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# DISCOVERING A NEW BURIED GEOTHERMAL FIELD WHICH HAVE BEEN FOUND OUT USING GEOLOGICAL-GEOPHYSİCAL AND GEOGHEMICAL METHODS IN UCHBASH-SHAPHANE, KUTAHYA WESTERN ANATOLIA, TURKEY

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**Keywords:** Geothermal, Gediz, Menderes Massif Shaphane, water-chemistry, magnetotelluric, resistivity, isotope, heat source, well, KSU-1, flow rate.

## ABSTRACT

The new buried geothemal area is located at near Ucbash (Shaphane) town, 5 km far from Gediz geothermal area at Kütahya province in Western Anatolia. The basement rocks of studied area comprise Paleozoic aged gneiss, schist and marble which belong to North- North-eastern margin of the Menderes Massif. These basement rocks are tectonically overlain by Cretaceous aged Dagardı ophiolitic melange. All these units covered by Neogene Quaternary aged sedimentary and volcanic rocks.
Geological (Detail geology, remote sensing, aerial photo studies, hydrothermal alteration) geochemical (hydrochemistry and hydrological isotope), geophysical (magnetotelluric and resistivitiy); well logging studies have been carried out in the study area.
There is no manifestatition in around the Shaphane buried geothermal area at the surface except Gediz Abide hot springs at 5 km south. Gediz geothermal area is one of the medium enthalpy geothermal areas in the western Anatolia. The hot spring temperature is 70-76 $^{o}C$ in the area. There are three production wells (301-542-752m) which have 78-93 $^{o}C$ geothermal fluid. Total thermal energy potential of the Gediz area is 27.57 MWt. Geothermal fluids have been used for thermal bath facilities. It can be suitable for district heating (equivalent 2700 dwellings).
The main aims of this study to define chemical characteristics of hot and cold waters to estimate relation between hot and cold water, calculate reservoir temperature using geothermometre and mixing models, clarify extending of recharging area estimate reservoir temperature with respect to water-chemistry, isotope, hydrothermal alteration studies; to define underground structure using geophysical soundings in Gediz geothermal field and in finally detect wheter or not presence of promising area around there by the the means of correlation each data compare with Gediz and probably promising area.
The fractured zones of gneiss form the main reservoir in the Gediz-Abide area. The cap rock of the geothermal reservoir is clay and marl stratas belonging Neogene aged lacustrine sediments and tuff deposited in NW-SE directional graben structure.
On the basis of water chemistry studies hot waters have been classified as Na-$SO_4$-$HCO_3$ type and cold waters Ca $HCO_3$ type. Silica-Entalphy and Chloride-Entalphy mixing models and silica geothermometer have showed that, original water temperature without mixing cold water in the range between 128-157 $^{o}C$ in the reservoir.
In addition to Chloride and $SiO_2$ iso-concentration maps, young tectonic activitiy and thick cap rock which formed Miocene aged lacustrin sediments indicate that promising area is the north. Magnetotelluric and resistivity studies were carried out at three profiles at the promising area. Two anomalies have detected in respect of magnetotellüric soundings. Anomalies were observed in each profiles. First one was near Gediz geothermal field and the second indicate promising area was 5km from the first, at the north. Reservoir possibilities are investigated using resistivity soundings at each profile. Two anomaly have been found on each profile which can be interpreta indicating reservoir according to resistivity soundings.
Evaluation of all studies which in carried out indicated that the promising area was suitable for one exploration well. So, Geothermal explaration well (KSU-1), have been drilled at 1330m depth in 2006. Reservoir rocks is marble and chalk-shist between 1100m-1330mand according to core samples and well logging. Geothermal fluid which have 216 T/h, flow rate and 90 $^{o}C$ (at the bottom 109 $^{o}C$) temperature were producted from the well. KSU-1

well have 13.81 MWt thermal potential. It can be suitable for district heating (equivalent 1400 dwellings), heating green houses, thermal bath facilities.

## 1. INTRODUCTION

Studied area is located at between Gediz Ilica (Abide) and Shaphane dag in Kutahya province (Figure 1).

Many researcher have studied about structurel position and character of the Menderes massive in detecting area. Schuiling, (1958-1962), noticed that gneiss is migmatite type that derived from the sedimantery rocks which have been intruded alkalies enriched magmatic liquids. Gneiss has dome structure and surrounded schist which metamorphizm degree has decreased from center to the marigine, schist is overlain by marble consists metamorphic boxite.

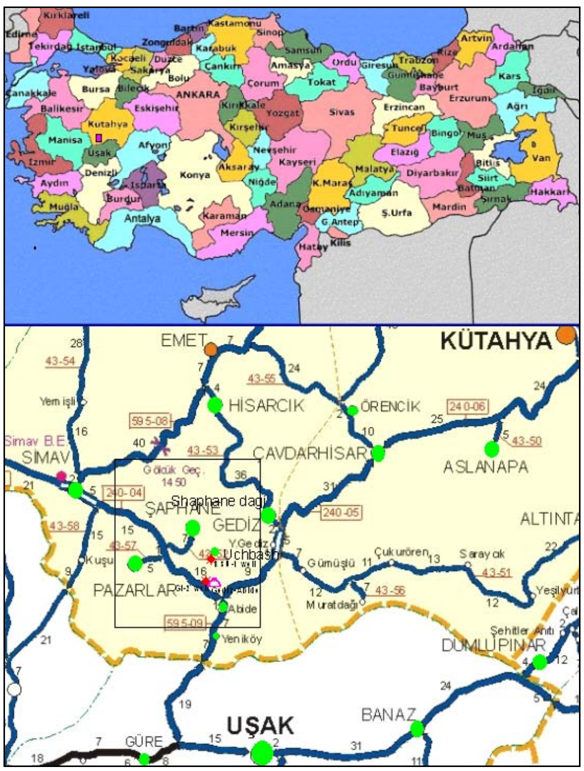


*Figure. 1. location map of the studied area*

Akdeniz and Konak, (1979), studied detail geology in the region near studied area. They noticed that, this metamorrrphic rocks are belong to North marigine of Menderes Massive and they were overlain tectonically by Cretaseous aged ophiolitic rocks called Dagardı Melange.

