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Geochemical Investigation in Areas Without Geothermal Surface Geothermal Manifestations Kucuk Menderes Graben Western Turkey

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ABSTRACT

Ground-based field geochemical work carried out in May 2008 at all hot discharges present in the field for assessment the geothermal potential at Küçük Menders Graben along the long axis, Turkey. Good interpretative practice starts with good sampling procedures. This includes both the wise selection of water for analyses and the proper preservation of samples between the time of collection and analyses. The best sampling strategy is to collect every available ground-water hot and cold. Even limited hot sprigs presence in a field can be accepted as surface manifestation. According to the general tariff of geothermal energy, the surface geothermal activities in the Küçük Menderes Graben fall in non-manifestation area category. The temperature of all samples from springs and streams adjacent to the studied area except for Bayindir Kaplica is under the local average annual air temperature but higher than that of short circulated water discharges found in the same districts. Altogether 20 water samples were collected for chemical and isotopic analyses. By applying geochemical geothermometers and isotope techniques, up to 70°C geothermal fluid existence was traced in the study region.

1. INTRODUCTION

Geothermal water can be broadly defined as ground water which has a temperature appreciably higher than that of the local average annual air temperature. Generally the geothermal water of an area contains large concentrations of dissolved minerals, such as sodium, calcium, sulfate, chloride, or silica higher than that of the local non geothermal ground water (Yildirim 1999). The water warms as it descends, possibly along fault zones that overlie the magma chamber, until it absorbs enough heat to become lighter than overlying water. The warm water then rises to the surface. The mechanism for the circulation of the water is the same, regardless of whether the water becomes heated by the geothermal gradient or by the buried, cooling magma. Information gathering on the surface thermal manifestations, such as springs, shallow wells or natural artesian etc. and their physical and chemical characteristics is of primary importance in geothermal energy exploration. This is one of the lowest cost exploratory techniques and is a useful starting point in any hydrothermal exploration program.

A geochemical study along the long axis of Küçük Menderes Graben was carried out to assess the geothermal energy potential of the region by means of geochemical technique.

The study area roughly is located on the two long flanks of Küçük Menderes Graben (Fig 1). A model for the geothermal area is tried to be derived from geochemical and isotopic data. The Physical, chemical and isotopic investigation of hot and cold ground waters make it possible to construct the thermal water evaluation from infiltration to discharge, including water-rock-gas interaction, heating and shallow water mixing.

2. GROUND BASE GEOCHEMICAL PROSPECTING

Geothermal systems can be defined and classified on the basis of their geological, hydrological and heat transfer characteristics (Yildirim 2000). Since the thermal energy of the earth crust is stored in large rock masses, a working fluid (water) is needed to carry and transfer this heat to the surface. In this phase of the research, more than 34 temperature measurements and water samplings were made, from the spring artesian and bore holes in the survey area to define hot water anomalies in the survey area. Table 1 illustrates the sampling point's districts and their sample codes. With this number of samples the diversity in temperature and chemical composition were tried to be obtained for the studied area. The drillings for domestic and irrigation purposes at depths up to 150 m allow the drawing of the isotherms at depths from 50 to 150 m and the definition of the most interesting geothermal manifestoes area. The resulting gradient was low, reaching 1°C/10 m. On the basis of the data stated below, the geochemically determined temperatures of up to 70° C should be located at depths between 700 and 1000 m. Geothermal surface activities in the survey area belong to non-manifestation type of hydrothermal system. The ions have been dissolved from the minerals in the rocks that compose the geothermal reservoirs vary as the mineral composition of the rocks varies. Ground water in the Küçük Menderes Graben which lies from Selçuk to Beydağ (Fig 1) contains large concentrations of dissolved solids. In general, geothermal fluid is formed by deeply circulating ground water that becomes heated by cooling magma (molten igneous rock) at great depths in the crust of the Earth. Precipitation that falls in highland areas recharges the aquifer system. Some of the water moves downward along faults and fracture zones to great depths. As the water descends, it becomes heated because of the geothermal gradient. At the some time the concentration of dissolved salts is increased parallel to physical and thermodynamic conditions. At some depth, the heated water becomes lighter than the overlying water and then moves upward along faults to discharge as spring flow. Some of the upward-moving water can be intercepted by wells. But unfortunately, the examined water in the survey area does not seem to be circulated deep in such geological environment. So their measured temperatures are under average annual atmospheric temperature. The heated deep circulating water may be not reached at near depth in the studied survey area. Figure 2 shows the EC and accordingly the total dissolved solids (TDS) iso-contour of the survey area water distribution in the Graben. As it can be seen from the figure, the highly mineralized water localizes on the straight line intersects Selçuk, Belevi Eskioba, Elifli and Bayındır.

2.1 Flow Direction

Water in the high plains aquifer system generally moves from west to east but locally moves from south to north. The physical measurements and isotopic analyses, shows reverse flow directions, from the two flanks of the Graben to low altitudes in Küçük Menders Graben. Recharge to the aquifer system is by precipitation that falls directly on basin floors and by snow melt that runs off the surrounding mountains and is transported into the basins by tributary streams. The streams lose much of their water by infiltration into the basin-fill deposits. The basin-fill aquifers discharge primarily to Küçük Menderes River that flow parallel to the long axes of the basins. Some discharge is to springs and by withdrawals from wells. Some of the shallow artesian/or pump draw wells in the Graben discharge moderate salinity but low temperature water. Withdrawals by wells located in Graben basin is capturing some of the water that previously discharged to the stream. If withdrawals are great enough, then the hydraulic gradient can be reversed, and water can move from the stream to the aquifer and then to the pumping well.

2.2 Ground Water Chemistry and Geothermal Interest

From the chemical analysis of the waters collected from springs, wells and drill holes, it emerged that the samples having geothermal interest are located mainly in the western part of the Graben. For the estimation of the probably temperatures at depth, there are high TDS indications from the waters of the artesian in the areas compromises Elifli, Eskioba, Belevi Selçuk and Bayındır (Figure 1 and Figure 2). The contribution of the remaining samples, which help us to understand better the mechanism of the circulation in the basin, does not show geothermal interest.

