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Canakkale-Yenice-Hidirlar Geothermal Field in Turkey

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ABSTRACT

The Canakkale-Yenice-Hidirlar geothermal area is in the vicinity of the Hidirlar village, Yenice country, Canakkale city in Turkey. In the area, there are three hot water springs, their temperatures ranging from 40 to 87 ^{0}C and their total flow is between 30 and 40 l/sec, geological and geophysical resistivity studies have been carried out in the area. The fluid to be obtained in the area can be used in not only thermal tourism but especially in greenhouse and household heating as well.

Geologically, the Karakaya Formation of lower Triassic age overlies the Kardağ group metamorpichs at the base. The Oligo-Miocene aged Eybek granodiorite unconformably overlies it. The lower Middle Miocene aged Hallaçlar volcanites are unconformably overlain by the Bigadic Formation precipitated in the lagoonal basin in Neogene, The Quaternary aged alluvion is the youngest unit in the area.

The region is within the western extension of the North Anatolian Fault Zone and has been affected by recent tectonic actvities. The Kalkim graben has been formed, tectonic movements in NE-SW directions are currently active as a result of these movements, debris materials can be observed over the Neogene units in the northern part of the region. As a result of these studies, it is seems that in the investigated area that there are downfalls in steps from north to south and that they are cut by both vertical strike slip faults developed in horizontal and vertical directions to them.

Hot water resources crop out in the northern part of the Kalkim graben and can be observed in 3 different points, the hot water resources are controlled by NE-SW directions of faults with secondary faults cutting them. No hot water resources were seen in the northern wing of the graben.

It is thought that the available hot water resources in the investigated area originate from crack-fracture systems. It is estimated that the cover thickens towards the northern part of the resources and that the main reservoir may be under these levels. As a result of this study, drilling locations have been suggested at two different points. One of them has been drilled.

1. INTRODUCTION

The fact that fossil fuels, which do not have a guarantee today and in the future, are leaving their place to new and renewable energy resources, has brought attention to the geothermal energy alternative and research and development studies of the available potential have become a necessity. Acting from this principle, geothermal energy studies have been carried out for years. In this respect, studies have been carried out in the Canakkale Yenice Hidirlar (Turkey) geothermal area with the aim of geophysical survey and detailed geology for geothermal purposes, in light of previous data, taking into consideration its suitability for mountain tourism, its vicinity to tourism centers, the fact that it has a geothermal potential and the geographic location of the region.

2. GEOLOGY

The investigated area is on the western extensions of the North Anatolian Fault Belt. The Kazdağ group of Paleozoic age constitutes the base in the area. The Karakaya Formation bearing Permian limestone olistoliths, unconformably overlies the metamorphics which constitute the base, and its age is accepted as lower Triassic, The Eylek granodiorite intrusion moved into the region during Oligocene-Miocene. The andesitic rocks which were formed as a result of volcanic activities which were affective during Upper Oligocene-Lower Miocene, are named as the Hallaçlar Volcanites. The Middle-Upper Miocene aged Bigadic Formation consist of sediments of lagoonal characteristics. In te investigated area, the Quaternary aged alluvions are located at the top (Figure 1).

The Kazdağ group, known as the oldest rock group in the region, consists of metamorphic rocks and granodiorites. The metamorphics are Pre-Permian aged metadunite, metaharzburgite, metagabro, piroxenite, amphibolite, gneiss, schist, marble and their epimetamorphic equivalents, and they are observed together with granitoids in places (Bingöl, 1968).

The unit is observed especially at Kazdağ and its vicinity, it extends in NE-SW direction and its base can not be observed.

2.1.The Karakaya Formation (Trk):

Over the Kazdağ massive rocks, rock units named as the Karakaya Formation (Bingöl, 1968) take place. This formation is composed of a sequence of spilitic basalt, diabase, gabro, mudstone, chert and feldspat bearing sandstone with radiolarites at times, quartzite, conglomerate and siltstone. It also bears Permian and Carboniferous aged white, dark grey and bladerish limestone blocks in the form of olistolith in places (P). The dimensions of these olistoliths vary from a few cm to a km and are fossiliferous. The Karakaya units have undergone very little metamorphism and the age is accepted to be lower Triassic (Bingöl, 1968).

2.2.The Eylek granodiorite (Te):

In the area, there are shallow intrusions generally of granodiorite composition as a result of volcanism. One of these is the Eylek granodiorite and according to radiometric age determinations carried out by various researchers, its age is in the Upper Oligocene-Lower Miocene boundary.