According to Izdar (1971), massive has two distinctive metamorphizm degree. The first one completed when Variscan Orogeny, the second had started when Alpine Orogeny. Auther defined that massive has dome type and composed of possibly Precambrien aged core rocks and Paleozoyic – lower Mesozoyic aged schist. Core rocks are represented Flaser gneiss, fine grained gneiss and biotite gneiss. Cover schists covered the gneiss with discordance as if it has lost with respect to new schistosity during Alpine Orogeny.

Erdogan ve Gungor (1992), noticeced that Cover schist which has rarely consist some mafic metavolcanics passing through Mesozoic aged carbonates rocks in northern margine of the Menderes Massive.

Petrological and geochronological studies were carried out by Bingol (1977, 1982) and geological studies have been carried out by Gunay at al, (1986) and Ercan at al (1978,1984, 1996) in the studied area.

There are also many researchers whose studies about geothermal and geophysical investigation. Initial geothermal geology studies were carried out by Ozbayrak (1984) and Açıkgoz (1996), local resistivity studies Önder and Duman (1998) and Karlı (1997) near the studied area. Two well were drilled in Gediz-Abide area by Hamut and Yucel (1996). Detail geology water chemistry, hydrothermal alteration, hydrological isotope, magnetotelluric, resistivity and drilling studies have carried out by Burcak et al (2003, 2004, 2005, 2006).

As young volcanic activity has effected from Miocene to Quaternary, NW-SE directional graben structure providing deep sirculation along the fault this region has important geothermal potential.

## GEOLOGY

The basement rocks of studied area comprise Paleozoic aged gneiss, schist and marble which belong to Northhern margin of the Menderes Massive. These basement rocks are tectonically overlain by Cretaceous aged Dagardı ophiolitic melange. All these units covered by Neogene Quaternary aged sedimentary and volcanic rocks (Figure 2).

Massive which expanded autcropping in the area have represented by the core rocks which composed of flaser gneiss, granitic gneiss and migmatite which covered by surrounding schist called Sarıcasu formation. Upper Paleozoic aged Sarıcasu formation which is composed of quartz schist, metavolcanic rocks, marble interlayered chalc-schist, quartz-mica schist and marble layers are covered by Upper Triassic-Maestrichtian aged cristalized limestone which called Budağan Limestone formation. Dagardı Melange is composed of serpentinized mafic and ultramafic rocks, limestone olistoliths and blocks. Limestone have been silisfied, chloritized, carbonatized (cupper carbonates such as malachite, azurite) minerals especially in related with fractered structure which can be called listwanitic zone.

Neogene is represented by miocene to pliocene aged lacustrine sediments interlayered volcanic levels which composed of conglomerate, sandstone, siltstone, clay, silty clay, marl, silty marl, limestone from basement to through bottom. Volcanic levels are represented by tuff and basalt lavas.

Quaternary are composed of basalt lavas and alluvium deposites (Figure 2).

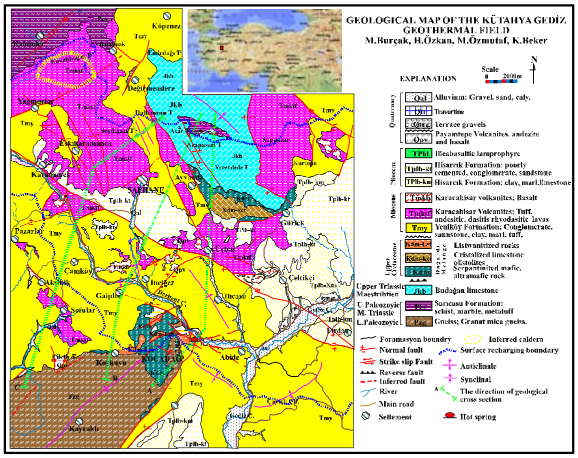


*Figure. 2.Geological map of the studied area.*

## WATER CHEMISTRY

There is no hot spring and any fumerol in new buried geothermal field at Shaphane- Uchbash in Kutahya. Only surface manifestation is in Gediz-Abide field. There are nine hot springs with having temperature between 57-75.5$^{o}$C Gediz-Abide geothermal area.

These springs outcropped with related E-W directionel normal fault south edge of the graben structur. Otherwise new buried area located at in the middle of the graben at 5km northern papart of Gediz-Abide geothermal area.

Water chemistry studies have been carried out on fortyseven cold and hot samples. Physical properties and chemical characteristics are shown in (Table 1).

