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High Enthalpy Geothemal Potential Possibility in SW of Büyük Menderes Graben, Turkey

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ABSTRACT

The objective of this study is partially to assess the geothermal energy potential of Ortaklar-Gümüşköy-Söke extension of Buyuk Menderes Graben, by means of geochemical surveys. The study area roughly located at the SW extension of Buyuk Menders Graben. A model for the geothermal area, derived from geochemical and isotopic data, indicates a promising geothermal potential, at least in northern part, near Gümüşköy region. From geochemical point of view, the Ortaklar-Söke geothermal field is not strictly connected to Gemencik-Hıdırbey geothermal field tectonics. Physical, chemical and isotopic investigation of hot and cold ground waters make it possible to construct the thermal water evolution from infiltration to discharge, including water-rock-gas interaction, heating and shallow water mixing. By means of the applied geochemical techniques 75-170 degree C geothermal fluid was found in the study area.

1. INTRODUCTION

The objective of this study is partially to assess the geothermal energy potential of Ortaklar-Gümüşköy-Söke extension of Buyuk Menderes Graben, by means of geochemical surveys. The study area roughly located at the SW extension of Buyuk Menders Graben. A model for the geothermal area, derived from geochemical and isotopic data, indicates a promising geothermal potential, at least in northern part, near Gümüşköy region. From geochemical point of view, the Ortaklar-Söke geothermal field is not strictly connected to Gemencik-Hıdırbey geothermal field tectonics (Simsek et al 2000).

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. The location of Sampled and analyzed resources in the studied areas are shown in Figure 1.

Geothermal surface activities in an area are broadly classified into three types:1) hot water dominated (hot spring), 2) vapor dominated (fumaroles, steaming ground altered zone), 3) non-manifestation area. The Ortaklar-Söke geothermal region compromises the first and the third categories (IAEA-TECDOC-641 1990).

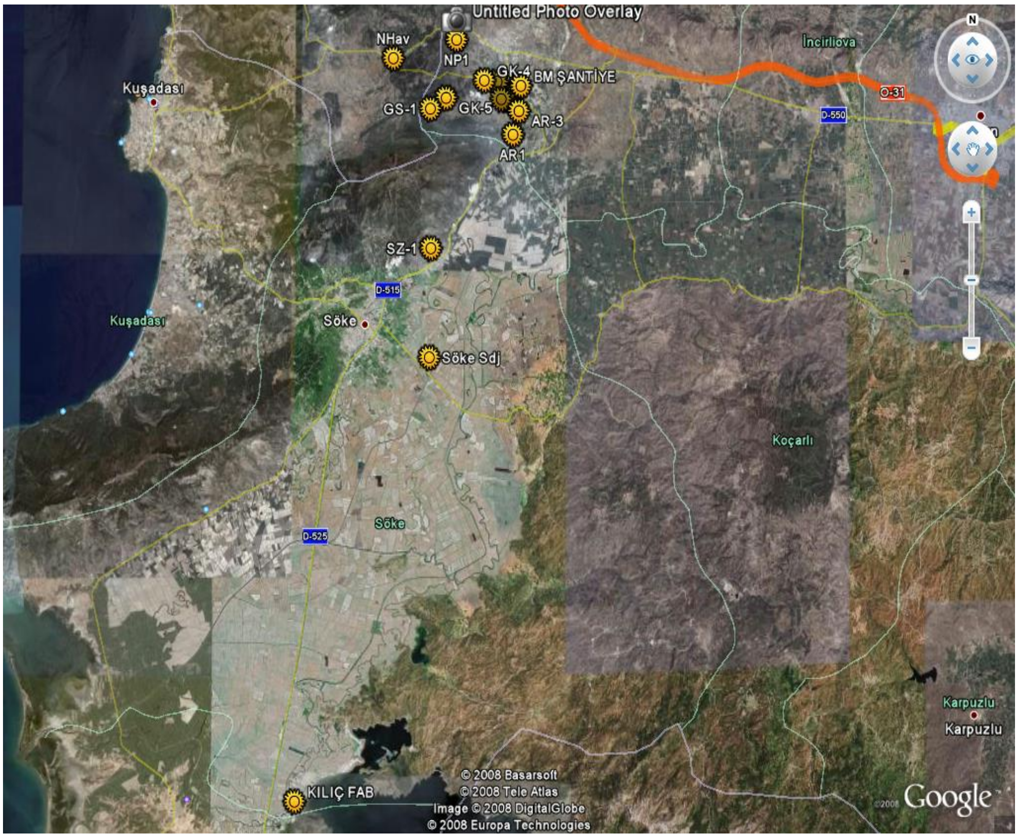


Figure 1. The location of the sampled resources

Ground-based field geochemical work was carried out in April 2008 at all hot discharges present in Ortaklar-Gümüşköy-Söke, NW extending of Buyuk Menderes Graben, on behalf of BM Muhendislik Holding Company. Some samples of cold waters were also collected at the same time from springs and streams adjacent to the thermal discharges. Hot waters points (25.5-41 ^{o}C) of this area did not receive serious attention untill BM Muhendislik Holding Company qualified with investigation right for the field. Therefore, detailed sketches or models for Ortaklar-Gümüşköy-Söke geothermal systems are not available before this study. Altogether 15 water samples were collected for chemical and isotopic analyses. Temperature, pH, conductivity, salinity and TDS (total dissolved solid) of 21 water points were measured in situ using portable meters. The results of field measurements are illustrated in Table 2. The six representative water samples for tritium (T) isotopes were analyzed in Turkey, Hacettepe University laboratoryThe major dissolved constituents were determined at YILDIRIM Geothermal Ltd. mobile laboratory by using following standard methods (Table 1).