In the granodiorite generally fracture- crack structural characteristics are observed and this gives the reservoir rock characteristics and contributes to the development of the geothermal system.

In the field studies, it is observed that generally the granodiorite is surrounded by the Karakaya Formation.

It is greyish pink in color and has many cracks. In the rock; quartz, feldspat and amphibole crystals can be differentiated macroscopically. Scarn zones can be observed at their contact points with the metamorpics.

2.3. Can Volcanites (Tvç):

Can Volcanites (Tvç): Is composed of andesite and dacite type lava, tuff and aglomerates. Part of the tuff and lava has undergone alteration. These are found in white, yellow red and brown colors in very different locations in the field. According to radiometric age determination, it has been proved that volcanism started to be affective as of the end of Upper Oligocene, continued till the Lower Miocene border and went on during Lower Miocene as well for a short period (Ercan at. al., 1990). In addition, since volcanites can be observed in the form of tuff levels within the Neogene sediments also, it can be said that volcanic effect lasted till Upper Miocene in the area.

Volcanic explosions of andesitic character due to NE-SW and E-W directions fault systems which are the reason for grabenisation of the area in Miocene occurring especially in the southern part of the region. They are partially overlain by sedimentary rocks; however some of them crop out.

2.4. Bigadic Formation (Tb):

The Neogene lagoonal sediments exhibiting large outcrops in the region are composed of generally yellow, yellowish grey, light grey colored conglomerate, sandstone, marl, claystone, clay limestone, lignite and limestone sequence and contain tuff levels in places. The unit overlies older units with a level, the base of which is poorly sorted and which is composed of pebbles and sandstones containing slightly round pebbles from various units. The layers dip towards N, NE and in places E, in other words generally the layers are in the direction showing the interior part of the basin and exhibit different dip degrees due to the effect of young fault activities. The unit is Middle-Upper Miocene in age. It is thought that the presence of thick downfalls materials at the northern side of the basin is due to the fact that the fault bordering the Neogene series at the North is big and active.

The Neogene lagoonal formations have been largely affected by young tectonic activities and since these basins have generally been controlled by tectonic activities, their layer dips and thicknesses have changed. Because of this, no definite data are available regarding their thicknesses. It is observed that it has a contact with the andesites at the South of the region, while at the North it unconformably overlies the metamorphites and granodiorites.

Alluvion (Qal): Lastly, in the investigated area, alluvion composed of block, sand, silt and clay are observed.

2.5.Tectonics

In Turkey, he Neotectonic period started with the collision of the Arabic and Anatolian plates in South-last Anatolia in Middle Miocene (Şengör, 1980, Şaroğlu and Yılmaz, 1990). The name Neotectonic period has been given to the tectonic regime which has been effective from that period till today. In this period, NE-SW oriented right directional strike slip faults, NW-SE oriented left directional strike slip faults and E-W oriented normal faults have been formed. These structural shapes are the result of compression in E-W direction. On the other hand, the compressing tectonic regime in E-W direction which constitutes them started with the compression of the Anatolian plate in N-S direction from Middle Miocene until the end of the Pliocene (during the first stage of the Neotectonic period and finally, after KAF (North Anatolian Fault) started to bear the characteristics of a right directional transform fault at the end of Pliocene and with the formation of DAF (East Anatolian Fault) bearing the characteristics of a left directional strike slip fault and with the escape of the Anatolian plate west and as a result of its meeting with the resistance of the Greek shearing zone at the west (Şengör, 1980, Şaroğlu and Yılmaz, 1990)).

With the field studies carried out at the Hidirlar hot spring and its vicinity, which is the investigated area, it has been concluded that the region has a structure which has been subject to compression tectonics. As a result of compression tectonics, generally NE-SW oriented right directional strike slip faults, NW-SE oriented left strike slip faults and E-W oriented normal faults have been formed. With this study, in addition to the faults, the characteristics of which have been determined previously, the presence of some faults, the characteristics and/or presence of which have not been revealed previously have been determined and they have been named after determining their characteristics. The faults formed during this Neotectonic period control the existence of the hot water springs.

The strike slip faults also have vertical components.

The Ilıca Fault: This fault is NE-SW oriented in the vicinity Koyustu source and Hidirlar hot spring and followes the contact of andesites with the Neogene lagoonal sediments. The fault is strike slip, its south-east block has collapsed and it shows oblique properties. Although the dip of the fault can not be measured exactly, it can be assumed to be nearly vertical. The length of the fault and its other characteristics can not be followed clearly due to intense plant cover.