| Sample | Location | T($^{o}$C) mg/l | EC mg/l | pH mg/l | Na mg/l | K mg/l | Ca mg/l | Mg mg/l | Cl mg/l | SO4 mg/l | HCO3 mg/l | SiO2 mg/l | B mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GD-1 | Abide | 65.5 | 2830 | 6.5 | 488 | 122 | 102 | 66.5 | 95 | 900 | 1006 | 45.0 | 8.5 |
| GD-2 | Abide | 69.1 | 2680 | 6.5 | 452 | 114 | 105 | 66.9 | 88 | 845 | 959 | 45.0 | 7.8 |
| GD-3 | Abide | 57.1 | 2550 | 6.6 | 413 | 99 | 105 | 69.8 | 80 | 756 | 952 | 58.0 | 7.2 |
| GD-4 | Abide |  | 2710 | 6.8 | 458 | 118 | 106 | 59.5 | 88 | 849 | 953 | 60.0 | 7.9 |
| GD-5 | Abide | 71.5 | 2980 | 6.9 | 542 | 140 | 116 | 55.3 | 103 | 955 | 1036 | 66.0 | 9.1 |
| GD-6 | Abide |  | 2990 | 6.9 | 536 | 141 | 114 | 54.7 | 102 | 961 | 1036 | 62.0 | 9.3 |
| GD-7 | Abide | 74 | 3000 | 7 | 533 | 133 | 111 | 55.6 | 104 | 893 | 1036 | 64.0 | 9.3 |
| GI-1A | Abide Well | 77.8 | 2870 | 7.2 | 498 | 128 | 93 | 58.3 | 97 | 947 | 1006 | 60.0 | 8.5 |
| GI-2 | Abide well | 93.1 | 3160 | 7.6 | 648 | 170 | 55 | 17.5 | 122 | 1157 | 799 | 94.0 | 10.5 |
| GI-3 | Abide well | 78 | 3410 | 7.3 | 690 | 165 | 60 | 43.4 | 118 | 1128 | 1160 | 82.0 | 10.2 |
| KSU-1 | Ucbash well | 90 | 3490 | 8.3 | 672 | 108 | 116 | 30 | 130 | 1070 | 813 | 80.0 | 8.5 |
| KÇ103 | Kurtcam | 21.2 | 888 | 7.5 | 15 |  | 55 | 101 | 24 | 21.4 | 725 |  |  |
| KK-121 | K.kuyu | 21.3 | 1018 | 7.3 | 6.4 | 1.6 | 88 | 111 | 13 | 296 | 551 | 14.8 |  |
| KK-119 | K.kuyu | 20.5 | 1934 | 7.4 | 18 | 9.7 | 158 | 262 | 22 | 919 | 783 | <10 |  |
| KK-118 | K.kuyu | 20.5 | 1176 | 7.6 | 7.6 | 4.5 | 102 | 129 | 15 | 303 | 667 | <10 |  |
| KŞ-1-18 | Krmnca | 18 | 2320 | 8.6 | 716 | 10 | 3.8 |  | 16 | 183 | 1685 | 12.6 | 2.5 |
| KŞ-20 | Şaphane | 27.6 | 409 | 7.6 | 23 | 7.7 | 36 | 19.1 | 3.6 | 70.5 | 209 | 10.1 |  |
| DD1 | DDeresi | 17 | 883 | 7.4 | 26 | 9.9 | 37 | 74.6 | 8.5 | 123 | 423 | 19.2 |  |
| UZ-124 | Uzumlu | 16.5 | 666 | 7.5 | 4.2 | 1 | 30 | 82.8 | 9.3 | 16.9 | 533 | 10.7 |  |
| KU-6 | K.Uzum | 15 | 812 | 7.8 | 11 | 2.5 | 58 | 88 | 21 | 39 | 632 | 25.3 |  |
| UCB-93 | Uchbash | 14.3 | 911 | 7.3 | 39 | 8.8 | 66 | 32.5 | 71 | 25 | 359 | 55.2 |  |
| IP-112 | Irahat P. | 13.8 | 81 | 4.8 | 5.3 | 8.5 | 4.9 |  | 5.7 | 21.6 | 12 | 47.9 |  |
| BS-11 | Besoluk | 15 | 323 | 7.8 | 1.5 |  | 35 | 24.3 | 7.4 | 32.3 | 186 | <10 |  |
| DD2 | D.Deresi | 18.6 | 821 | 7.5 | 22 | 9.8 | 83 | 60.7 | 9.9 | 233 | 348 | <10 |  |
| DD3 | D.Deresi | 16.5 | 894 | 7.5 | 24 | 9.9 | 48 | 70.3 | 9.2 | 238 | 325 | 13.1 |  |
| IL-125 | Ilıca | 22.4 | 1088 | 8.4 | 1.9 |  | 5.3 | 199 | 4.6 | 11.7 | 1020 | 14.3 |  |
| IL-126 | Gediz | 19.7 | 1102 | 8.6 | 1.9 |  | 9.9 | 201 | 4.2 | 17.1 | 985 | <10 |  |
| CH-127 | Cheltikchi | 20.6 | 641 | 7.3 | 6.4 | 2.9 | 80 | 55.3 | 5.9 | 17.7 | 533 | <10 |  |
| GR-129 | Gurlek | 19.2 | 410 | 7 | 4.6 |  | 98 | 26.5 | 9.9 | 13 | 487.5 | 34.7 |  |
| SH-107 | Shaphane | 7.2 | 686 | 7.1 | 5 | 1.9 | 110 | 32.4 | 6.4 | 156 | 354 | 12.3 |  |
| SSU110 | Shifalısu | 9.3 | 266 | 7.6 |  |  | 41 | 17.2 |  | 10.4 | 220 | <10 |  |
| UCB-92 | Ucbash | 13.7 | 563 | 7.1 | 11 | 3.7 | 65 | 28.6 | 14 | 67.1 | 255 | 18.8 |  |
| IR-16 | Irmees P. | 16 | 665 | 7.4 | 7.8 |  | 99 | 19.9 | 16 | 25.2 | 354 | 19.9 |  |
| DG-1 | Dg.dere | 14 | 45 | 6.2 | 2.2 | 1.6 | 7.2 |  | 6.1 | 7.2 | 17 | 31.4 |  |

*Table 1. Cheical analyses results of the hot and cold waters studied area .*

## Classification of Waters

Cold water samples fell into the part of section Ca+Mg>Na+K and $HCO_3+CO_3>SO_4+Cl$ according to the Piper ternary (Figure 3) and hot waters are fell into the part of Na+K>Ca+Mg and $SO_4+Cl \geq HCO_3+CO_3$, in respect of cations and anions accordign to Piper diagram (Figure 4). Cold waters are poorly mineralized Ca-Mg-$HCO_3$ type, and hot waters are Boron bearing Na-$SO_4$-$HCO_3$ type mineralized waters according to IHA.