Table1. Applied analytical Methods

Analyzed parameters	***Methods***
K^+	***Spectrometer***
Na^+	***Ion selective electrode***
Ca^{++}	***Titration***
Mg^{++}	***Titration***
NH_4^+	***Spectrometer***
Li^+	***Ion selective electrode***
$Fe_{(T)}$	***Spectrometer***
SiO_2	***Spectrometer***
HCO_3^-	***Titration***
CO_3^{2-}	***Titration***
Cl^-	***Titration***
F^-	***Spectrometer***
SO_4^{2-}	***Spectrometer***
NO_2^-	***Spectrometer***
NO_3	***Spectrometer***

2. GEOCHEMICAL PROSPECTING IN THE FIELD

Hot water sources in the Ortaklar-Gümüşköy-Söke geothermal field distribute mainly around Northern part of the field. Hot springs in this field except for GS-1 and GK-5 drillings are naturally discharging (artesian) or primer pump sucking. This observation indicates that the water discharging from hot spring in the valley of the Graben is recharging to the system from higher altitude area except for GK-5 and GS-1. Therefore, hot water from Oktay well GK-5 is drawn up by pump. Results of field measurements are shown in Table 2. This table indicates that hot water temperature at Gümüşköy was the highest and artesian discharges of around 30 ^{o}C are concentrated at the lower altitude of the Graben. From the features of the natural discharges (springs-artesian), the surface activity of the studied area seems to be high. The so called Ortaklar-Gümüşköy-Söke geothermal system falls in hot water dominated category. Since the investigated area categorized as hot water dominated type, hot water dominated prospecting methods are applied in the geochemical investigation of the field. Observable natural features in the hot water dominated field are characterized by liquid water as the continuous fluid phase. These waters of the investigated region include most of the constituents of ordinary water analysis such as Na, K, SiO_2, Li, Ca, Mg, F, Cl, SO_4, HCO_3, B, etc. Spring or wells of highest in temperature and discharge are generally highest in SiO_2, Cl, B, Na, K, Li, relative to surrounding non-thermal ground water (Güner and Yıldırım 2005). During the chemical survey, samples from natural springs and artesian were collected (Table 3). As mentioned previously, temperature, pH, conductivity, salinity and TDS (total dissolved solid) were measured in situ. New measured values were compared with available old ones, as for Gümüşköy hamam (GK-4).

Remarkable changes have not been observed between new and old chemical data. So, field water chemistry judged to be stable over passed time. The Cl ion concentrations were used extensively to see dilution trend of water points scattered over the area. Higher Cl concentrations near the main fault of the studied area follow relatively lower resistivity contours. Maximum Cl concentrations which are not caused from sea intrusion indicate permeable zones from deep to the surface as in around Gümüşköy (GS-1) and Oktay shallow drillings. But this is not true for southern part (Yeniköy region) of the field where sea water intrusion is evident.

2.1 Chemical Analysis Interpretation

The chemical compositions of the sampled ad analyzed hot and cold water sources are hown in figure 1 and Table 3. The equivalent ratios between various chemical components calculated from the data in Table 3 are shown in Table 4.Two hot water discharges in this field show weak acid while the remains show weak alkaline or natural pH and almost hot water belong to Na-Cl or HCO_3 type by the classification of dissolved major ions. All the examined spring waters except for Sazlıköy (SZ-1) are characterized by high concentration of Cl and HCO_3 ions and relatively low concentration of SO_4 as in Germencik and Hıdırbey geothermal fields. With these characteristics it differs from Kizildere geothermal fluids. In General, the deep water in reservoir of active geothermal field contains 1000-2000 ppm Na and a few thousand of Cl as main chemical components which are considered to be percolated from deep reservoir rocks. The Ortaklar-Söke geothermal field compromises those features with excess. it can be seen in the analysis table (Table 3), non-diluted or less diluted samples of the studied area (GS-1, GK-5) contain fairly high Na and Cl ions. The relatively low concentration of the main chemical components, especially chloride ion indicates that low activity of the system (temperature and quantity) or large dilution of deep hot water by cold ground water. It is not generally true, but according to these conclusions, the geothermal activity towards Argavlı and Sazlıköy seems to be diminished.

There are some cases that even hot water containing rich HCO_3 and belonging to HCO_3-SO_4 (-Cl) type may discharge from active geothermal system. Kizildere is an example. Kizildere geothermal fluid contains only as much as 120-140 mg/l chloride. In case of dilution of Cl rich deep water leaking from deeper level by cold water or by secondary reservoir water, the promising high temperature fluid can be expected at the deeper level than that of HCO_3 or SO_4 type reservoir supplying relatively low temperature fluid to hot spring of surface. Because of above explained fact, HCO_3 dominated and Cl rich Argavlı region seems to be not so much but a little promising. Figure 2 shows total dissolved solid (TDS) distribution map of the field. GS-1 and GK-5 drillings TDS richness consists of Na and Cl major ions while AR-3 TDS richness consists of Na and HCO_3 major ions. The dilution process takes place toward south-westward of the area.

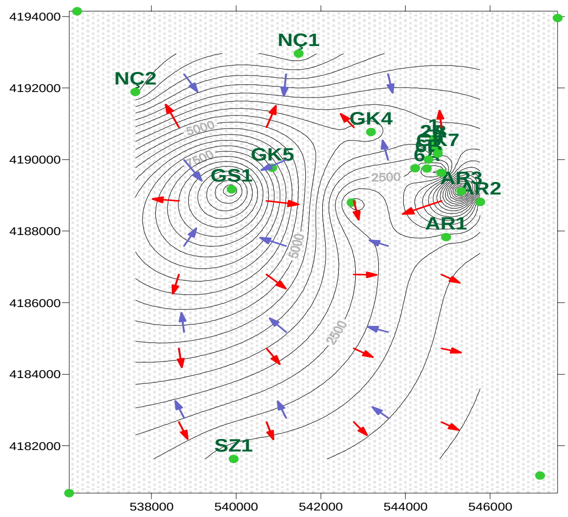


Figure 2: TDS distribution in studied field

Table 2. Field physicochemical measurements of representative water point in the investigated areas