The Bicki Dere Fault: Although its data can not exactly be determined, it has been determined both morphologically and as a result of data which can be observed in very limited areas within granodiorite, it has the characteristics of a normal fault which NW-SE oriented, can not be determined.

The Koyustu Fault: It is found in the NE of Hidirlar Village along the Kızılağaç Stream and is NW-SE oriented, left directional strike slip fault. It is thought that the hot water resources which come out at the surface here, comes out from the intersection area of this fault with the Ilica Fault.

The Ilicadere Fault: Although the characteristics of this fault also can not be determined exactly, it is supposed that it may be left directional strike slip fault. It is thought that the Hidirlar main resource under the control of this fault and the Ilıca Fault.

In addition, there is yet another fault, passing along the border of the Neogene units and the Karakaya Formation, which is a right strike slip fault and which is almost parallel to the Ilica Fault. As can be seen from the geological map of the area, although not definitely, there are step faults going in steps from the springs towards south, geophysical-gravitational data also verify this opinion. However, although the characteristics of the faults can not be determined exactly since the area is covered with intense plant cover, it is thought that they are right directional strike slip fault, having also a vertical component and oblique characteristics.

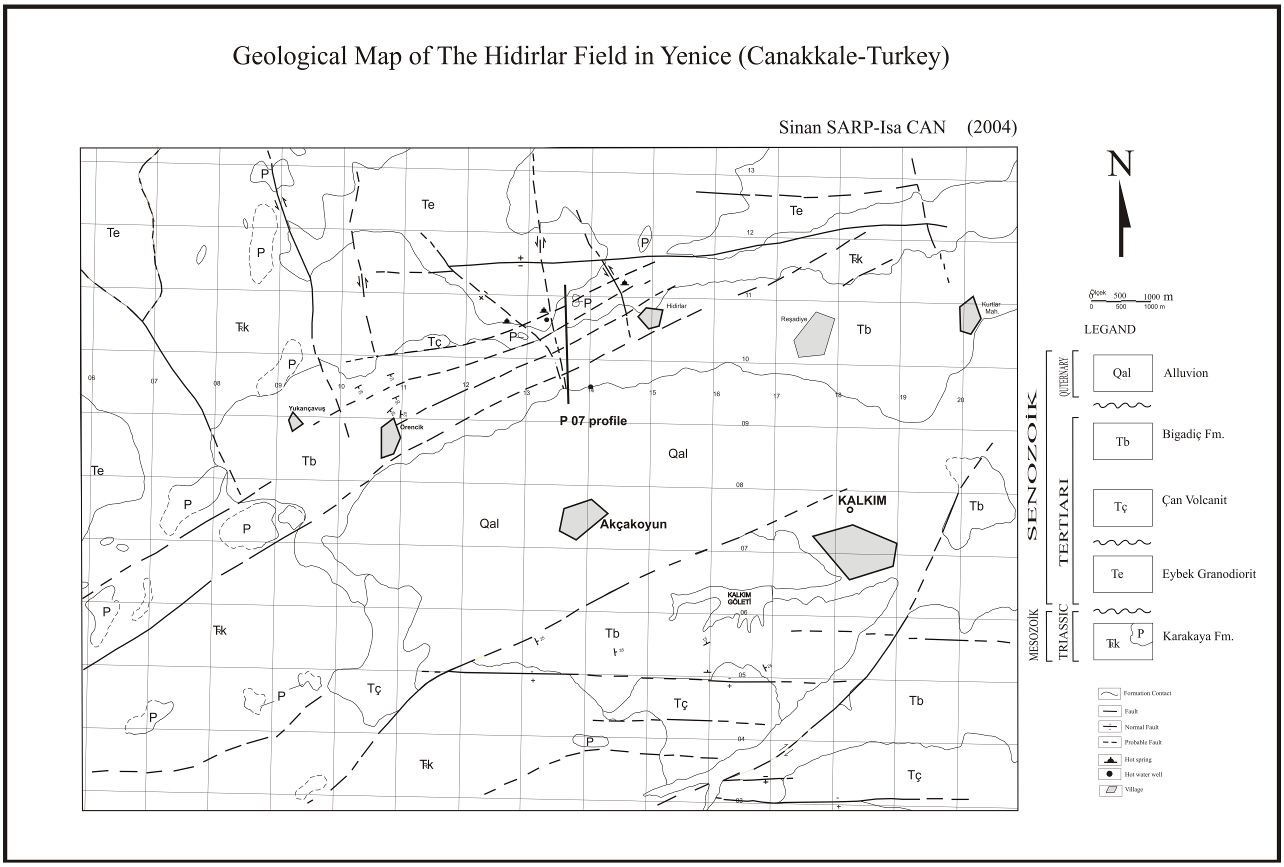

Figure 1: Geological map of the Hidirlar field in Yenice (Canakkale-Turkey)

