area Kazdag the metamorphic massif of Paleozoic age occurs and it is overlain by the Lower Triassic Karakaya formation and Upper Jurassic-Lowe Cretaceous (sandy or chert nodules bearing) limestones rest upon the Karakaya Formation (Fig. 1 a, b). Products of volcanic activity that has been effective from Upper Oligocene to Lower Miocene and granodiorites coeval to these volcanites are observed at the area**.** Sedimentary rocks representing the Middle-Upper Miocene time period were deposited in the lacustrine environment. The Pliocene aged volcanites are overlain by basaltic rocks developed by fissure volcanism and, in turn, these are capped by cemented pebblestones, sandstones and claystones of the same age. It is concluded that the important tectonic lines that provide the geothermal discharge are NE-SW trending dextral strike-slipe faults, NW-SE oriented sinistral faults and normal faults running in E-W direction. The rock units in the region are porous and permeable; thus, they can store groundwater that percolated into the depths.

3 Material And Method

Geological maps, cross sections, reports and geochemical data, which were presented by previous researchers, were investigated and made necessary arrangements. During the field survey general geological features of the region (formation boundaries, hydrogical settings, fracture, fault and fissure systems, etc.) and hot/cold source points were determined. All the samples collected in-situ in polyethylene vessels were washed by source water three times. The pH, EC and temperature were measured by means of a multiparameter device of ELMETRON CPC 401. For each source three sets of samples were taken (Table 1). Finally the radioactivity was measured for both water and soil samples and the results are shown in Table 2.

The first set, which was put under protection by adding 5 ml concentrated HCl for 500 ml, is for cation analysis. The second set is for anion and third one is for isotope and heavy metal analysis. Water samples were sent to the I.S.K.I (Istanbul Water and Canalisation Authority) laboratory for major anion and cation analyses and also Agency of T.U.B.I.T.A.K M.A.M. for the isotope analysis. Using oxygen 18 and deuterium values East Mediterranean Sea meteoric water line was drawn, data were transferred to the SMOW graph and an attempt was made to find out a the recharge paths. Hot and cold water sources were correlated by using the Piper and Schoeller diagrams (Fig. 2 a, b).