No	Sample Code	Coordinates X	Y	Sampling date	T °C	pH	EC (25°C)	TDS mg/l	Salinity ppt
1	GK-1	4190578	544670	20/03/2008	29.7	6.8	3568	2430	1.9
2	GK-2A	4190404	544661	20/03/2008	30.7	6.8	3585	2438	1.9
3	GK-2B	4190404	544658	20/03/2008	32	6.67	3627	2466	1.9
4	GK-3	4190269	544761	20/03/2008	32.7	6.5	3683	2504	1.9
5	GK-4	4190769	543184	20/03/2008	41	7.2	4304	2930	2.2
6	GK-5	4189767	540853	21/03/2008	71.3	7.33	6880	4678	3.5
7	GK-6A	4189749	544505	21/03/2008	18.4	7.5	1440	980	0.7
8	GK-6B	4190000	544546	21/03/2008	16	7.5	3182	2160	1.7
9	GK-7	4190167	544763	21/03/2008	26.3	7.1	3782	2570	2.0
10	DR-G	4190167	544763	22/03/2008	22.8	7.6	3805	2700	2.1
11	GS-1	4189167	539893	22/03/2008	80	8.2	11560	7939	6.5
12	N1	4192962	541475	22/03/2008	16.4	7.8	590	410	0.3
13	Nhav	4191890	537618	22/03/2008	15.9	6.8	369	255	0.2
14	SZ-1	4181632	539940	23/03/2008	24.6	7.5	1135	783	0.6
15	AR-1	4187833	544959	23/03/2008	17.9	-	1712	1020	0.9
16	AR-2	4188815	545766	23/03/2008	19	8.35	1816	1235	0.9
17	AR-3	4189110	545316	23/03/2008	17	7.05	11140	9960	6.4
18	PS-1	4189630	544849	24/03/2008	19.9	-	1205	830	0.6
19	PS-2	4189756	544229	24/03/2008	18.6	-	2256	1740	1.3
20	PS-3	4188797	542724	24/03/2008	14.7	-	1245	860	0.6
21	NGB			22/03/2008	14.5	-	503	347	0.2

Table 3. Collected and analyzed water samples

Analyzed	GK-1	GK-3	GK-1	GK-5	GK-6A	GS-1	AR-2	AR-3	SZ-1
T °C	29.7	32.7	41	71.3	18.4	80	19	17	24.6
pH (20 °C)	6.8	6.64	7.5	7.33	7.53	8.2	8.3	7.05	7.5
ECl (µS/cm 25 °C)	3568	3683	4304	6880	1440	11560	1816	11140	1135
Salinity (ppt)	1.9	1.9	2.2	3.5	0.7	6.5	0.9	6.4	0.6
TDS (mg/l)	2430	2540	2849	4556	983	7939	1248	9686	917
Total Hard °A	32.83	38.24	24.58	22.2	33.80	7.01	47.47	63.99	31.78
Temp Hard °A	32.83	38.24	24.58	22.2	23.46	7.01	31.40	63.99	29.37
Perm Hard °A	0.00	0.00	0.00	0.0	10.34	0.00	11.07	0.00	2.41
	mg/l	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
K^+	40.6	40.6	53	102	4.1	208	2.1	78	1.7
Na^+	516	506	727	1337	43	2650	21	2380	27
Ca^{++}	177	214	130	123	184	32	102	230	153
Mg^{++}	35	36	34	22	35	11	144	138	45
NH_4^+	2.68	2.75	3.87	16.25	1.05	14.35	0.84	1.43	0.34
Li^+	1.1	1.1	2.3	2.7	0.8	4.6	0.8	1.2	0.3
$Fe_{(T)}$	<0.05	<0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
$B_{(T)}$	6.1	6.3	7.6	14.0	2.4	25.2	0.6	57	1.2
SiO_2	64	65	95	110	27	175	21	42	24
HCO_3^-	960	1036	923	1213	511	1482	713	5500	640
CO_3^{2-}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cl^-	667	659	945	1695	196	3456	106	1360	54
SO_4^{2-}	24	24	28	39	10	70	160	<5	7.0
NO_2^-	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
NO_3	1.8	1.9	1.25	1.75	0.9	3.0	1.1	4.5	1.7

2.2 The chemical Characteristics of Geothermal System and Fluid Condition in the Reservoir

Results of chemical analysis and Tritium isotope analysis for hot spring water and cold water were used for the following discussions in order to evaluate the Ortaklar-Söke geothermal system.

a) Estimation of characteristics of geothermal system and fluid condition in the reservoir
b) Estimation of reservoir fluid temperature
c) Assumption of reservoir rock and heat source
d) Prediction of scale deposition and environment impact of for seen fluid

Chemical characteristics of geothermal system are estimated by using chemical classification of hot spring, atomic ratio of non-reactive chemical components and isotope of water composer atoms (Table 4). Dilution and mixing processes of geothermal fluid is discussed by using Cl/B ratio and piper, Schoeller, SiO_2-enthalpy diagrams. From the high Cl/B ratio (Table 4) and low Cl/HCO_3 concentration, reservoirs of almost hydrothermal system in this field are considered to extend in not only sedimentary rocks but also in volcanic rocks. 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 in Gümüşköy Söke geothermal system are high. The gas content probably composed of CO_2 is rich in Argavlı but seems to be poor in Gümüsköy and Söke regions highly mineralized cool and hot geothermal fluids. CO_2 which is a major component of the HCO_3-rich mineralized water in Argavlı district indicates very high P_{CO2} and high HCO_3 in relating district reservoir. The high CO_2 concentration in the reservoir of Argavlı originates from decomposition of organic materials in sedimentary rocks. The chemical composition of the water sources scattered in the studied area confirms distinction of three main groups of high chloride thermal type, low/high mineralized cold type and moderate mineralized relatively cool water type.