As a result of field studies carried out in the region, it has been concluded that the region has been subject to compression tectonics. The main structural elements are NE-SW oriented right strike slip faults formed as a result of compression in approximately E-W direction, expansive cracks developed due to NW-SE oriented left directional strike slip faults and E-W oriented normal faults developed in the direction of maximum compression due to the same compression.

3. Hot Water Springs

There are hot water resources coming out at the surface in three regions at the Hidirlar Hot Spring and its vicinity, within the borders of the city Canakkale, Yenice Country, Kalkım Area, Hidirlar Village which is the investigated area. The Hidirlar hot spring, which is the first of the three, is located approximately 2 km west of the Hidirlar village. It comes out at the surface within the Ilıca stream in the form of a resource group. The Eybek granodiorites crop out in the resource area. Hot spring resources come out at the sırface in the intersection area of the Ilıca fault with the fault which extends in NW-SE direction along the Ilıca stream, which is assumed to belong to the strike slip left directional the Hidirlar hot spring area there are resources at 80-87 ^oC having fluid at a total flow of 10 waters reach the aquifer with low mineralization and despite high temperature, it cannot reach saturation regarding chemical element content in the aquifer as well. Another reason for this is the low CO_2 content, because CO_2 content which gives the underground waters the property of breaking materials off the rocks is low in the Hidirlar hot waters. High pH value is another proof that water and CO_2 gas do not move together at depth.

As is seen in Table 1, the pH values of the hot waters are around 8.25, with these values, the Hidirlar hot water resources bear basic characteristics. The chemical composition of the springs is the similar. While their TDS content varies from 804 to 816 mg/l in the group of resources in the vicinity of the hot spring, they have been measured as 773 and 460 mg/l in the Uyuz and Koyustu springs, respectively.

According to analysis and measurements made by MTA at various dates, the dominant cation is sodium (Na) and the dominant anion is sulfate (SO_4) in all the hot waters in the region. In all the resources, the secondary cation is calcium and the secondary anion is bicarbonate. Hence, all the resources bear sodium sulfate. Chlorine, which is one of the major anions, is low in area waters. In all the hot waters investigated, the cation sequence is $(Na^{+}+K^{+})>Ca^{2+}>Mg^{2+}$ and the anion sequence is $SO_4^{-}>HCO_3^{-}>Cl^{-}$ According to physical measurement and chemical analysis results corresponding to different seasons and various years made by MTA; it is observed that resource waters are not affected by seasonal changes, and it is seen that the resource waters continuously keep their physical (heat) and chemical characteristics. This shows that the geothermal resources can be continued with the same characteristics, and as long as there is a balanced production, there will be no changes in the physical and chemical characteristics.

NH_4 and NO_2 parameters have been analyzed with kits at the resource in order to observe the contamination parameters in the hot waters in the area. This is seen in the analysis table

The contamination parameters are below the analyses deduction limit, and are considered to be negligible. It seems that the resources in the area have not been affected by surface contamination.

The hardness scale of the waters is caused by the calcium and magnesium bicarbonate ions they bear together with the Ca-Mg SO_4, Ca-MgCl and Ca-$MgNO_3$ ions. As it is seen in Table 1, since the ion concentrations causing hardness in the investigated waters are quite low and calculated hardness scale are low and the hot waters found in the region are classified as soft waters while the cold waters are mid-hard waters.

Underground waters collected in the same aquifer after flowing through the same formations under the same physical and thermodynamic conditions have the same chemical compositions. Rising physical and mixture events they encounter may cause slight changes in their chemical compositions. As is seen in Table 1, and in the semi-logaritmic Schoeller diagram in Figure 2 below, the groups of resources in the vicinity of the Hidirlar Hot spring are similar to each others with respect to all the physical and chemical parameters. The mixture events the Uyuz and Koyustu springs have encountered while rising to the surface has been the cause of some changes in the physical and chemical properties of these resource waters, in other words, it has been the cause of dilution. Consequently, these resources are far from their natural state with respect to chemical and physical properties. Because of this, these two springs have to be evaluated separately from the main spring group.