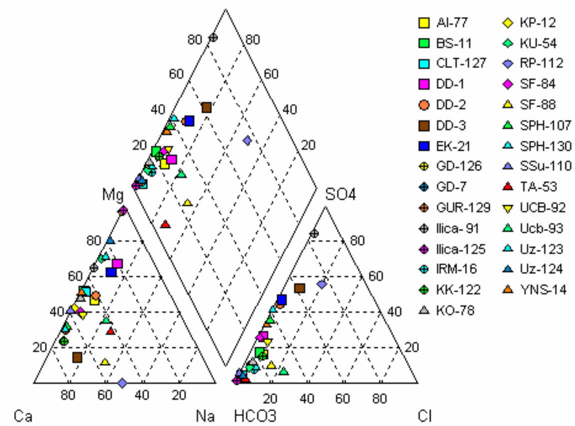


*Figure. 3. Piper ternary diagram of the Cold waters in studied area.*

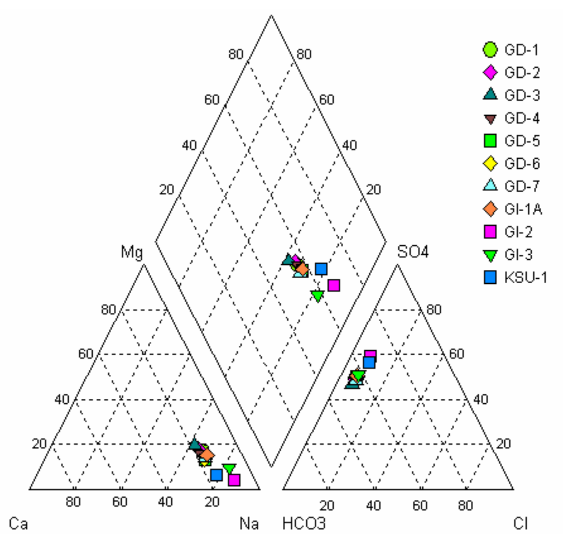


*Figure. 4. Piper ternary diagram of the hot waters in studied area*

Cold waters are Mg-Ca-$HCO_3$ and Ca-Mg-$HCO_3$ type they are the same origin related to palellel ion concentration according to Schoeller (Figure 5). Hot waters are Na+K-$SO_4$-$HCO_3$ type based on Schoeller diagram (Figure 6). It has the highest Cl and lowest $HCO_3$ concentration that KSU-1 well sample at buried geothermal system. Other ions of KSU-1 are similar to Gediz-Abide hot waters. It can be say that

KSU-1 and GI-2 samples represent original waters with minumum cold water mixing with respect to relatively low Mg, high Cl concentration (Figure 6).

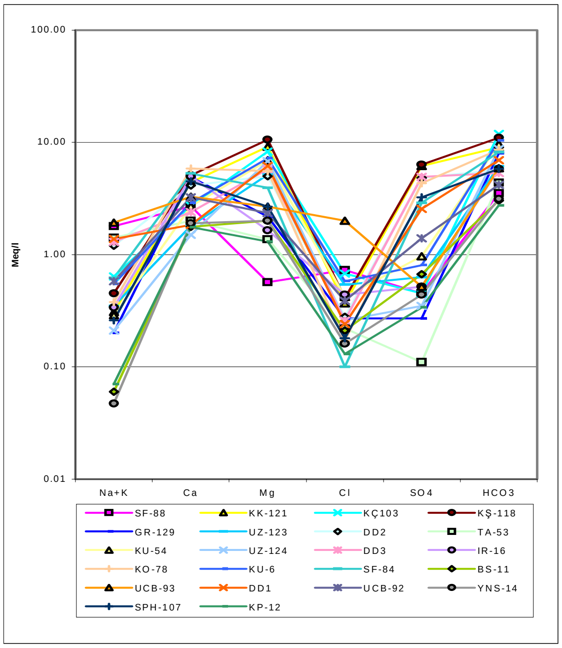


*Figure. 5. Schoeller diagram of the cold waters in studied area*

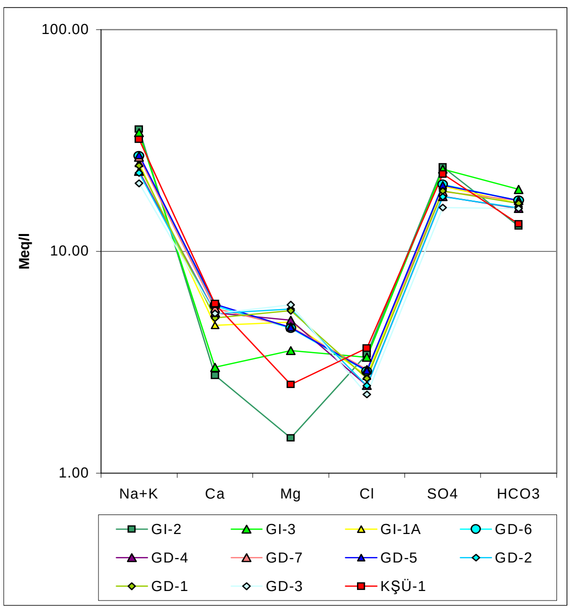


*Figure. 6. Schoeller diagram of the cold waters in studied area.*

## Geothermometer Calculations

Water chemistry studies have been carried out on 33 water samples. On the basis of water chemistry studies hot waters have been classified as Na-$SO_4$-$HCO_3$ type and cold waters Ca $HCO_3$ type. Since all of the hot waters are immatured (Figure 7) with an other words non of them haven't completed water-rock interaction according to the Giggenbach, (1988). Cation geothermometer couldn't been carried out. So silica geothermometer were been used to estimate reservoir temperature. Reservoir temperature 97-107 $^oC$ was calculated with respect to Silica (calcedony ) and 97-134 $^oC$ acoording to Quartz geothermometer (Fournier, 1977).

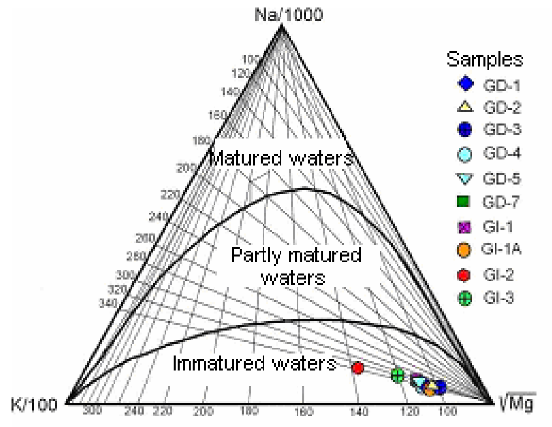


*Figure. 7. Giggenbach Na-K-Mg ternary diagram of the hot waters in studied area.*

Silica-Entalphy and Chloride-Entalphy mixing models have showed that, original water temperature without mixing cold water in the range between 128-157 $^oC$ in the reservoir. According to mixing models, besides having found mixing rate of cold water within hot water as the range between 31-55% and some conductive cooling was found for some hot water springs.