The waters which has geothermal clue in the region belong to the sodium-bicarbonate –sulfate type, while the salt content is relatively low reaching the value of TDS = 800 mg/1 (Table 1 and Table 2). As deduced from the geochemistry of the water samples, there exists not a constant relation between chemistry of the region ground water; this is mainly due to the changes of the concentration in Na and Cl ions. The Cl/Na ratio in the superficial cold waters is nearly 0.5, while in the water samples from Selçuk, Elifli and Kayaköy it observed to be greater (Cl/Na>1). From the T/Cl ratio it is clear that a change in the Cl concentration is connected with a corresponding change of the temperature at the surface.

Hydrologic chemical constituents and ratios of certain important chemicals (such as sodium, potassium, magnesium, calcium, silica and tritium) can be used to estimate much information. For example the amount of dissolved silica in the fluid samples can indicate the temperature, as the solubility of many silicates is temperate dependant. These types of surveys can also determine the specifics of whether the resource can provide information about its homogeneity and direction of groundwater flow, as well as any fouling issues that may become a problem in exploiting the resource.

The investigated water composition is plotted on Cl^- versus Na diagram (Fig.3), in comparison to a marine composition line. Such plots can help to evaluate the origin of thermal water solutes (Yildirim and Simsek 2003). If the sample plots along the marine composition line, their solutes may represent simple dilution of seawater or the dissolution of unfractionated marine aerosols in the recharge area. Derivations from the marine composition line may indicate that additional processes or solute sources were involved in generating the solute composition. The basin ground water does not plot on marine composition line. So additional processes or solute sources were involved in the basin.

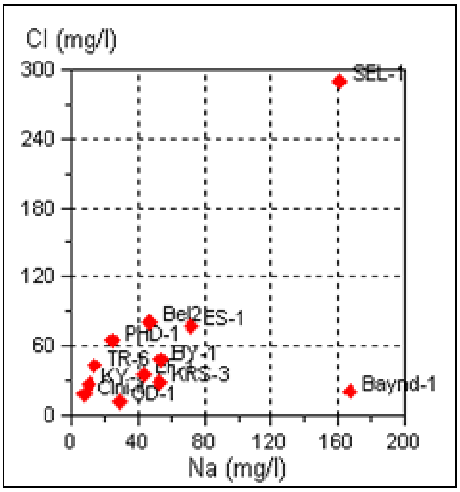
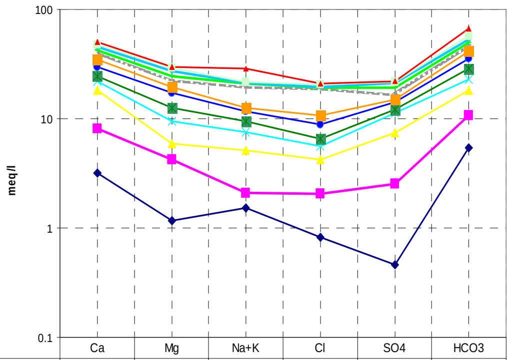


Figure 3: Na/Cl diagram of analyzed water samples in the region.

The non-geothermal water is generally characterized by high concentrations of sodium and low concentrations of potassium, having Na/K mass ratio of about 42 (atomic ratio of about 71). The some of investigated water Na/K ratios ranges from 10 to 30. The water hardness of these samples is generally high and it results principally from calcium ion. The total dissolved solids are approximately 1000 mg/l for western part along SW-NE section. The alkalinity values indicate that the major contributor to pH is bicarbonate ion and that these waters are highly susceptible to downward pH shifts (Yildirim 1989). The silica concentrations in the Graben waters except for Bayındır Kaplıca typically is in the range 12 to 26 mg SiO2/l which is too low to indicate high temperature. Artesian such in Elifli, Eskioba, Belevi and Selçuk which are involving relatively cool heat sources have a cation/anion pattern notably different from those wells which are not heat sources (Table 1 and Table 2). Most of the sampled sources, while having notably very close sampling temperatures, each share certain chemical composition patterns.

Dilution and mixing processes of geothermal fluid is discussed by using Cl/B ratio and piper, Schoeller, SiO_2-enthalpy and Langelier Ludwig diagrams. Silica–enthalpy is not applicable to the survey area due to lack of adequate hot sources in surrounding. Schoeller diagram of investigated region waters sources are shown in Figure 4.

Result of chemical analyses which are presented in Table 1; reveal that total dissolved solids of districts water range from 340 to 1000 mg/l. The most abundant solutes are Ca and HCO_3 while Na and SO_4 are also prominent ions (Figure 4). The chloride of the analyzed water is low. The pH values are neutral (7.0-7.7).



	Ca	Mg	Na+K	Cl	SO4	HCO3
Baynd-1	3.05	0.67	7.26	0.59	0.6	9.79
KY-1	2.45	1.58	0.498	0.76	0.31	3.46
Cini1	3.1	3	0.31	0.5	2.13	3.78
OD-1	2.1	1.83	1.212	0.33	2.56	2.29
Sel-1	5	3.17	6.97	8.16	1.6	5.37
PHD-1	5.4	2.25	0.984	1.83	0.71	6.15
Bel2	5	4.5	2.12	2.28	2.23	6.9
EF-1	2.6	3.08	2.06	0.98	0.85	5.69
BY-1	3.85	3.67	2.4	1.35	3.85	4.59
ES-1	9.92	1.65	2.98	2.17	4.83	7.59
TR-6	4.95	3.08	0.58	1.21	2.1	5.29
KRS	3.2	1.17	1.525	0.83	0.46	5.39

Figure 4: Semi-logarithmic Shoeller plots of the region springs.

2.3 Estimation the Characteristics of Geothermal System and Fluid Condition

Chemical characteristics of geothermal system can be defined by using chemical classification of hot spring, atomic ratio of non-reactive (Table 3) chemical components and isotope of water composer atoms.