Table 4: Atomic ratios analyzed water samples

	Na/K	Na/Ca	Cl/HCO$_3$	Cl/SO$_4$	*Cl/B*
GK1	14.18	2.49	1.19	37.57	*33.27*
GK3	13.76	2.01	1.09	31.82	*31.82*
GK4	16.53	4.79	1.76	45.63	*37.83*
GK5	13.63	7.29	2.40	58.76	*36.83*
GK6A	17.78	0.20	0.66	26.5	*24.84*
GS1	15.79	70.87	4.01	66.8	*41.72*
AR2	16.95	0.18	0.26	0.89	*53.75*
AR3	51.74	8.99	0.42	368	*7.28*
SZ1	*16.96*	*0.09*	*0.14*	*10.4*	*13.69*

The high temperature wells (GS-1, GK-5) of Gümüşköy are characterized by higher mineralization and dominance of the ions Na, K and Cl, HCO_3. On the other hand the mineralization of the "low temperature" springs of Argavlı (except for AR-3) and Sazlıköy is much lower and dominated by the Ca, Mg and HCO_3. Finally the natural artesian discharge of Gümüşköy shallow mixture water displays intermediate mineralization between two main groups and represents a NaCl- type (Figure 3).

The classic Piper diagram is shown in Fig. 4. The diagram is 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-sulphate ones. According piper diagram, among the samples of Ortaklar-Söke geothermal area, only Sazlıköy spring (SZ-1) falls in the earth alkaline (Ca-Mg)-bicarbonate waters division. The AR-2 and GK-6A share the earth alkaline –bicarbonate-chloride water characteristics. AR-3 falls in alkaline–bicarbonate and the remain sampled GS-1, GK-1, GK-3, GK-4 and GK-5 fall in alkaline-chloride categories division

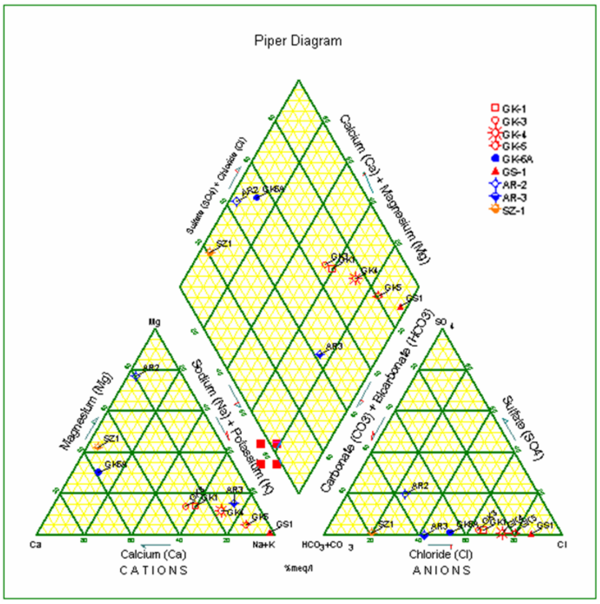
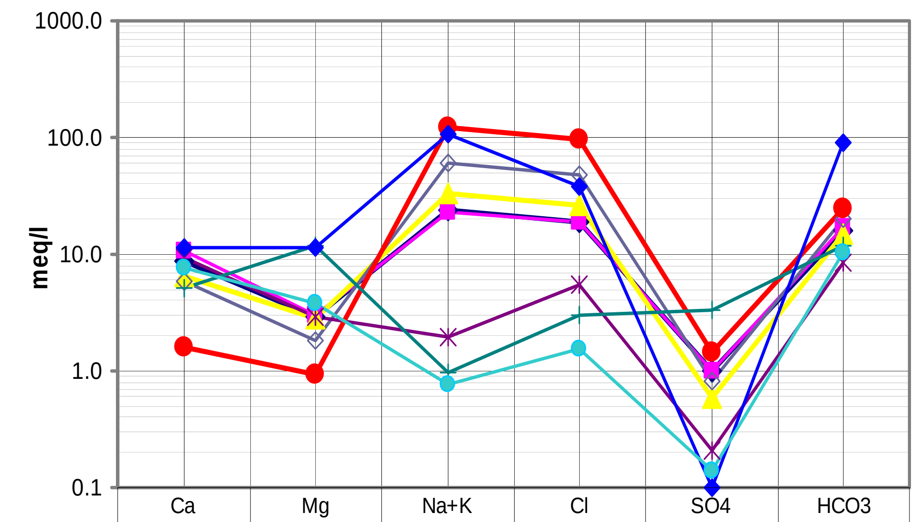


Figure 4. Piper diagram



	Ca	Mg	Na+K	Cl	SO4	HCO3
GK-1	8.9	2.9	23.60	18.8	1.0	15.7
GK-3	10.7	3.0	23.06	18.56	1.0	16.98
GK-4	6.5	2.83	32.97	26.62	0.58	15.1
GK-5	5.85	1.83	60.75	47.75	0.81	19.88
GK-6A	9.2	2.9	1.975	5.52	0.21	8.38
GS-1	1.6	0.92	120.58	97.35	1.46	24.29
AR-2	5.1	12	0.963	2.98	3.33	11.7
AR-3	11.5	11.5	105.48	38.3	0.1	90.2
SZ-1	7.65	3.75	0.76	1.52	0.14	10.49

Figure 3. Semi-logaritmic Schoeller diagram

2.3 Geotermometry application

During the exploration phase, geothermometry is used to estimate the subsurface temperatures expected to be encountered by drilling, using the chemical and isotopic composition of hot spring or shallow well discharges (Gulec 2005). Geothemometry is also useful in elucidating chemical reactions occurring in the zone of depressurization around wells that result from boiling and cooling by recharging cold water. Chemical geothermometers are developed on the basis of temperature-dependent chemical equilibrium between water and minerals under reservoir conditions the use of chemical geothermometers is based on the assumption that the water preserves its chemical composition during its ascent to the surface. The assumption of the preservation of water chemistry may not always be held. This is because the water composition may be affected by processes such as mixing and cooling. So silica mixing model was applied to the sampled water from the field. The most widely used chemical geothermometers are the cation–exchange and silica solubility geothermometers. The two kinds of the chemical geothermometers are applied to estimate the reservoir temperature of Söke ortaklar-Gümüsköy geothermal system. The calculated results are given in Table 5.