## Water Chemistry Maps (Iso-concentration Maps)

Recharging are are defined uasing water chemistry and istopical studies. Iso-concentration map of the chloride (Figure 8) and $SiO_2$ (Figure 9) have shown that recharging area extends through the Saphanedag and consists almost 750km$^2$ area. Either Cl and also $SiO_2$ concentration map have two main anomalies. The first intensive anomaly is at southern part of the studied area accrossed Gediz-Abide geothermal field and other is at the northern, around buried geothermal area near Uchbash town (Figure 8 and 9). The anomaly which at the north encouraged us as if light the way and indicate promising area.

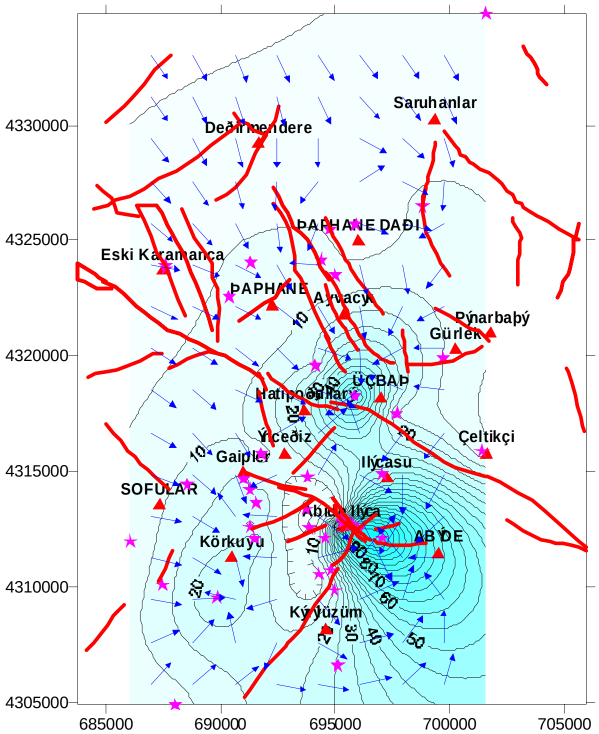


*Figure. 8. Iso-Chloride concentration (of the waters) and teconic map of the studied area.*

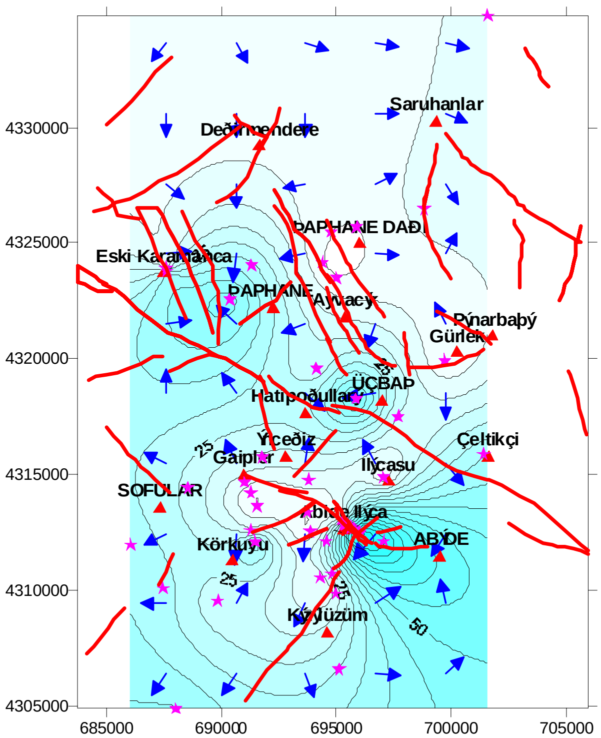


*Figure. 9 .Iso-$SiO_2$ concentration (of the waters) and teconic map of the studied area.*

## HYDROLOGICAL ISOTOPE STUDIES

Stable (Oxygen-18 and deuterium) and radioactive isotopes (tritium) studies have been carried out to learn about recharge area and travel times. Since All of the samples fell on between GMWL and AKD-EGE-MWL (Mediterranean-Aegean meteoric water line) which are meteoric origin. Group 1 represents cold waters in recharging area. They are near to the AKD-EGE MWL. It indicates that these waters are fed by Mediterranean and Aegean region rain waters. Group 2 shows increasing about $^{18}0$-$\delta^2$D either so indicates have some evaporatization. Hot waters are represented by group 3 which have shifted through the right indicates water rock interaction . Increasing $^{18}$O shows changing $^{18}$O between in rocks and fluids (Figure 10). Tritium analyses showed that three groups of water which has different ages. The first group of water are old water, had been fed from the precipitation before 1952 with respect to TU almost "0"(zero).the second group of water are represented by high TU (larger than 4). This group are young water which can be considered that 5-10 years aged waters. The last group which have 2-4 TU are represented by geothermal waters. It can be concidered that this group of waters had been fed from the either the young and old precipitition so these are sub-modern (Figure 11).