In case of only sedimentary rocks reservoir Cl/B ratio is extremely low and HCO_3 concentration is extremely high. Both Cl/B ratio and HCO_3 concentration indicate different characteristic water presence in the surveyed areas. The gas content is not rich in Graben water sources. This may be due to disconnection of shallow ground water with deep reservoir.

Table 3: Atomic ratio of some chemical components.

	Na/K	Cl//Na	Na/Ca	Cl/HCO_3	Cl/SO_4	Cl/B
KRŞ	15.05	0.58	0.89	0.52	1.8	83
Tr-6	4.2	2.57	0.12	0.23	0.58	37.8
ES-1	18.9	0.74	1.77	0.29	0.44	51.7
BY-1	23	0.57	0.59	0.29	0.35	135
EF-1	9.3	0.56	0.84	0.17	1.15	28.8
Bel-2	7.48	1.22	0.75	0.33	0.99	26.2
PHD-1	12.3	2.01	0.34	0.29	2.58	22.9
SEL-1	20.8	1.26	2.6	1.52	5.1	816
OD-1	27.8	0.28	1.11	0.14	0.13	66
Cini-1	9.3	1.78	0.18	0.13	0.23	166
KY-1	26.7	1.58	0.39	0.22	2.45	30
Baynd-1	19.7	0.09	4.53	0.06	0.98	8.43

2.4 Classification of the Water Samples

The chemical analyses of ground water discharges are listed in Table 1. Generally, the most of the analyzed ground water in the survey area are characterized by high bicarbonate, low chloride low sulfate contents indicating bicarbonate type water. (Fig. 5 and Fig. 6). Of sampled water points, Eskioba, Beydağ and Odemiş artesian ground water contain relatively high sulfate. The high sulfate suggests that the sedimentary gases, particularly H_2S, oxidize near the surface, influencing the shallow ground water composition. The water chemistry suggests immature water beneath in the basin (Fig.7, and strong mixing with shallow ground water.

The chemical concentrations of Selçuk, Belevi and Eskioba ground waters are different from the water found in other parts of survey area. They have relatively high sulfate and chloride contents, indicating neutral pH water flowing sedimentary terrain and interacting with shallow ground water. The Eskioba sulfate-chloride water with high bicarbonate concentrations presumably is a result of sedimentary gases mixing with brine water and then influencing shallow ground water. The most important hot springs (from the geothermal point of view) appear mainly along the zone extending between 530,000 and 560,000 easting coordinates in SW-NE direction (Fig. 1). According to measured conductivity these springs are situated on straight line from South to north (Fig. 2). This weak geothermal anomaly is located almost at the most western part of Küçük Menders Graben.

The scarcity of vigorous thermal manifestations in such an active Graben is probably due to the hydrogeological conditions: the superficial fresh volcanic products which are generally the most important element of geothermal system is not present in the near depth of the studied areas. The area having a particular geothermal interest is located on the north side of the Bayındır city, as is clear from the measured temperature. From the geochemical point of view, the NE-SW extensional zone compromising Belevi-Eskioba-Bayındır presents a favorable geothermal interest and has a priority for future exploration. In this area there probably exist geothermal fluids at least of medium enthalpy, at economic depths. Hydrothermal system in the lower part of the Graben (valley) may be masked by superficial cold water at shallow depths. The area could probably have a geothermal interest at greater depths, but it is not possible to consider this area as a realistic target for electricity generation.

The classic Langelier Ludwig diagrams for studied area chemistry are shown in Fig. 5. The diagrams are divided into four divisions and samples are generally distributed as follows. In the first SW are found the earth alkaline (Ca-Mg)-bicarbonate waters, generally linked to shallow circulation; in the second SE the alkaline (Na-K)–bicarbonate; in the third SW alkaline-chloride waters occur, normally considered of deep origin; in the fourth NW, the earth-alkaline-sulfate ones. According Langelier Ludwig diagram, all the samples of Küçük Menderes Graben area except for Bayındır Kaplıca, Selçuk and Ödemiş water samples (Baynd-1) fall in the earth alkaline (Ca-Mg)-bicarbonate waters division which linked to shallow circulation. The Bayındır Kaplıca shares the alkaline–bicarbonate- water characteristics. Selçuk (Sel-1) and Ödemiş (ÖD-1) fall in alkaline and earth alkaline–Cl-SO_4 categories divisions.

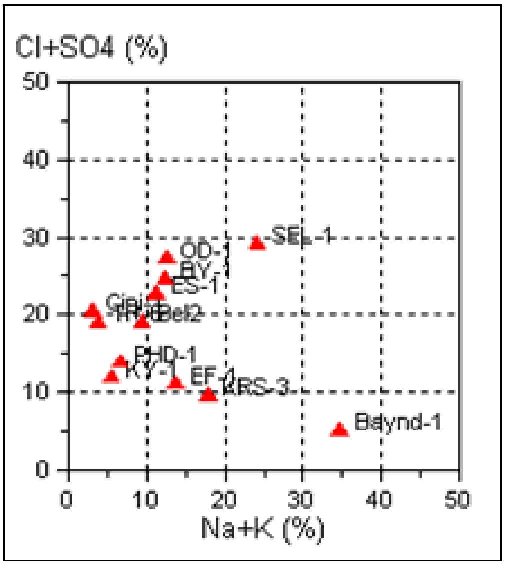


Figure 5: Na+K versus Cl+SO4 diagram.

From Piper's Diagram (Fig 6), it is evident that all representative samples show a homogeneous group of calcium-magnesium bicarbonate type waters. This type of water points scatters on the most part of investigated area. Despite their homogeneity some interesting difference can be observed. In the diagram it is evident that, as the Cl decreases, the Mg and sulfate increase, where as Na, Ca and HCO_3 decrease. This characteristic is not linked to geothermal futures but should be considered during geochemical investigation.