Main spring group reservoir temperatures with respect to silica content and mixture models have been applied to the area. A reservoir temperature of about 100°C for the area has been found according to SiO_2 content. According to analyses results made in various years, the natural spring waters of the Hidirlar Village hot springs can be classified as acrothermal waters. These waters bear a total mineralization between 800-820 mg/l.

Table 1: Chemical analysis results of water samples

Name	t°C	pH	EC µs/cm	TDS mg/l	Ca^{++} mg/l	Mg^{++} mg/l	SiO_2 mg/l	HCO_3^- mg/l	$CO_3^=$ mg/l	Cl^- mg/l	SO_4 mg/l	Total Hardness °AS
No 1 spring	87	8.25	960	816	18.5	1.8	90	47	23	39	396	3.0
No 2 spring	81	8.26	959	810	19.2	1.9	82	50	25	37	391	3.12
No 3 spring	81.3	8.25	925	787	19.3	1.2	78	53	23	35	394	2.98
No 4 spring	85	8.25	957	804	18.7	1.2	83	47	23	37	392	2.89
MTA H-1 Well	64.6	8.1	953	810	21.5	<1.0	67	47	<10	37	381	2.98
Uyuz spring	55	7.9	943	773	21.5	0.9	45	93	<10	31	334	3.2
Köy üstü spring	30	7.8	564	460	24	<1	34	185	<10	22	172	3.36
Stream	10.2	7.8	303	243	43	5.5	10	164	<10	9	<10	7.28
Fountain	9.4	7.8	326	256	43	12	10	187	<10	8	<10	7.28