Table 5: Calculated temperatures by different chemical geothermometers

Sample Code	Silica Temperature °C			Alkali ratio Temperature °C			
	CHAL	QUAR	QUASL	Na/K(f)	Na/K(t)	NaKCa	Na/Li
GS-1	149	171	161	157	163	197	93
GK-5	116	143	137	157	163	188	78
GK-4	107	134	130	151	158	174	107
GK-3	85	114	113	160	165	169	84
AR-3	63	93	95	83	92	148	46
SZ-1	39	70	75	136	143	115	-

From chalcedony and quartz figures (Figure 5 and figure 6) illustration, can be seen that dilution processes exists in the field. That is why silica enthalpy mixing model is applied to sampled field water (Figure 8). Compared to the silica geothermometers, the Na/K geothermometer is less affected by processes like boiling and mixing; this is because ratios not absolute abundances are used in this geothermometer. Even though cation-exchange geothermometer are given fairly high and unreliable temperature for the some water sources in the basin. Figure 7 shows Na, K, Mg diagram for the studied geothermal system. The deep temperature for the most representative expletory well GS-1 is around 160 °C. Silica concentration/temperature distribution in the area is shown in Figure 8 silica counter map. All the studied region’s springs and wells present dilution phenomena as confirmed, in the corresponding diagram. GS-1 falls very close to the partial equilibrium curve confirming the reliability of geothermometric estimation. But all the remain sampling points (GK-5, GK-4, GK-3, SZ-1) fall far from equilibrium curve that is in the immature region of the corresponding diagram. So, the reached equilibrium degrees of those waters except for GS-1 are not reliable for geothermometric subsurface temperature estimation.

The temperatures that calculated from GS-1 water chemistry can be expected from the deep reservoir field.

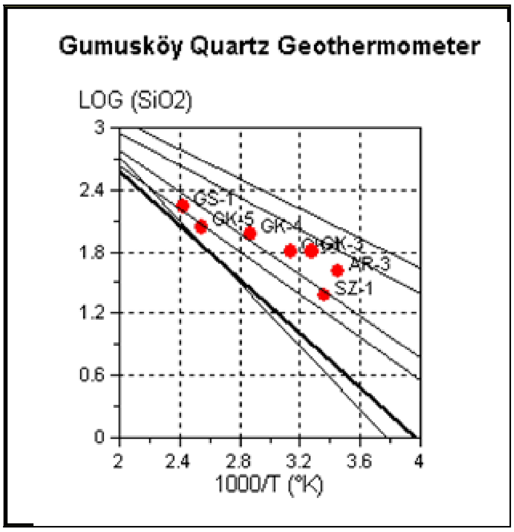


Figure 5: Quartz geothermometer plots applied to the field hot water sources

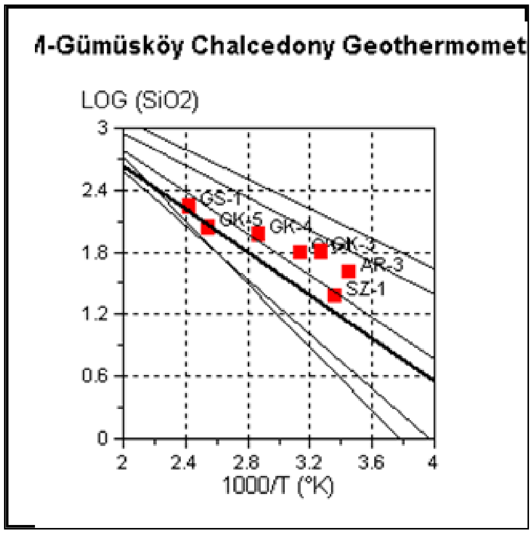


Figure 6: chalcedony geothermometer plots applied to the field hot water sources

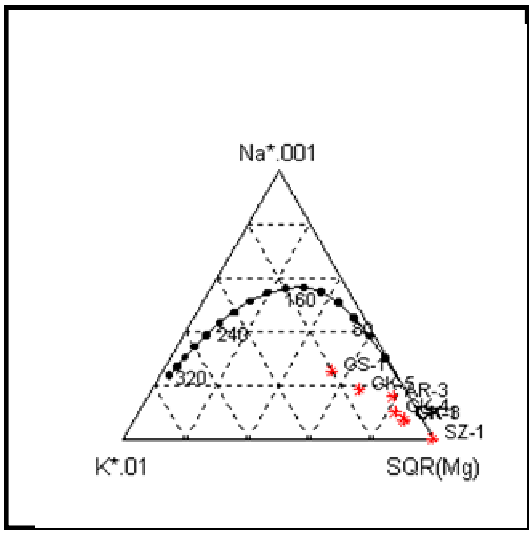


Figure 7: Gigenbach Na, K. Mg equilibrium t-kn, t-km geothermometer

2.3.1 Silica mixing model temperature

By means of chemical and isotopic data, mixing phenomena for all analyzed water points in the field is confirmed. So, silica enthalpy mixing model was applied and following deep reservoir temperature for Gümüşköy region of the field was found (figure 8).