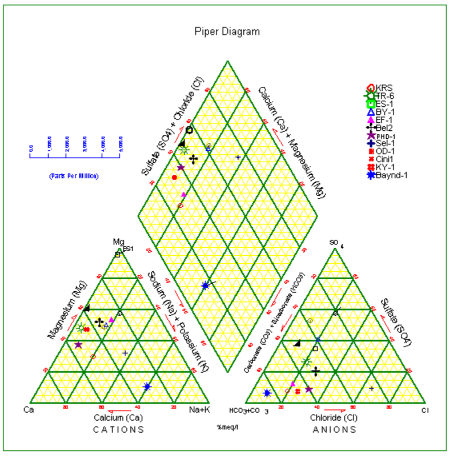


Figure 6: Piper diagram of analyzed water in the area.

3 THE GEOTHERMOMETRY APPLICATION

In general, the geothermometers of SiO_2, Na-K, and Na-K-Ca are used to calculate the probable reservoir temperature of the deep-origin fluids. If the conditions favor applying the geothermometers based on the content of the dissolved SiO_2 and the relation between the Na-K-Ca elements, the probable temperature of the fluids at depth can be calculated. The Na-K-Ca and Na/K geothermometer is not applicable for investigated sample water in the Graben. Because, the Graben ground waters display immaturity on the Giganbach ternary cationic geothermometer evaluation (Fig 8). Silica compound can not be in the form of quartz at the practically measured temperature of the sampled water sources. So, only chalcedony geothermometer is applied to the analyzed water samples. We deduced as indicative values of the original temperature of the fluids 40°C - 65°C, by chalcedony geothermometer for Bayındır and similar chemistry Graben waters such as Selçuk Belevi, Eskioba and Elifli. For some extent, Beydağı can be included to the mentioned group of waters.

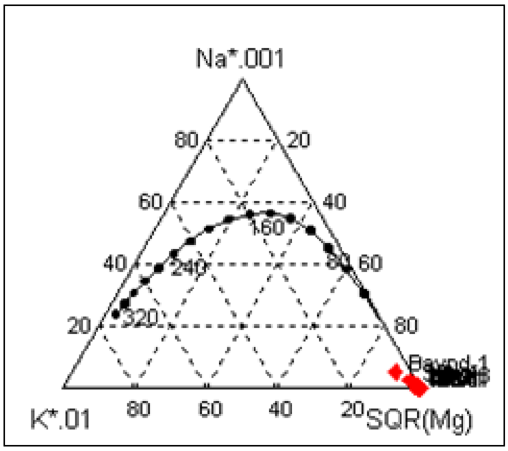


Figure 7: Gigenbach t-km and t-kn geothermometers plots.

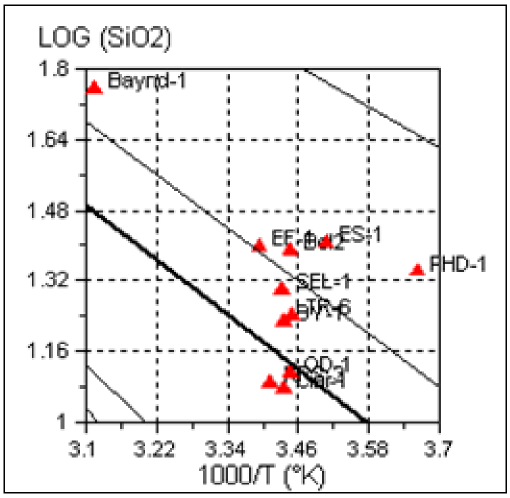


Figure 8: Chalcedony geothermometer plots.

4. ISOTOPE APPLICATION

The tritium content of the shallow ground waters in the survey area is low and does not correlate with electrical conductivity (Fig. 9). The tritium concentration of the Küçük Menderes Graben ground waters varies between 2.55 TU and 3.82 TU (Table 4). In old ground water system the tritium should correlate negatively with conductivity (Yildirim N. and Güner İ. 2005). The higher the conductivity (mineralization) is the lower tritium content of the related water must be. Independent from mineralization, all surveyed water samples contain very close tritium concentration. So, mineralization degree of examined water samples depends on the terrain that the water circulated in rather than the time of staying in underground (Simsek, S. 20003). From tritium content of view, the mixing phenomena of old and young member waters in the survey areas can be inferred.

Table 4. Tritium content of sampled waters.

	(TU)	Analyses Error(±)	Temp °C	Cond. µs/cm
Yağcılar (Yağ-1)	3.5	0.29	20	883
Belevi (Bel-2)	3.82	0.29	17	1129
Yakapınar (Y-1)	3.50	0.28	18.2	785
Pehlivanlı (PHD-1)	2.55	0.27	19.7	890
Kürşat (KRS-1)	3.18	0.28	19.9	768
Elifli (EF-1)	3.6	0.29	21.5	772
Eskioba (ES-1)	2.94	0.28	20	1260
Besi Çiftliği (-6)	3.79	0.28	19.2	787
Young End mem.	6.5	0.42		750
Old End Mem.	0.0			

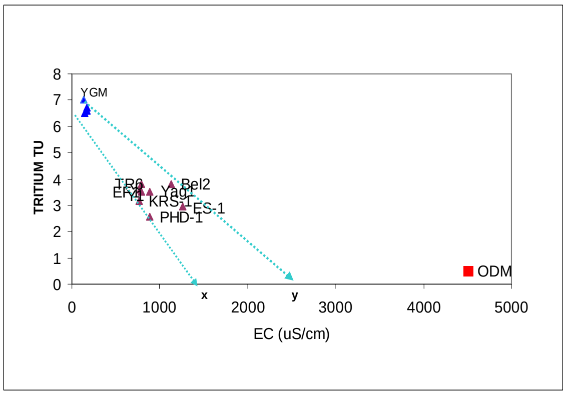


Figure 9. Characterization of the deep water by means of tritium and EC graphic extrapolation.

All the analyzed samples show an intermediate tritium value between young and old members water in the field (Fig. 10). Considering the tritium concentration of young end member (6.5<TU) and supposed mixture for surveyed ground water is so large. The negative or positive correlation between tritium of ground waters and their physical and chemical parameters allow us to define the chemical composition of the original hot deep water of each district by means of extrapolation. If the mixing of shallow and ground water pheromone have not occurred, the conductivity of unmixed water would be in the range of 1500 µS/cm - 2500 µS/cm at depth in the Graben.