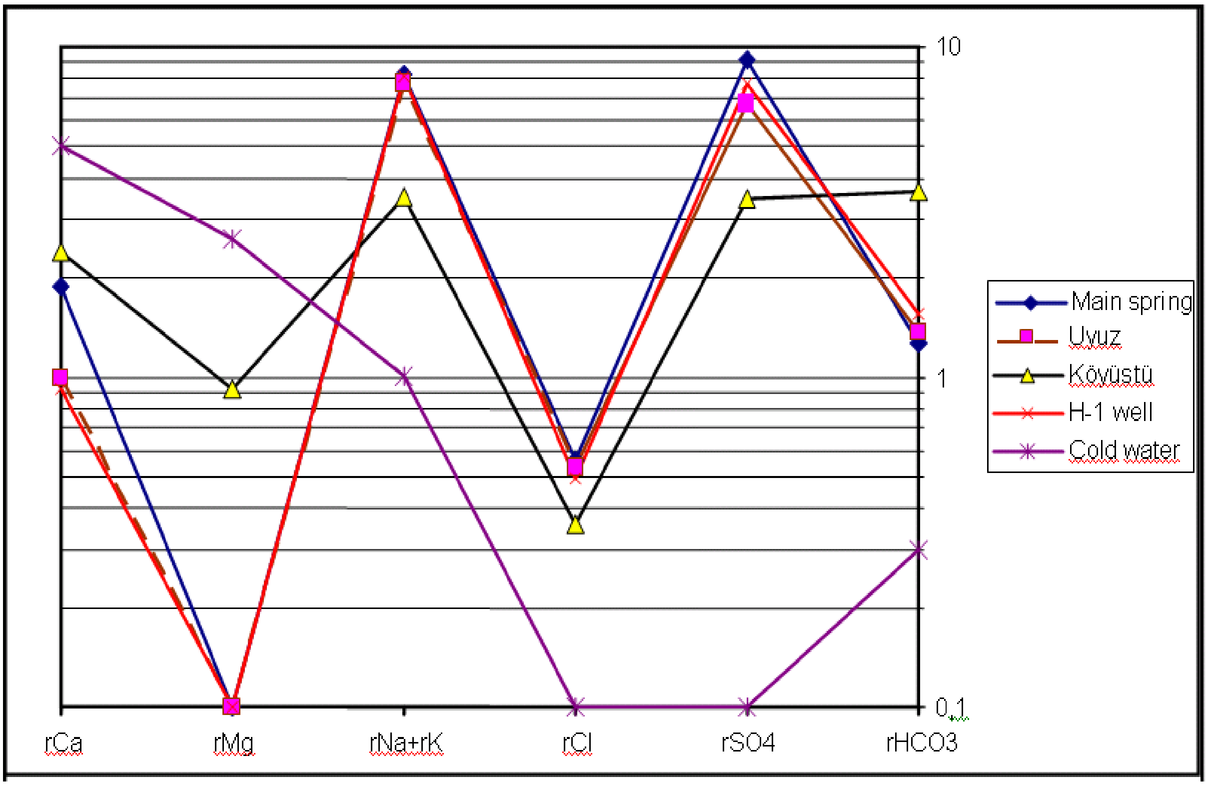

Figure 2: The semi-logaritmic Schoeller diagram

4. GEOPHYSICS

Low resistivity values were measured at the surface and the resistivity values increase towards the base. The increasing resistivity values may be the pebbly levels of Kocaçay which are not very thick at the surface until the east of the cross section. Below these levels, from west to east, the pebbly, sandy and silty levels of the Quaternary take place. These levels, Quaternary units, the resistivity of which is ρ=10-90 ohm. m, and thickness of which changes from 50 to 530 m take place. Below these levels, Tertiary (sandstone, claystone, marl, tuff, tuffite, agglomerate and andezite) and Triassic (Karakaya) aged units, the values of which range from 320 to 740 in thickness, and the resistivity of which is ρ =1,2-13 ohm.m, take place. Levels over values of resistivity value ρ =100-1000 ohm.m may be the Tertiary aged Eybek granodiorite having high resistivity which we call electricity basement.

4.1.PO7 Profile:

The PO7 profile starts at DES point no.51 over the Bigadic Formation at the South of the studied area and ends on The Triassic aged Karakaya Formation at DES point no 075-350

in the North. In this profile which is S-N oriented and which is 5.25 km in length a total of 18 DES measurement points have been taken (Figure 3).

When the observed resistivity cross-section is investigated high resistivity values can be seen at the surface starting from between DES points numbered 51 and 48 in the southern most of the cross-section to DES point no 58. Below these levels, low resistivity values i.e. values going down to below 5 ohm.m approximately can be seen. At DES points North of DES 58, high resistivity values show an increase towards North in vertical direction. Throughout there is a rise at the base and in the middle parts there is basing. It is thought that the high resistivity values in the upper levels are the sandy, pebbly, silty levels of the alluvion, and the low resistivity values below the levels are the Bigadic and Can volcanites of the Tertiary. The resistivity values show variations horizontally in the upper levels, and laterally in the northern part of the cross-section.

As the electrical basement since units of high resistivity values grater than 20 ohm.m at the base take place, levels of high resistivity below these values can be taken into consideration.

When the structural cross-section is investigated, decrease is seen at the electricity basement between DES points 51 and 48 in the south, and a similar decrease is seen between DES point 15 and 925-350. These decreases can be considered as faulting. Between these points resistivity values greater than ρ =80 ohm.m at the surface the pebbly and sandy levels of Kocacay Stream having a thickness of about 5-35 m, under it the clay levels of the Bigadic Formation, the approximate resistivity values between ρ =5-10 ohm.m, under it the pebbly and sandy levels of the Can volcanites having thicknesses of 50-100 m, high resistivity ρ =8-20 ohm.m, and below these units the Karakaya Formation takes place. The approximate resistivity values of the Karakaya Formation are between ρ =2-10 ohm.m and thicknesses is between 150-450 m. In the North of the cross-section, faulting is seen between 58 and 025-350, electrical basement depth decreases towards North. Faulting is also seen between DES points 0650-350 and 077-350, towards North it is seen that the electrical basement gets shallow.

Points in the North of the DES point numbered 050-350 have been measured on the Karakaya Formation, at these points high resistivity values are seen at the surface and relatively low resistivity values are seen at the bottom parts. The resistivity of these levels is over ρ =100 ohm.m at the surface and below ρ =50 ohm.m underneath. The thickness ranges from 140 to 320 m. Levels over resistivity values of ρ =100-1000 ohm.m may be the Tertiary aged Eybek Granodiorite of high resistivity which we named electrical basement.

4.2. 900 m Level Map

When this level map (Figure 4), is investigated high observed resistivity values in the South of the area, low values right in the North, high values as in the other levels in the northern most part and low values in the east and west are seen. Being different from other level maps, in this map, the very fractured structure in the North of the investigated area continue as in the previous level; while in the south it is seen that they continue with less and wide opening calmer and in addition without interrupting much the general tectonic structure starting from the surface.

4.3. Electricity Based Topography

In the South of the investigated area (Figure 5), the electricity base depth starting from, an elevation of about 300 m deepens as we go towards North, according to the map, at DES point no 46 it goes down to 600 m. At DES (drilling of deep electrical) point no 45 an elevation is seen, this elevation goes up to about – 100 m. At DES 33 there is deepening again and this goes down to -550 m. At DES point 39 and 925-400, it goes up to -100m and towards North of these point it goes down again -550 m. Shallowing is seen in the electricity base as we go from po4 profile towards North. In this interval lengthening is seen in same places. And it is thought that they coincide with the points altered by the faults developed in approximately north-south orientation.