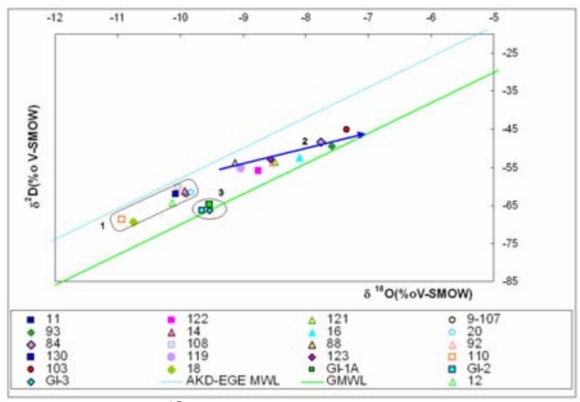


*Figure. 10. $^{18}$O-Doterium graffic of the studied areae.*

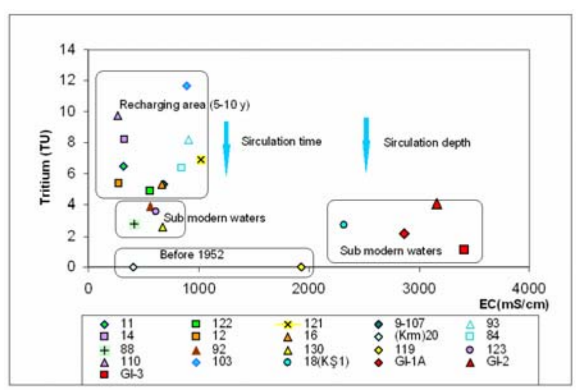


*Figure. 11 .Tritium-Electrical conductivity of the of the water samples in studied area.*

## GEOPHYSICAL STUDIES

### Magnetotelluric Studies

Magnetotelluric studies have been carried out along three profiles on 45 measurement point. The profil-1 which related buried geothermal area is aveluated for this paper. There are 14 station in this profil (Figure 12). In the magnetotelluric method (MT) the orthogonal components of the horizontal electric and magnetic fields induced by natural primary sources are measured simultaneously as a function of frequency. The natural time-varying EM field can be observed as variations in the Earth's magnetic field called micropulsations. The predominant origin of the micropulsation is interaction of Earth's magnetopause with charged particles ejected from the sun. Having frequencies of less than 1 Hz. used as source for magnetotelluric method. MT methods have been used to investigate deep structure, heat source exploration by Beblo et al., 1983. MT studies have been considered to investigate deep structure, upper mantle and crustal thickness, heat source exploration (Vozof, 1972, Jupp and Vozof, 1977, Hersir and Björnssonn 1991, Burcak at al, 2005 a,b). The predominant origin of the micropulsation is interaction of Earth's magnetopause with charged particles ejected from the sun.

### Data Acquisition

Phoenix V5 MT equipment has been employed in order to record three orthogonal magnetic (**H**) fields and two orthogonal electrical (**E**) fields' components. 100 m. dipoles extending N-S and E-W geomagnetic directions and Pb-PbCl electrodes were used for **E** field. Horizontal components of **H** field were measured with induction coil. Vertical component of the **H** was recorded with an air loop on the ground.

The V5 system is calculated all sounding parameters in real-time. In this system, data acquisition is divided into two frequencies levels. High frequencies level is 320-7.5 Hz. These were processed using Fourier transform techniques in a frequency band. Every band is contains two frequencies. Low frequency level is 6- 0.00055 Hz, were processed using cascade decimation (Wight and Bostick, 1980).
Electric and electromagnetic waves are measured with horizontal pairs of orthogonal electric dipoles and magnetic sensors.

$$E_x = Z_{xx}H_x + Z_{xy}H_y$$
$$E_y = Z_{yx}H_x + Z_{yy}H_y \qquad (1)$$

The notation $Z_{ij}$ in equation (1) are the transfer function called impedances. They are a measure of Earth's response to magnetic fields in x and y directions. If the subsurface is homogeneous or horizontally stratified (one dimensional), the impedances $Z_{xx}$ and $Z_{yy}$ are equal to zero and $Z_{xy}$ and $Z_{yx}$ impedances will be equal as below (2).

$$Z_{xy}(f) = \frac{E_x(f)}{H_y(f)} \qquad (2)$$

If the direction of electric field (E) parallel to geological strata, vertical magnetic field is polarized linearly and called Transverse Electric mode or E-polarization. In this situation the direction of electric field, related to two orthogonal axis, if the direction is x,

$$Z_{xy} = \frac{E_x}{H_y}$$

If the electric field perpendicular along the strike, magnetic field will be polarized as linear. If 'y' is perpendicular to strike Transverse Magnetic mode or H polarization is defined as,

$$Z_{yx} = \frac{E_y}{H_x}$$

And the components of Zxx and $Z_{yy}$ are zero. As not knowing the direction of axis, MT measurements are recorded in geographically as being a direction of North-South and East-West. In data process to calculate the impedances belonging to the mode of TE and TM, tensor components ($Z_{xx}$ and $Z_{yy}$) as to be minimum level, impedances tensor is rotated using least square method. In two orthogonal directions the orthogonal magnetic (H) and electric components (E) of natural fields can be related at each frequency by tensor impedance (Z). The impedance tensor and impedance are given in equations (1) and (2) respectively.
For a homogeneous earth, it is easy to calculate the resistivity from the elements of immedance tensor, the formula for apparent resistivity is (Cagniard 1953);

$$\rho_{aC}(f) = \frac{|Z|^2}{w\mu} \qquad \textbf{(3)}$$

Central loop TEM measurements have been completed at each MT station in order to remove the static shift effect from the MT data and to get near surface information. Static shift corrections have been made by the use of transient electromagnetic (TEM) data (Pellerin and Hohman 1990). All TEM data inverted and 1D model are obtained. MT and high frequency responds of 1D TEM models are plotted together. Both TE and TM apparent resistivity data shift towards to the responds obtained from model based on TEM method. One point should be emphasis that the shifting process using 1D model may cause information loss in case of existence of shallow 2D - 3D structure that departs the TE and TM mode apparent resistivities from each other even in very high frequencies.

This fact is accepted as a sacrifice for the methodology followed.