Figure 11 shows the tritium and SiO_2 concentration relation of sampled water sources. According the extrapolation between tritium and silica concentration of shallow ground water, the silica content of deep unmixed ground water in the Graben is 25 mg/l -45 mg/l. This silica concentration of ground water refers to 40°C - 66°C by silica chalcedony geothermometer.

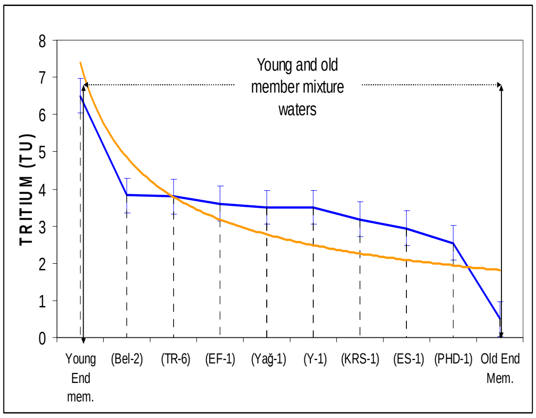


Figure 10. Tritium content correlation between young and old members water.

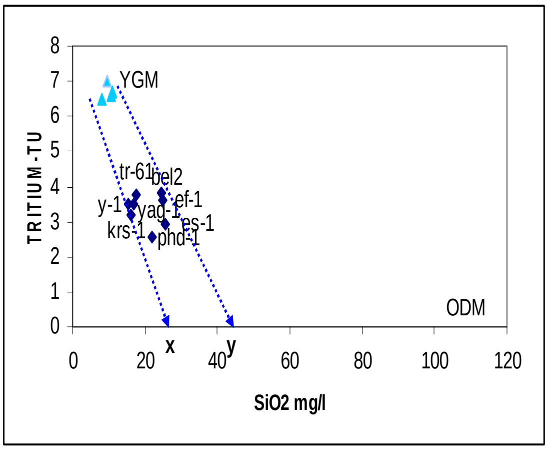


Figure 11. Characterization of the deep water by means of tritium and SiO_2 graphic extrapolation.

5. CONCEPTIONAL MODEL

According to the survey result discussed above, the hydro geochemical model on exist water flow patterns and on water temperature was made as shown in Fig. 12. The model can be summarized as follows: This model shows that three kinds of water exist in Küçük Menderes Graben. The water of low temperature and rich–HCO_3 at shallow level originates only from groundwater precipitated on the basin floors and by snow melt that runs off the surrounding mountains (JICA 1986). This water is transported into the basin by tributary streams. The streams lose much of their water by infiltration into the basin-fill deposits. As described in the previous sections this kind of water in the basin does not carry evidence that they circulated deep or mixed with ascending hot water. The apparent circulation time of this kind water in all over the Graben are considered to be younger than 54 years (Simsek 1986). This must be due to mixing of deep old and shallow young water at near depth (Simsek et al 2000). This water hardly flows directly into deeper HCO_3 -(Cl) type fluid reservoir. The location of leaking of Cl-rich water is not clear but it is possible to assume that the leaking spots is on line intersects Selçuk Belevi Eskioba and Bayındır Kaplıca. Because, waters on the intersection line contain higher Cl than surrounding waters in the area. The water of very little Cl-rich, leaking from deepest level in the Graben and represents the system hot fluid seems to flow into Bayındr kaplıca hot spring area.

The deep temperature of this water is calculated to be 49°C -70°C by using the tritium value of mixture water which helps to infer original SiO2 content. According to geochemical model, the usable geothermal resources in the Graben will not be limited to shallow hydrothermal reservoirs. The deep temperature of the original water (Cl-rich) is not traceable since the deep Cl-rich hot water can not reach the surface directly. Simple SiO_2 mixing model is not applicable to the system since all sampled water points contain very close SiO_2 concentration.

6. CONCLUSIONS

In the Küçük Menderes Graben areas, more than 34 cold and highly mineralized cool springs and artesian discharges were investigated. Using field situ measured data on temperature and chemical composition, 12 water samples for complete chemical analysis and 8 samples for tritium analysis were collected.

There are three kinds of water in the survey areas: Cl-rich earth alkaline bicarbonate, SO_4-rich earth alkaline bicarbonate and Cl-rich alkaline Na+K-HCO_3) waters. Water from most discharges shows of weakly neutral earth alkaline Ca-HCO_3 (-Cl) type. Piper, Scholler and stiff diagram plotting show the same Na- chemical characteristics patterns. The dominant cation in some water points is Na+K and in some is Ca. The dominant anion is HCO_3 in all sampled water kinds. The second anion is SO_4 and Cl respectively.

The tritium isotope shows that all the water kinds in the Graben a mixture of shallow and intermediate level ground waters. The two end member of the mixture composers are of meteoric origin.

Cationic geothermometer which depends on Na-K-Ca interactions is not applicable to the field waters. Because all the examined water found to be in immature characteristics from the side of this elements. So only chalcedony geothermometer is applied to the surveyed field water (Yildirim and Güner 2005). According to silica content which inferred from tritium extrapolation graphic, 40-70 °C deep reservoir temperature was calculated for the Graben geothermal system.

According to the CO_2, Ca^{2+} and HCO^-_3 ions contents and pH values, the field fluid tends to form $CaCO_3$ scaling. Also, the Langelier Ca equilibrium calculation shows that the field water chemistry has scaling tendency.

The gas content composed of CO_2 is not encountered in the water hosting levels of the Graben. The gas content of the fluid will be low.

The water of very little Cl-rich, leaking from deepest level in the Graben and represents the system of hot fluid seems to flow into Bayındr kaplıca hot spring area. The deep temperature of this water is calculated to be 40°C - 70°C by using the tritium value of mixture water which helps to infer original SiO2 content.

The location of leaking of Cl-rich water is not clear but it is possible to assume that the leaking spots is on line intersects Selçuk Belevi Eskioba and Bayındır Kaplıca. Because the water on this intersection line contains higher Cl than surrounding water spots.