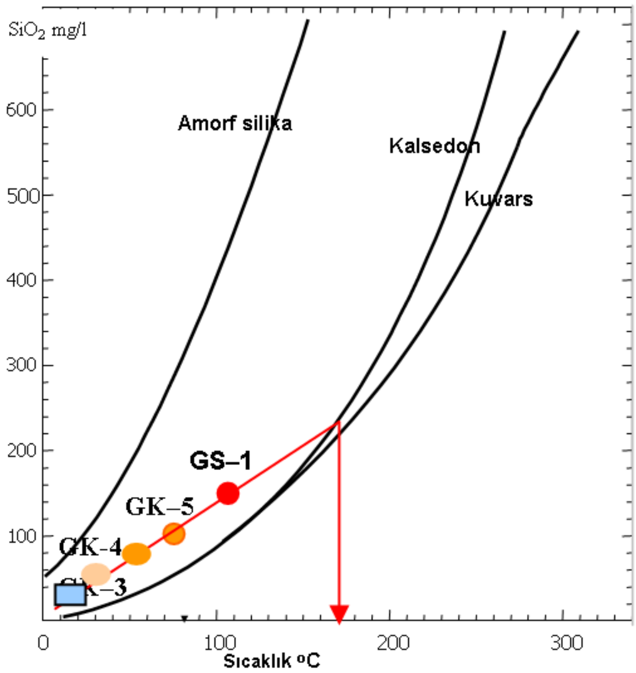


Figure 8: Silica mixing model for Gümüsköy region

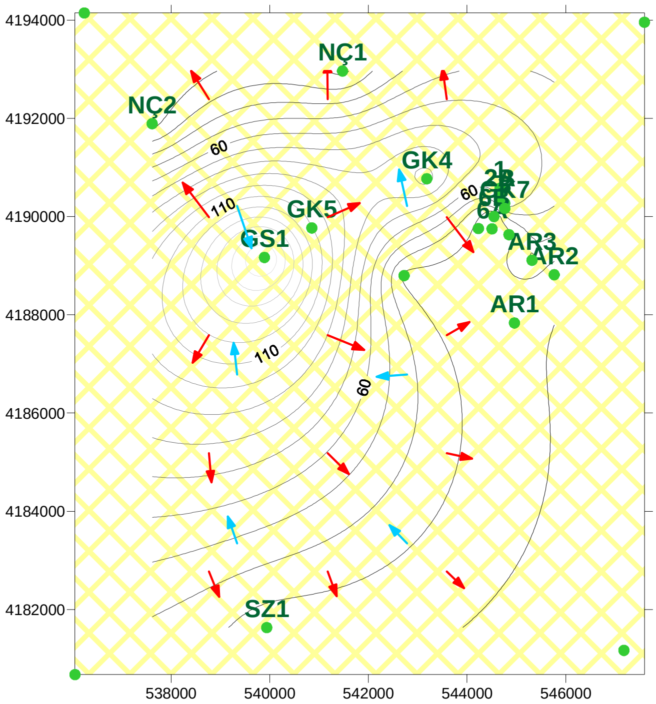


Figure 9: Silica concentration/temperature distribution in the area

2.3.2 Tritium Isotope

The tritium concentration of the Ortaklar-Söke geothermal field's cold and thermal waters varies between 1.32TU and 4.36TU. In the all districts samples the tritium concentration correlates negatively with its temperature and electrical conductivity excluded GK-3 which has lower temperature, lower electrical conductivity and also lower tritium concentration than GS-1and GK-5 (Table 6). This can be explained by mixing within outflow zone. In this case the calculated silica temperature of the sampled water would be lower than deep level fluid real temperature. For the survey area an old, tritium free deep seated thermal ground water (GS-1) and a young tritium- rich (AR-2) can be assumed end members for interpretation (Simsek 1997. The negative correlation between temperature/electrical conductivity and tritium of cold-thermal waters, excluding GK-3, allows us to determine the theoretical mixing end members.

Table 6. Tritium concentration of collected water samples

	T (TU)	Analyst Error	temp °C	**Cond. S/cm**
AR-2	4.36	0.36	19	1235
GK-6A	3.37	0.33	18.4	1440
GK-5	2.64	0.32	71.3	6880
GS-1	1.58	0.31	80	11560
SZ-1	2.68	0.33	24.6	1135
GK-3	1.32	0.28	32.7	3683
PrienCS	6.5	0.42	21.4	750

All the analyzed samples show an intermediate tritium value between young and old members water in the field (Figure 10). Considering the tritium concentration of young end member (6.5TU) and supposed mixture GS-1(1.58 TU) hot water, the mixing portion of young water is not so large. So, the expected deep level reservoir water temperature will not be much higher than the calculated one with silica geothermometer. The calculated 130 -170 °C deep level reservoir temperature with silica and cation geothermometers seems to be reasonable.

Figure 10 shows that thermal waters including GS-1 is a mixture of young end member and old end member water found at the surface and in the deep reservoir of studied area respectively.

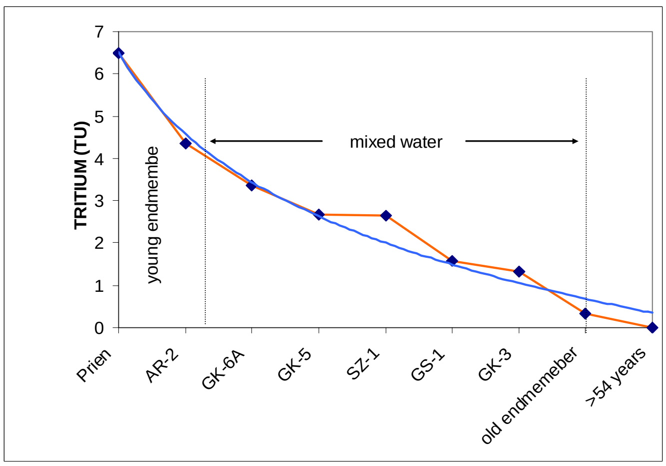


Figure 10: Tritium relationship between young and old end member waters

Figure 11 depicts the negative correlation between analyzed tritium and measured electrical conductivity of sampled water. The higher the conductivity is the lower the tritium values.

2.3.3 Prediction of Scale deposition

In some hot water geothermal fields like Kizildere and Germencik, mineral deposition occur along the artificial flow channels (pipes, plant and so an) associated with geothermal utilization schemes (Yildirim 1989).In the system of this field, the silica problem will not be problem, compared to Kizildere and Germencik, the silica concentration contained in the discharge water is relatively low. If the temperature of the system is found to be in order of 160-170 ^{o}C, around 200 mg/l Silica concentration of the original water is not going to increase at normal separation condition. This silica in the separated water will be under saturated with amorphous silica.