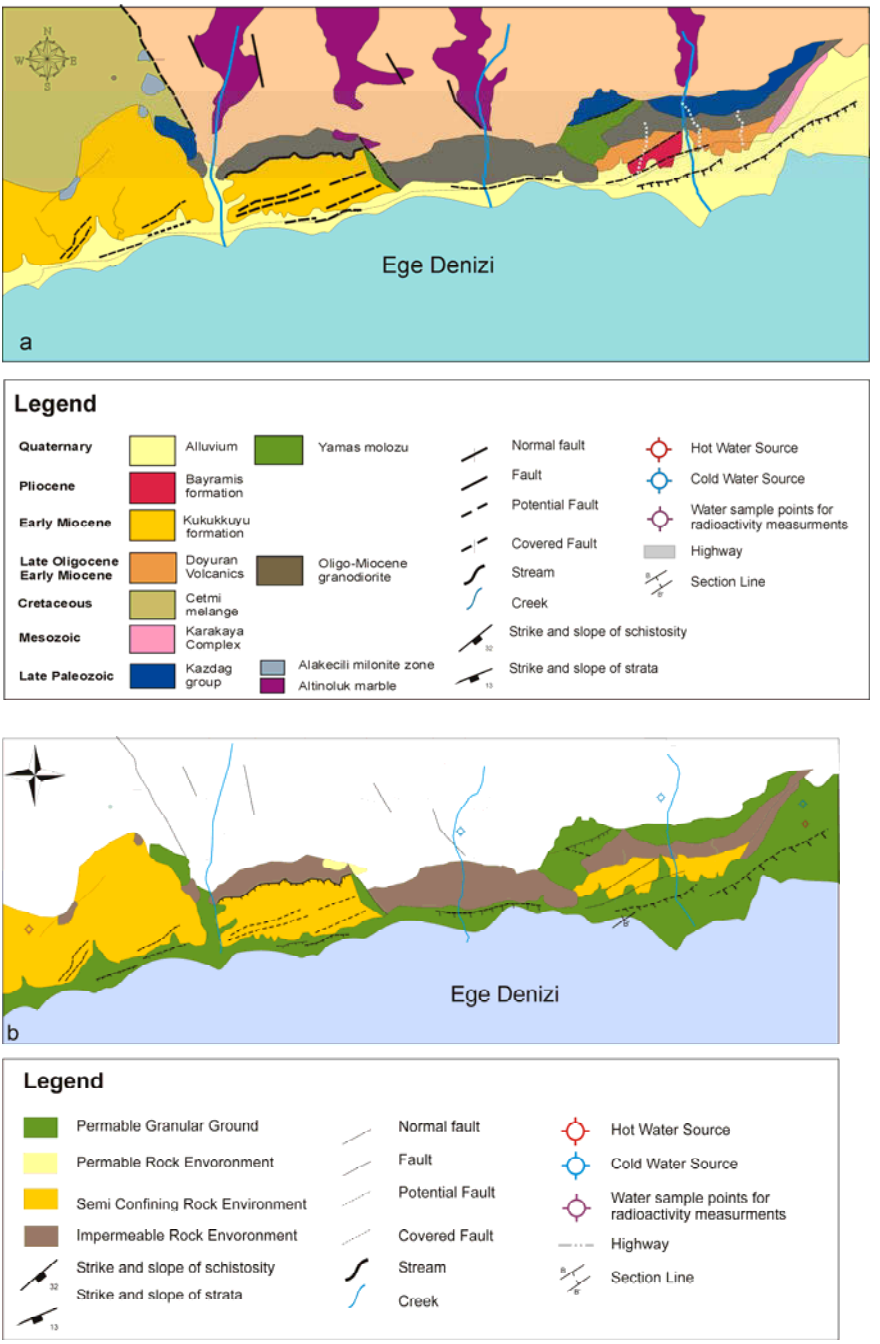

Fig. 1. a Geology map of the Gure-Altınoluk-Kucukcetmi area (Talay 2010), **b** Hydrogeology map of the Gure-Altınoluk-Kucukcetmi area (Talay 2010).

In order to calculate reservoir temperature a chalcedony geothermometer was used as the temperature range was under 180 Celsius degree. In addition, geothermal waters were classified based on TSE (Turkish Standards Institute), W.H.O and A.B.D. Corel-Draw, Aquachem, Rockware, Surfer and Didger softwares were used to establish.

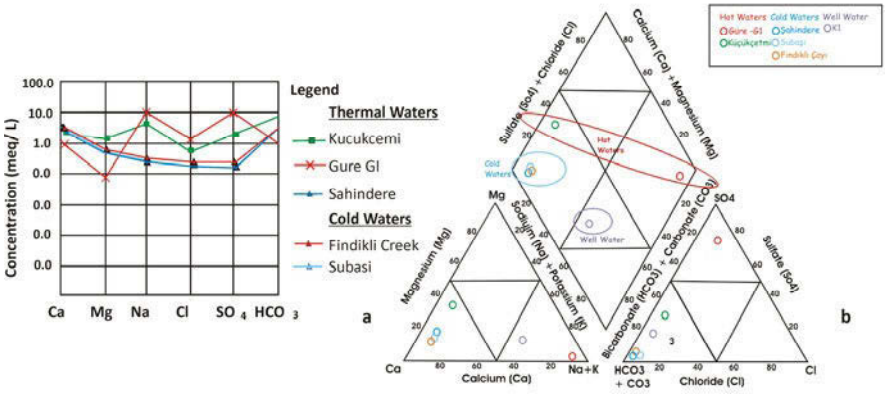

Fig. 2. a. Schoeller diagram for thermal waters and cold surface waters **b.** Piper diagram for thermal waters.

Table 1. Chemical composition of the samples.