From the geochemical point of view, the Selçuk, Belevi, Eskioba and Bayındır intersction line seems to be the most promising geothermal section in the Küçük Menderes Graben system.

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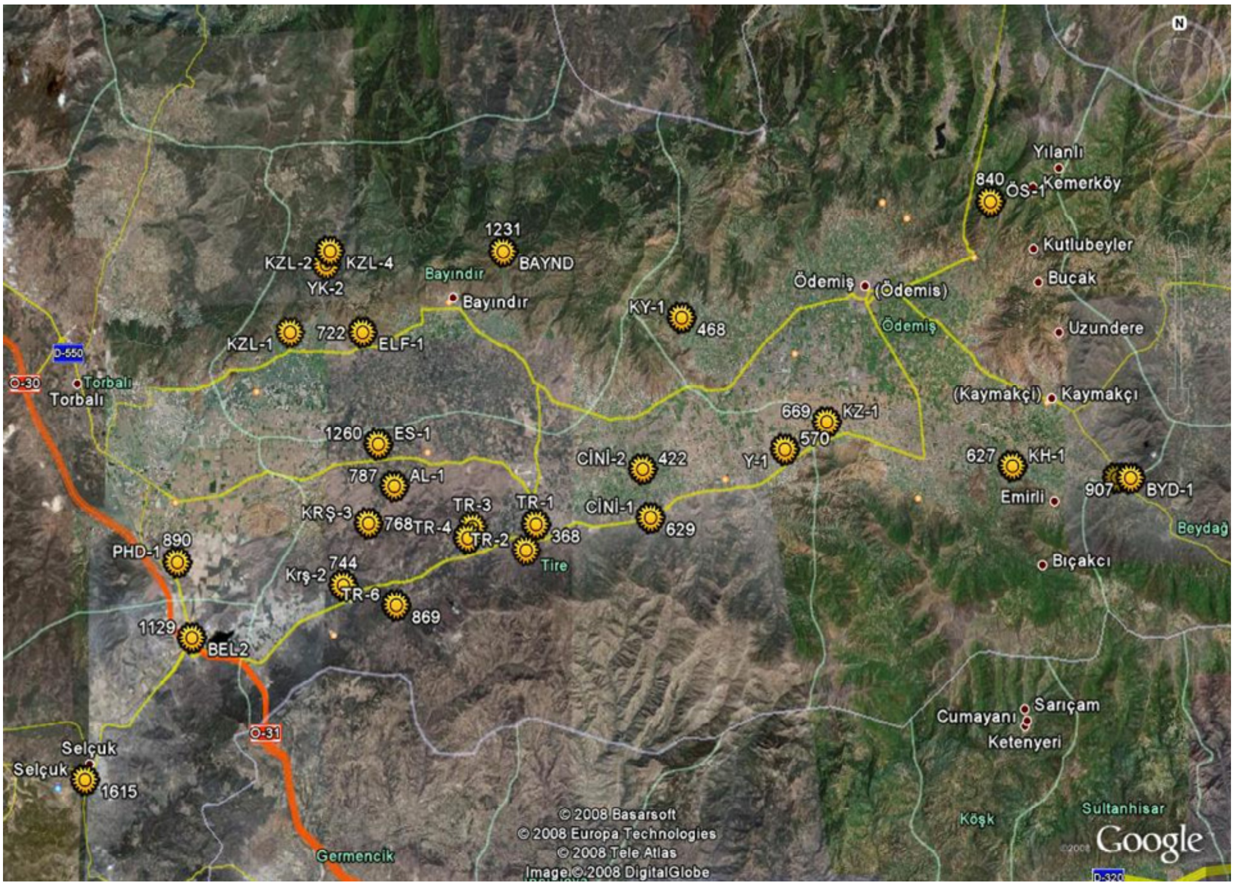

Figure 1: The location of the all examined water sources in the studied region.