Scale maker calcium and bicarbonate ion concentrations are very high in the investigated field fluid. According to our practical experience in operation of geothermal fields in Turkey, if the deep produced fluid comes up with the same chemical characters to the surface, in this field also the calcium carbonate scaling will be inevitable (Yildirim and Simsek 2003). There are several methods to predict calcium scale formation. It can be predicted beforehand by using chemical data of examined hot water. One is method of saturation index S_{IC} [S_{IC} = (practically measured activity product)/ (thermodynamic activity product)] and the other is method of Langlier saturation index S (S = pH [measured] - pHs [calculated]. Calcium carbonate scale tends to deposit from the waters having high (positive) S_{IC} and S values. The saturation index formula developed by Langelier is as follows: (Table 7).

2.3.4 Geochemical Conceptual Model

Figure 12 illustrate the geochemical conceptual model of the whole studied field. From geochemical point of view, the fluid circulation in Söke-Gümüşköy geothermal field system can be summarized as follows: It is reasonable to consider that the meteoric water recharged from high altitude area permeates to deep level, mixes with sea origin saline water and is heated by heat conduction of rocks relating to magma (JICA 1986).

The heated water is considered to rise in fracture zones along faults and discharge from hot spring and/or artesian as in low altitude of Gümüşköy and Sazliköy districts. The geothermal fluid of the system is a mixture of meteoric and sea origin at different proportions depending on topography and tectonics of the field. According to chemical character, tritium content and correlation matrix analysis, the shallow GS-1, expletory well and almost all other discharges in the field is derived from deep reservoir by leaking through sealing zone fractures. Not any well or discharges in investigated field are taping its fluid directly from deep reaching main fault or from deep reservoir. GS-1 seems to produce geothermal fluid very close to original one. The other differs from the original fluid according to their dilution degrees. The most isolated or remote one from the original is Sazlıköy (SZ-1) hot spring. This spring can be considered to belong to separate reservoir. The water in Gümüşköy district is composed of meteoric and sea water origins. It is possible to infer that hot water in Gümüşköy district partially including GS-1, derives from secondary reservoir containing leaking Cl rich deep water through sealing zone located between main and secondary reservoirs.

Table 7: Langelier Saturation Indices

No. of	At boiling temperature (atmospheric pressure,	At its present temperature
GS-1	+2.30	+2.15
GK-5	+1.98	+1.63
GK-4	+1.85	+1.0
GK-1	+1.30	+0.35
GK-3	+1.14	+0.19
SZ-1	+1.95	+0.95

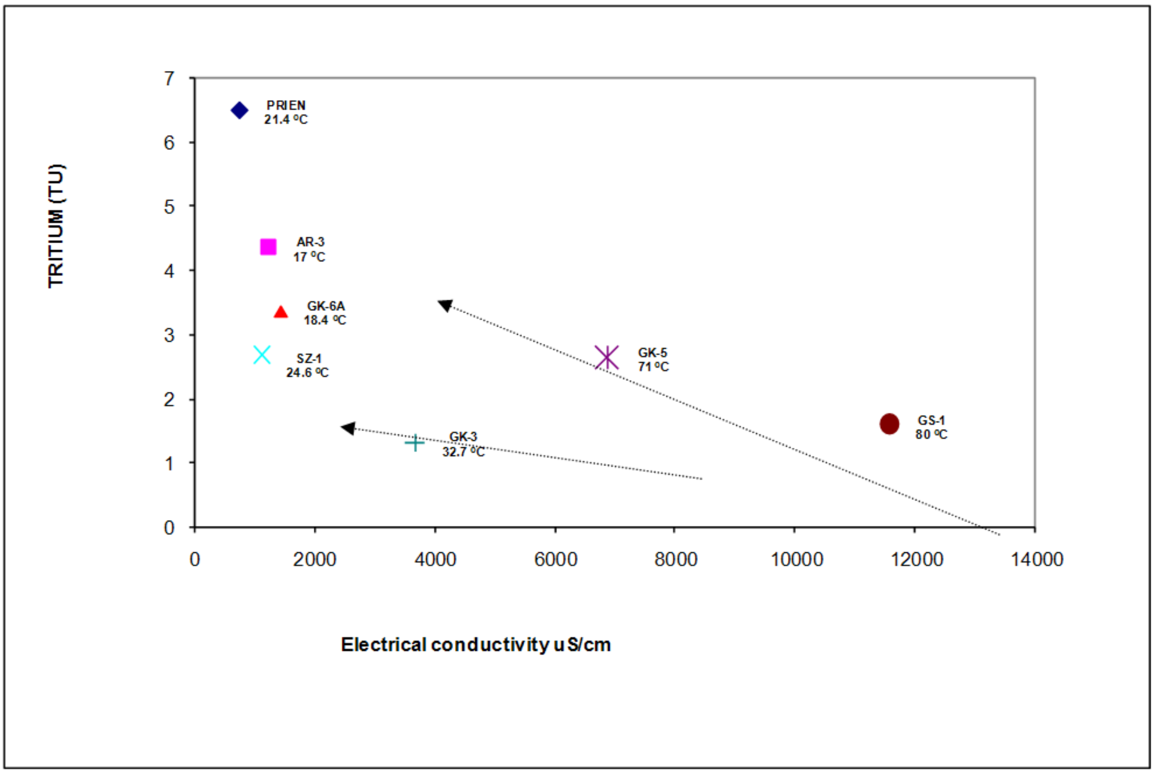


Figure 11: Relationship between electrical conductivity and Tritium

3. CONCLUSIONS

- In the Ortaklar-Söke geothermal area, there more than 20 hot and highly mineralized hot spring and artesian discharges. Using field 21 situ measured data on temperature and chemical composition, 9 water samples for complete chemical analysis and 6 samples for tritium analysis were collected.