Sample Id	Gure G1	Kucukcetmi	Subası	Sahindere	Fındıklı Creek	K1
Date	10/2009	10/2009	10/2009	10/2009	10/2009	10/2009
Coordinate (UTM)	X:0490081 Y:4382362	X:0465598 Y:4380180	X:0479204 Y:4381235	X:0479204 Y:4381730	X:0485501 Y:4382224	X:0482836 Y:4380665
Elevation (m)	10	131	122	110	105	40
Temp. (T°C)	51	41.6	15.2	17.8	18	21.3
EC (µs/cm)	1050	750	580	670	870	1570
pH	6.65	7.24	7.49	8.36	6.65	7.15
Ca^{+2}	17.8	51	51.8	53.4	67.2	114.2
K^{+}	6.08	8.89	0.96	1.05	1.8	3.42
Mg^{+2}	1	16.5	8.3	6.8	7.3	46.2
Na^{+}	238	118	6.2	6.6	8.4	17.8
Cl^{-}	50	22.6	7.56	8.84	29.7	29.7
$HCO3^{-}$	156.6	463.6	229.36	204.96	253.76	390.4
SO_4^{-}	411.8	92.6	8.52	8.1	12.7	158.1
SiO_2	59	49	-	-	-	25

Table 2. Radioactivity levels of water and soil samples.

Features Sample	Location	Total alfa (Bq/L)	Total beta (Bq/L)
	Adatepe	0.113 ± 0.024	0.263 ± 0.029
	Avcılar	0.040 ± 0.012	0.122 ± 0.016
	Camlıbel	0.050 ± 0.017	0.184 ± 0.025
Water	Gure	0.019 ± 0.005	0.040 ± 0.012
Samples	Kucukcetmi	0.070 ± 0.019	0.365 ± 0.030
	Subası	0.036 ± 0.011	0.070 ± 0.014
	K1	0.025 ± 0.016	0.218 ± 0.041
	Tahtakuslar	0.068 ± 0.014	0.098 ± 0.015
	Avcılar	584 ± 59	1257 ± 64
	Camlıbel	569 ± 59	772 ± 50
Soil	Gure	1154 ± 81	1874 ± 76
Samples	Kucukcetmi	433 ± 51	1009 ± 57
	Narlı	590 ± 60	810 ± 53
	Tahtakuslar	975 ± 75	1677 ± 73

4 Discussion

Although the formation is a little bit different in Gure and Kucukcetmi thermal fields, the system basically is the same. Meteoric waters percolate into the depths, gets hot depending on geothermal gradient in fault zones, come up to the surface, mix with cold water around the surface in porous and permeable units and finally outcrop at the surface as a hot spring like Gure and Kucukcetmi. Even though the cap rock is thick in Gure, as water circulation is long and flow yield is low the temperature is low as well. Usually, if any geothermal system takes place nearby the seaside, it is thinkable that the hot liquid consists of sea and meteoric water. But, in this case, Cl level must show an increaseas opposed to a decrease in Mg-SO_4 and HCO_3 level. In spite of the fact that Gure is located at the seaside, (Cl level is low, but SO_4 and HCO_3 level is high (Table 1). According to the isotope rates which were sampled before rainfalls in the region only Kucukcetmi hot spring takes place between East Mediterranean Meteoric Water Line. So it is understood that all the water sources are of meteoric origin and recharge from local rainfalls. As volcanic rocks outcrop in wide areas, there comes a question to the mind. Is the origin of the hot liquid volcanics or not? But the low level of Cl, Br, B, As, and Li provide an answer for it.

5 Conclusions

Based on the lithology and structural features, the units were divided into different hydrogeological environments. According to this Triassic aged limestones in the Cetmi melange and marbles in the Kazdag massive are permeable rock units, the Fındıklı formation and silicified volcanites are semi-permeable rock units, the Pliocene aged Bayramic formation and Quaternary aged alluvium and talus are granular permeable units. Neogene aged lacustrine sediments and tuffs at Gure and Kucukcetmi are cap rocks. Fault zones, fractures, fissures were mapped out. In addition, NE-SW trending dextral strike slip faults NW-SE oriented snistral faults and normal faults were observed. Some of the rock units in the region are porous and permeable; thus they can store groundwater that percolated into the depths and some of them have a secondary porosity as a result of tectonic activities, like Kazdag metamorphics. Annual precipitation of the area is 679.50 mm. 52% of the rainfall evaporates and 42% of it is discharged. For the calculation of reservoir temperature using a silica geothermometer, as the temperature range is under 180 degree a chalcedony geothermometer was preferred. Thus, approximate temperature was calculated to be between 60-80 degree.

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