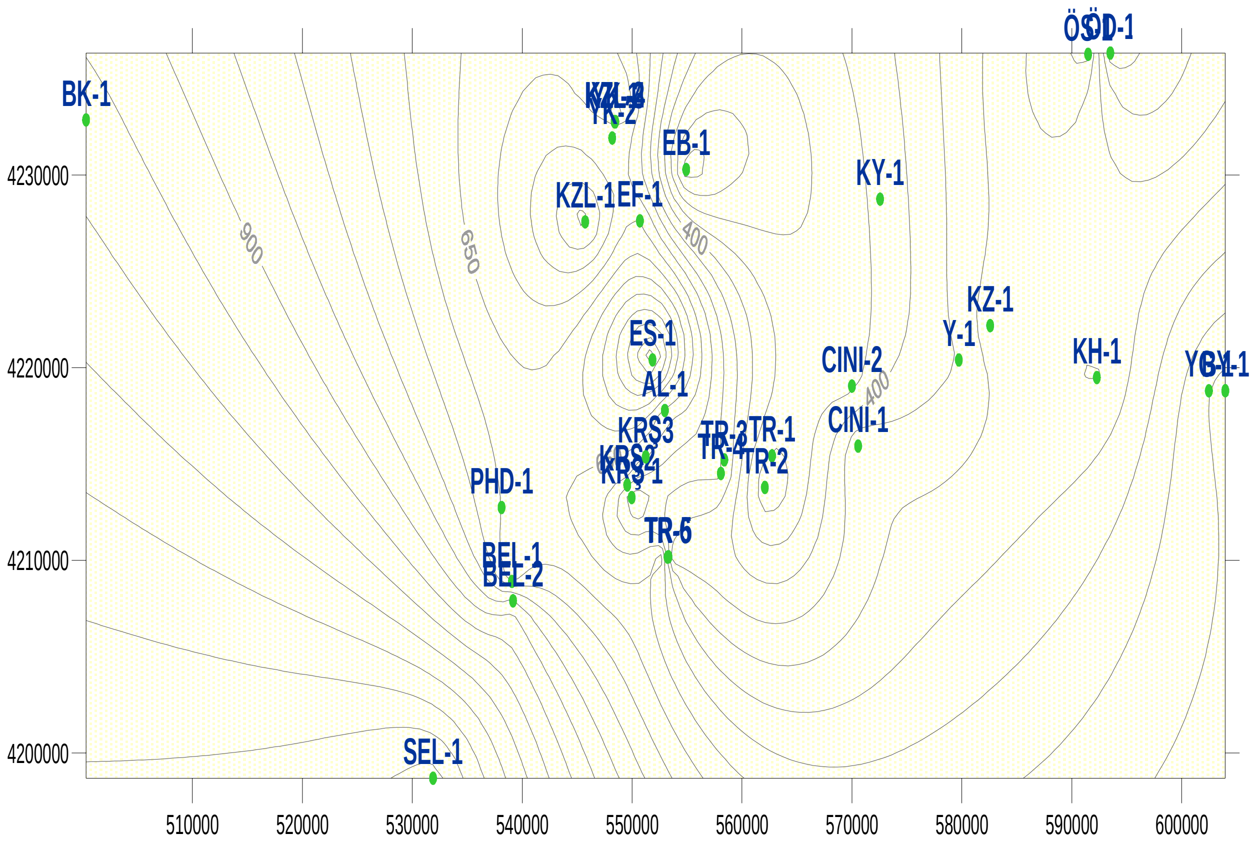

Figure 2: TDS distribution of sampled resources.

Table 1: Field physiochemical measurements of the all examined water resources in region.

	Field Name	Sample.	Coordinates		Sampling	T °C	pH	EC	TDS mg/l	Salinity
1	Kürşat	KRŞ 1	4213260	549959	01/05/2008	17	7.89	543	428	0.3
2	köyü	KRŞ2	4213910	549556	01/05/2008	19	7.34	744	587	04
3		KRŞ3	4215372	551239	01/05/2008	19.9	7.07	768	607	0.4
4		TR-1	4215426	562732	02/05/2008	16.7	7.27	368	291	0.2
5	S-14-15	TR-2	4213785	562076	02/05/2008	15.8	6.90	323	256	0.2
6		TR-3	4215215	558390	02/05/2008	20.8	7.71	625	494	0.3
7	Çayırlı	TR-4	4214510	558074	02/05/2008	18.2	7.53	644	510	0.3
8	ad	TR-5	4210184	553308	02/05/2008	16.5	7.33	523	412	0.3
9		TR-6	4210168	553225	02/05/2008	16.8	7.21	869	685	0.4
10	Aloba	AL-1	4217778	552979	02/05/2008	19.2	7.30	787	620	0.4
11	Eskioba	ES-1	4220406	551854	02/05/2008	20	7.19	1260	996	0.7
12	Ciniyeri	CINI-1	4215932	570563	03/05/2008	18.8	7.7	629	497	0.3
13		CINI-2	4219047	569997	03/05/2008	17.8	7.36	422	330	0.2
14	Yeyenli	Y-1	4220400	579722	03/05/2008	17.5	7.32	573	450	0.3
15	Kazanlı	KZ-1	4222183	582576	03/05/2008	18	7.51	669	530	0.3
16	Karahayit	KH-1	4219489	592280	03/05/2008	20.8	7.39	627	495	0.3
17	Yağcılar	YG-1	4218801	602473	03/05/2008	20	7.67	883	700	0.4
18	Beydağı	BY-1	4218803	603970	03/05/2008	18	7.32	907	720	0.4
19	Saha 19	ÖS-1	4236266	591487	03/05/2008	17	7.70	790	620	0.4
20	Ödemiş	ÖD-1	4236330	593511	03/05/2008	17	7.04	472	370	0.2
21	Kayaköy	KY-1	4228750	572560	03/05/2008	18.5	7.39	468	365	0.2
22		KZL-1	4227569	545730	03/05/2008	19	7.13	531	420	0.3
23	Saha 13	KZL-2	4232774	548403	03/05/2008	18.5	7.23	697	550	0.3
24	Kızılcaköy	KZL-3	4232756	548430	03/05/2008	15.4	8.25	343	265	0.2
25		KZL-4	4232778	548460	03/05/2008	19.2	7.43	812	642	0.4
26	Yakapınar	YK-1	4232756	548460	03/05/2008	19	7.21	680	535	0.3
27		YK-2	4231922	548187	03/05/2008	18.2	7.09	785	620	0.4
28	Elifli	EF-1	4227621	550709	03/05/2008	21.5	7.26	772	610	0.4
29	Elf-B yolu	EB-1	4230287	554918	03/05/2008	15	7.48	208	160	0.1
30	Bayındır	BK-1	4232861	500318	03/05/2008	38	7.00	1231	972	0.6
31	Belevi	BEL-1	4208903	539065	04/05/2008	17	7.40	832	660	0.4
32		BEL-2	4207903	539165	04/05/2008	17	7.31	1129	890	0.6
33		PHD-1	4212745	538120	04/05/2008	19.7	7.30	890	700	0.4
34	Selçuk	SEL-1	4198692	531890	04/05/2008	18.2	7.40	1615	1275	0.8

Table 2: Chemical analyses of the selected water sources in the studied region.