- Hot and mineralized water from most discharges is of neutral weakly alkaline Na-Cl (-HCO_3) type. Piper, Scholler and stiff diagram plotting show the same Na-Cl (-HCO_3) type chemical characteristics. The dominant cation is Na and the dominant anion is Cl in the fluid. The second cation and anion are K and HCO_3 respectively.

- The tritium isotope and chloride data of some discharge including GS-1 show that the origin of the hot waters discharging from Gumüşköy district is a mixture meteoric and sea origins. The sea water share in the mixture is fairly low.

- According to T-SiO_2, T-Na/K and T-NaKCa-magnesium corrected geothermometers, the calculated deep reservoir temperature of the field ranges between 130-174 ^oC for silica, 136-160 ^oC for T-Na/K and 115-197 ^oC for T-NaKCa respectively. The geothermometers gave different reservoir temperatures in order of T-SiO_2>T-NaKCa> T-Na/K. This means there is no full equilibrium in the field fluid chemistry.

- 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 fluid chemistry has scaling tendency.

- When the hot water is underground, is in equilibrium with quartz. However the form of silica normally precipitated at the surface is amorphous silica. The difference in solubility between amorphous silica and quartz allows a considerable drop in temperature before the solution becomes saturated with respect to amorphous silica. So the silica precipitation will not be serious for Ortaklar-Söke geothermal brine.

- The gas content composed of CO_2 is rich in Argavlı but seems to be poor in Gümüsköy and Söke regions highly mineralized cool and hot geothermal fluids. CO_2 which is a major component of the HCO_3-rich mineralized water in Argavlı district indicates very high P_{CO2} and high HCO_3 in the relating district reservoir. The high CO_2 concentration in the reservoir of Argavlı may originate from decomposition of organic materials in sedimentary rocks.

- The geothermal fluid of the system is a mixture of meteoric and sea origin at different proportions depending on topography and tectonics of the field. According to chemical character, tritium content and correlation matrix analysis, the shallow GS-1, expletory well and almost all other discharges in the field is derived from deep reservoir by leaking through sealing zone fractures. Not any well or discharges in investigated field are taping its fluid directly from deep reaching main fault or from deep reservoir

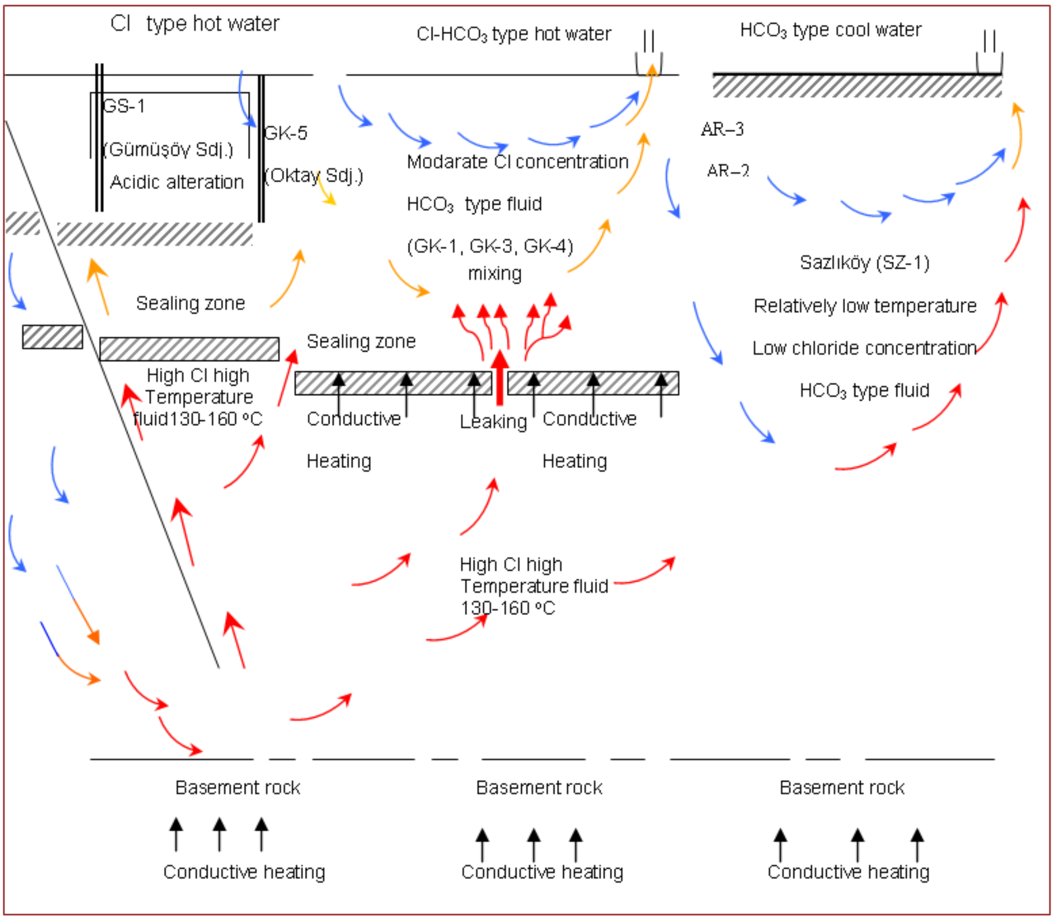


Figure 12: Connectional Model of investigated area

- It is possible to infer that hot water in Gümüşköy district partially including GS-1, derives from secondary reservoir containing leaking Cl rich deep water through sealing zone located between main and secondary reservoirs
- The BM, GS-1 expletory well and other discharge hot waters in the Gümüşköy geothermal region, seems to be derived from a reservoir of 130 -160 ^{o}C
- Last but not least, the geothermal activity in Ortaklar –Gümüşköy- Söke -Büyük Menderes Garaben Basin seems to be diminished towards S and SW directions
- In the most southern part of the area near Bafa Lake (Didim road junction), sea water intrusion is evident. The shallow warm wells drilled at that area, completely produces sea water origin.

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