## 7.2. Two Dimensional Inversion Interpretation

Two dimensional inversion plots are generated in the field. 45 MT data were observed along the three profiles, on measurement stations. To calculate the true subsurface resistivity 2D inverse interpretation give information related to direction as well as depth. The models presented here are obtained by the use of WinGLink™ interpretation package, which uses 2D inversion code of d2inv_nlcg2_fast (Mackie et al. 1997). Initial models for each profile have been taken as a homogeneous half space of 100 ohm-m. To justify the models, all sections were inverted with starting models of homogeneous half space of 1 ohm-m (results not presented). Comparison of both result for each section delineate the depth of investigation (e.g. Oldenburg and Li, 1999) and confirm the existences of some small size features. 2D inverse model is interpreted by way of the electrical section formed by a software program called finite difference method by using 'Network analogy' (Jupp and Vozoff, 1977). Infinite Difference Network the thick and width of the cells are chosen with respect to used frequencies, measured resistivity and accepted average resistivity.

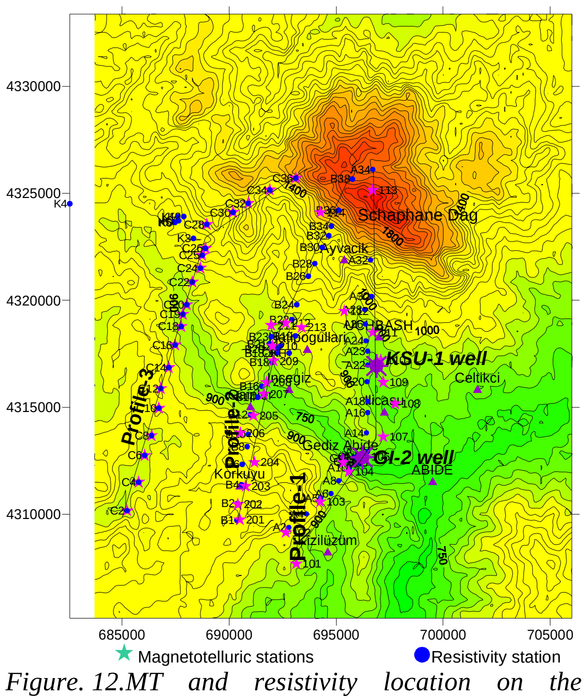


*Figure. 12.MT and resistivity location on the Topographical map in studied area.*

On the basis of the 2D MT modeling two lowe resistivity anomalies have been found on profile 1 (Figure 13). One of them is at southern part come accrossed Gediz -Abide geothermal field and second at the northern part met promising area. These lowe resistivity anomalies were interpreted to be hot, solid and / or partly molten magma bodies which can be considered the heat source of the geothermal system in promising area. It has been found that the average depths of the heat sources are about 5-6 km (Figure 13) These anomalies have fallowed at second and third profiles too. MT model show good correspodence with geological structure and and geochemical map (Figure 14).

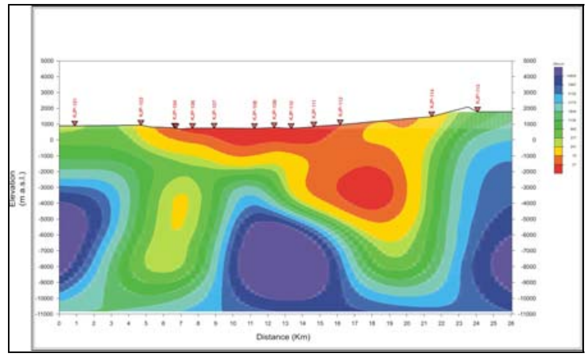

*Figure. 13 .2D Magnetotelluric model of the studied area (profile 1).*

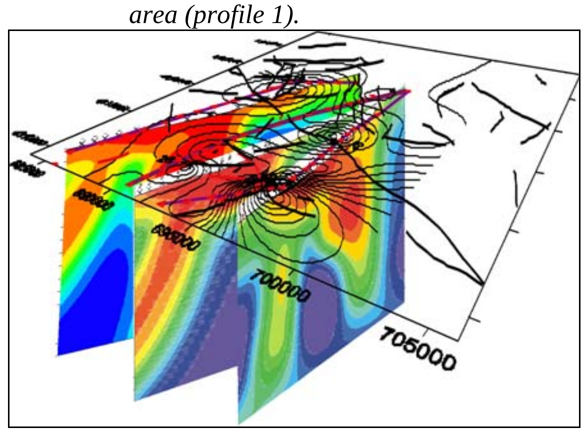


*Figure. 14 .Perspective 3D sight of Magnetotelluric profiles of 2D models, tectonic and $SiO_2$ concentration maps (profile-1 is at the right)*

## Resistivity studies

Resistivity studies are carried out through three profiles on 75 measurement station. 15 measurement point fell on profile-1 (Figure 12). On the basis of the resistivity studies, two main anomaly have found. One of them is at the south and run accross with Gediz Abide hot springs area. Second anomaly is at the 5 km north from the first anomaly. This anomaly has been indicated buried geothermal system (Figure 15). These anomalies have been followed in other two profile (Figure 16). Accordig to apperent resistivity section and structurel section the first anomali which is at the south indicates that the reservoir is at shallow depth than the north depend on the fault system. This result (500m depth) was corrected by GI-2 production well.

Low resistivity zone are interpreted as cap rocks of the reservoir for both anomaly. If reservoir depth and cap rock thickness of the geothermal systems compare with each other in south and north, about 500m at southern and 1100m at the northern. The low resistivity zone (exists from the surface to 250-300m at south and 800m depth in northern) considered with to lacustrine sediments as a cap rocks, and medium resistivity (250-500m at south and 800-1100m at north) below the low resistivity zone considered with ophiolitic melange. Finaly relatively high resistivity rocks under the medium resistivity zon was interpreted as the reservoir rocks (average depth 500m in souhern and 1100m at northern). This results were coorected by KSU-1 well logging (Figure 17).