Analyzed parameters	KRŞ-3	TR-6	ES-1	BY-1	EF-1	BEL2	PHD-1	SEL-1	ÖD-1	Cini-1	KY-1	Baynd-1
T^{o} C	19	16.8	20	18	21.5	17.0	19.7	18.2	17	18	18.5	38
pH (20^{o}C)	7.34	7.21	7.19	7.32	7.26	7.31	7.30	7.40	7.04	7.7	7.39	7.00
ECl (µS/cm 25^{o}C)	768	869	1390	907	772	1129	890	1615	472	629	468	1231
Salinity (ppt)	0.3	0.4	0.7	0.4	0.4	0.6	0.4	0.8	0.2	0.3	0.2	0.6
TDS (mg/l)	524	616	945	680	562	814	632	1006	321	446	332	889
Total Hard ^{o}A	12.2	23.3	32.0	20.9	15.8	26.44	21.33	22.75	10.9	16.97	11.2	10.37
Temp Hard ^{o}A	12.2	14.8	32.0	12.85	0.0	26.44	21.33	22.75	10.9	16.97	11.2	10.7
Perm Hard ^{o}A	0.0	8.5	0.0	8.05	0.0	0.00	0.00	0.00	0.0	0.00	0.00	0.00
	mg/*l*											
K^{+}	3.5	2.3	5.9	3.9	7.3	4.9	2.9	12.5	1.67	1.2	0.7	13.8
Na^{+}	33	11	65	53	40.0	43	21	153	27	6.4	11	159
Ca^{++}	64	99	33	77	52	100	108	100	42	62	49.0	61
Mg^{++}	14	37	119	44	37.0	54	27	38	22	36	19.0	8
NH_4^{+}	0.03	0.03	0.01	0.03	<0.07	0.34	0.01	7.08	<0.05	<0.05	0.24	2.3
Li^{+}	<0.5	0.89	0.73	0.65	0.62	0.56	0.37	0.97	0.12	<0.1	<0.1	0.4
$Fe_{(T)}$	<0.05	<0.05	<0.05	<0.05	<0.05	<0.5	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
SiO_2	16	17.5	25.5	17.0	25.0	24.5	22	20	13	12	12	57
$B_{(T)}$	0.1	0.32	0.42	0.1	0.34	0.87	0.08	0.10	0.05	0.03	<0.1	0.7
HCO_3^{-}	329	323	463	280	347.0	420	375	328	140	231	211	597
CO_3^{2-}	0.0	00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cl^{-}	29.0	43	77	48	35.0	81.0	65	290	12	18	27	21
SO_4^{2-}	22	101	232	185	41.0	112	34	77	123	102	15	29
NO_2^{-}	<0.07	<0.07	0.04	<0.07	<0.07	<0.07	0.07	<0.07	<0.07	<0.07	<0.07	<0.07
NO_3	0.03	1.1	1.3	0.54	0.87	0.49	1.42	2.4	0.35	0.45	0.27	0.6

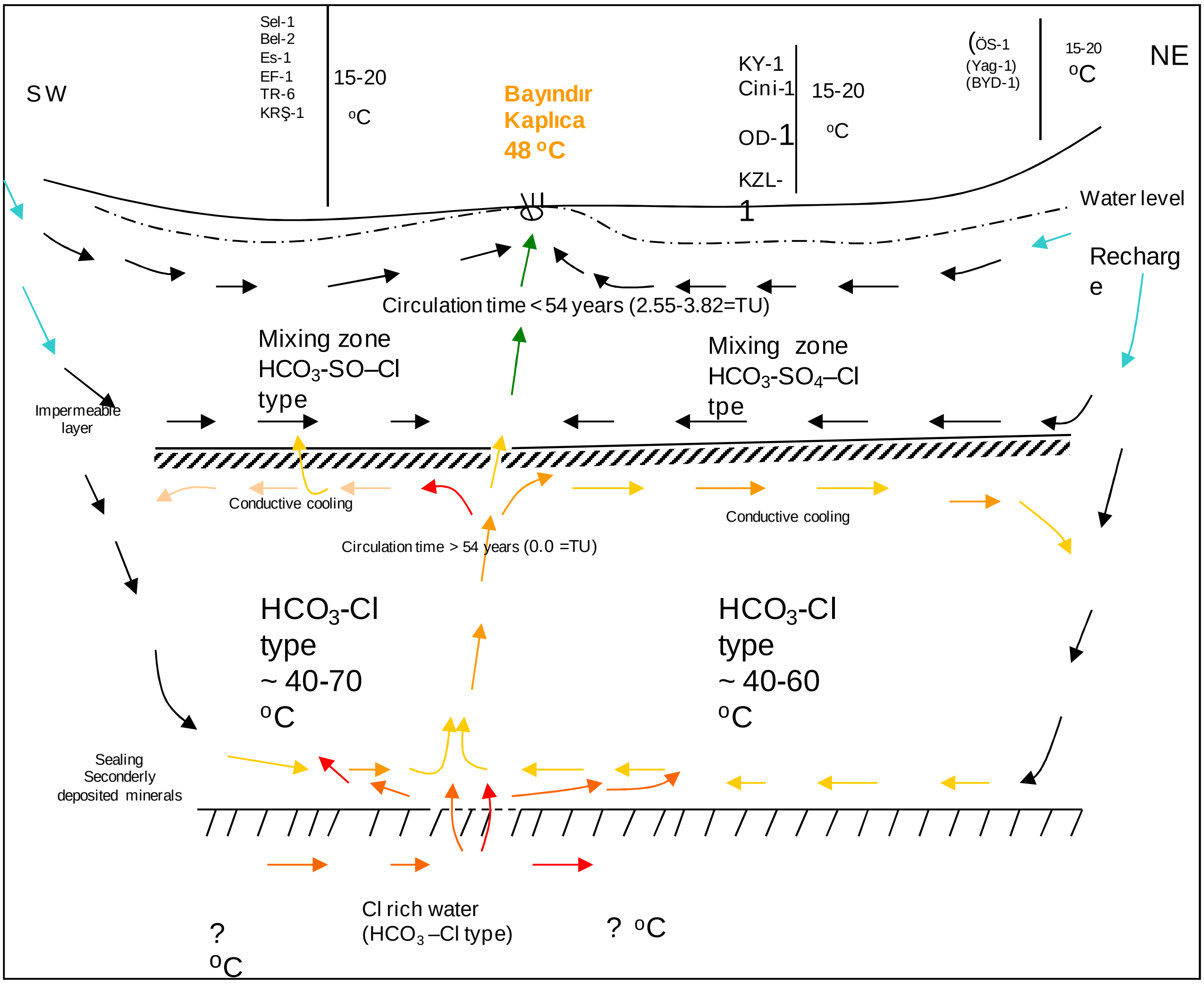

Figure 12: Conceptual model of studied region.