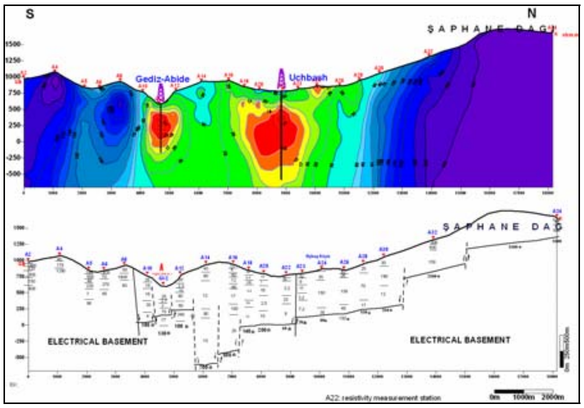


*Figure. 15. Apperent resisitivity section and structurel resistivity section of the studied area.*

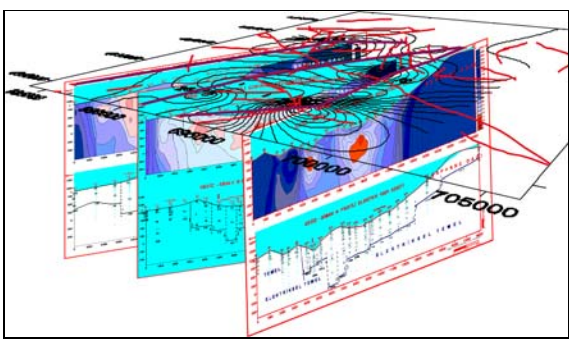

*Figure.16. Perspective 3D sight of resistivity profiles, tectonic and $SiO_2$ concentration maps (profile-1 is at the right)*

## DRILLING

One well location (KSU-1) was defined at the and of the evaluation all of the studies which carried out at studied area. Drilling were started in April 2006 and It completed in end of the september 2006. The last depth of the KSU-1 well is 1330m. Miocene aged lacustrin sediments are cut between 0-800m, Cretaceous aged melange is cut between 800-1030m depth, Jurassic-Cretaceous aged cyristalized Limestone (Budagan formation) have been cut between 1030-1100m and finally Paleozoic aged schist and marble were cut between 1100-1330m depth (Figure 17). Partial sirculation lost have started after 1200m depth. Sirculation have completely lost at 1290m depth. Between 1290-1330m well was drilled without sirculation. Total mud which lost was 150m$^3$. Well have completed at 1330m depth after well logging studies. We measured two different waiting thermic logging. The first measure was applied end of 12$^{th}$ , second was 56$^{th}$ hours after drilling. 105,5 $^{o}$C temprature have been measured at and of 56 hours waiting (Figure 17). After that 109 $^{o}$C (static temperature) temperature have been measured in the well.

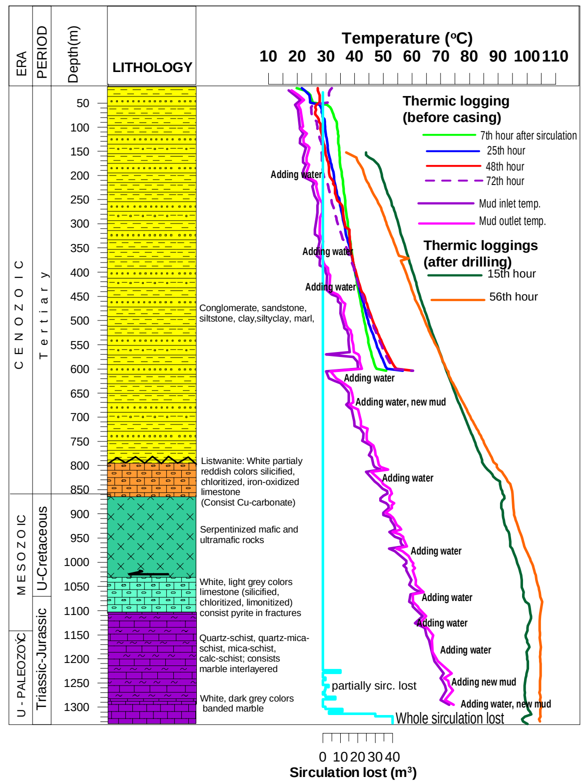


*Figure. 17. Well logging of KSU-1 geothermal well*

## GEOTHERMAL MODEL OF STUDIED AREA

Geology, geophysics geochemistry and drilling datas have been assested with together to form geothermal model of the gethermal system. Reservoir depth, thickness of caprocks, recharging and expanding reservoir have defined on the model (Figure 18). reservoir entrance depth changed between 500-1100m depth according to geothermal model. It has been found that two heat source based on the MT studies and two different reservoir with respect to resistivity studies.

It has been claryfied that reservoir rocks have represented by fractured gneiss at southern (Gediz-Abide area) and marble and schist in buried geothermal area in northern part (Uchbash area) according to this study. (Formed marble and Chalk-schist (Figure 18) in the north. A good correlation have been found with geological, geophysical and geochemical data in the promising area.

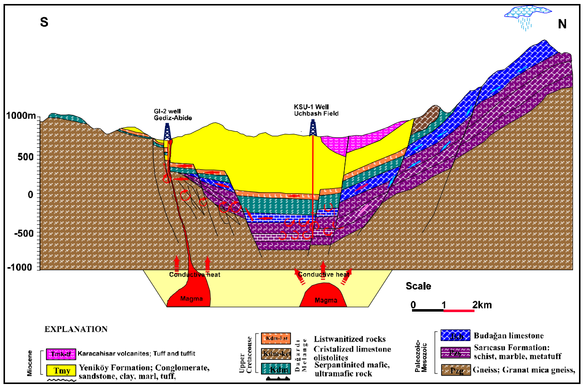


*Figure. 18 .Geothermal model of the studied area .*

## CONCLUSION

The main aim of this study was to find buried geothermal reservoir at the northern part of the study area. It has been reached to main aim of the study founding new buried geothermal reservoir at the end of the drilling.

Geophysical modelling show good correspondence with geological structure, well data and gechemical data.

Although production tests haven't been completed yet. Geothermal fluids which have 90 $^{o}$C temperature and 216 T/h flow rate have been producted initial compressor test. KSU-1 well have 13.81 MWt potential. It can be suitable for district heating (equivalent 1400 dwellings), heating green houses, thermal bath facilities.

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