4.4. General Summary of the observed Resistivity, Structural Cross-sections and SP(Self Potential) profiles

Anomalies seen in observed resistivity, structural cross-sections and SP profiles, indicate that they are in conformity with same points, coinciding with faulting, the traces of which are sometimes seen at the surface, and at some other points indicate the presence of tectonic activities not observed at the surface.

The shape of counter distributions in observed resistivity cross-sections is seen to be in conformity with the tectonic structure in the structural cross-sections.

Since SP measurements have not been made along all the profiles, a SP derivative map can be made only in some important destinations. SP profiles have been made along some DES profiles. Anomalies seen in these profiles have also been seen in the DES profiles. It is seen that some SP anomalies coincide with the Karakaya and granodiyoried contact. Hot water exits are seen at points coinciding with faults where these contacts are.

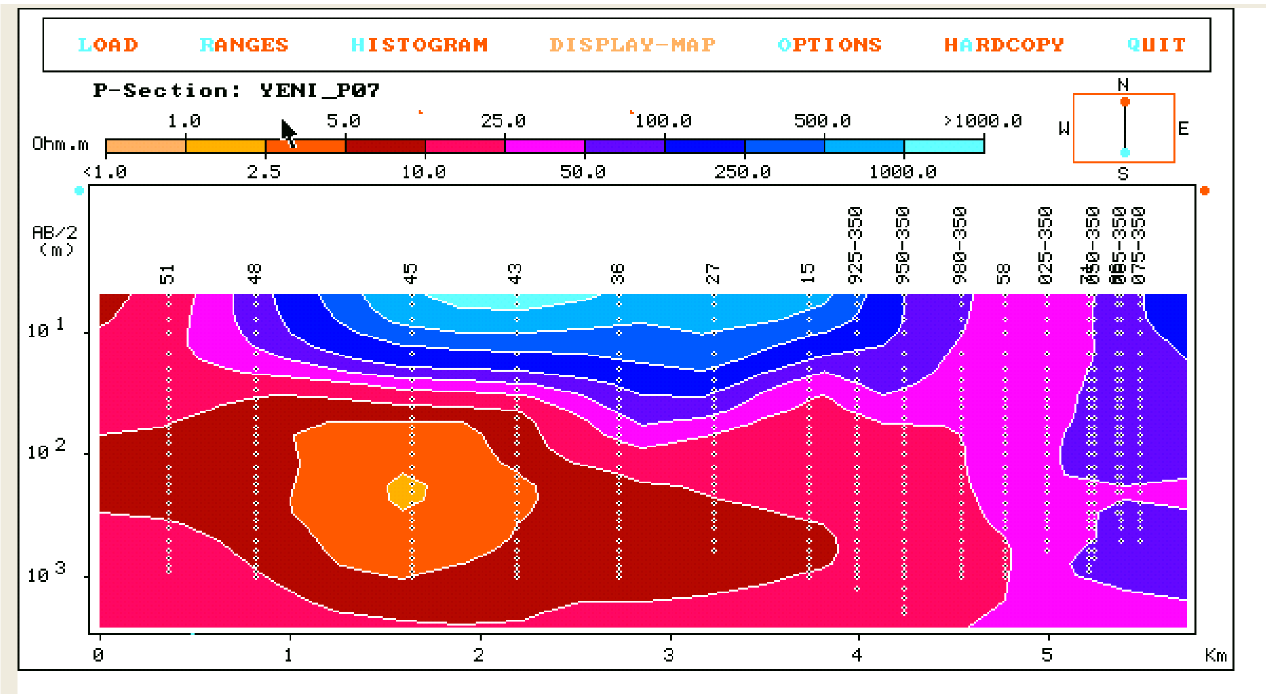

Figure 3: P07 profile

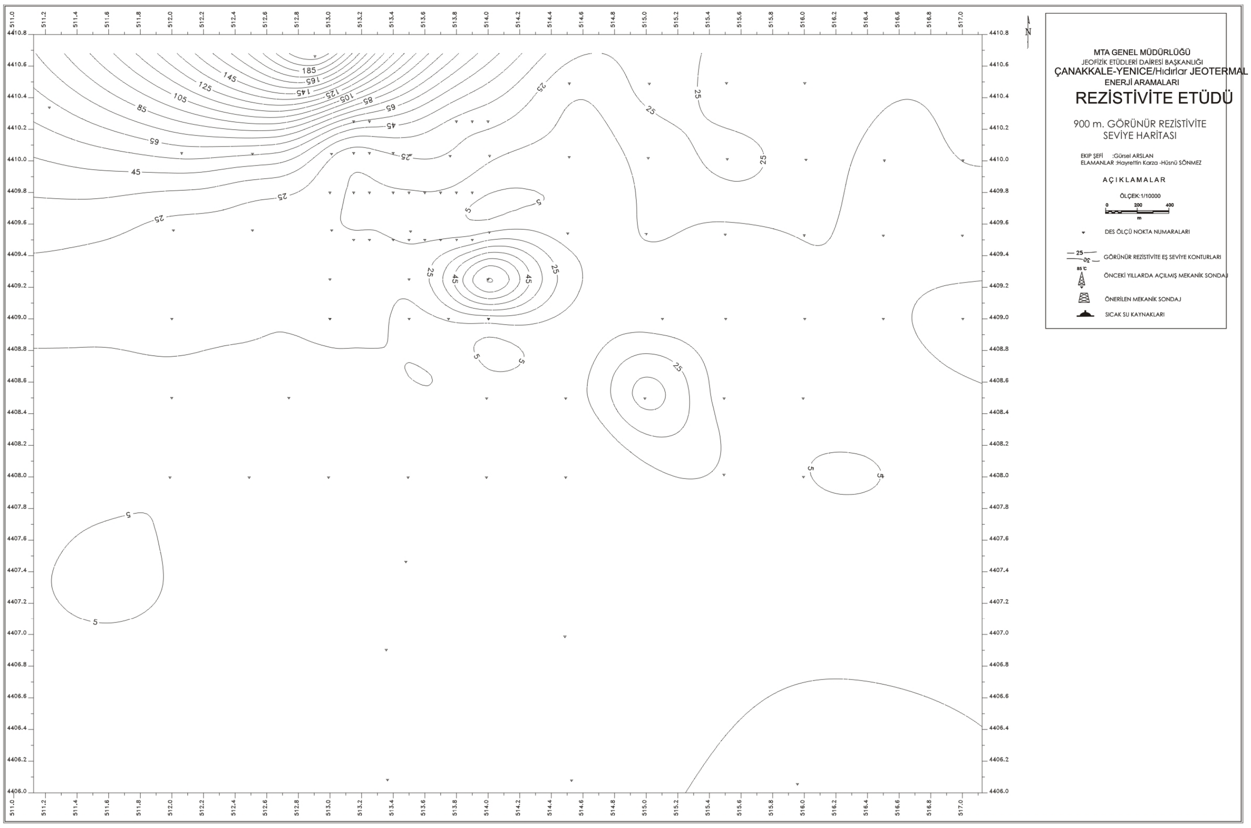

Figure 4: 900 m resistivity level map

There is no considerable difference in general between electricity base map and level maps. The electricity base forms the Eybek Granodiorites which have higher resistivity values in the field in general.

5. CONCLUSION

The extensions of the traces at the surfaces of the tectonic structure (according to data obtained in geological studies) and tectonic structure of the units in the covered areas are seen to be in conformity with the results of the data obtained in the study.

There is not much difference in the enthalpy and chemical contents of the hot waters collected in the area. This brings to mind that cold and hot waters have mixed with each other at least a little. Even if, it is accepted that the mixture is 50 % it is seen that the reservoir temperature is not above 100 °C. These results show that the areas are suitable for greenhouse, heating and for spa.

In the region two different units have been found which can heat the water. It is thought that these are the Oligocene-Miocene aged granodiorite intrusions and the Miocene aged acidic and neutral characterized volcanism.

All hot waters in the area are Na-SO_4 in classification.

When all the DES points are investigated, curves which may be important in geothermal have been evaluated. As a result of geological and geophysical data correlations in the studied area, it can be seen that the most suitable point is the area around DES point number 5. This point is at a point where the vertical and strike slip faults extending from North to South and also step faults falling from North towards South coincide at an electricity basement depth of about 800-900 meters. Mechanical drilling has been advised for this point and a well having a depth of 800 m has been drilled. However sufficient fluid could not be obtained from the well and the aimed granodiorite formation was not intersected.

As a result, when research by drilling is made in such granitic areas, the crack, fracture and fault systems within the granitic rocks must be investigated very well and one must not go too far away from the resource region. Also the fracture system decreases with depth in granitic rocks.

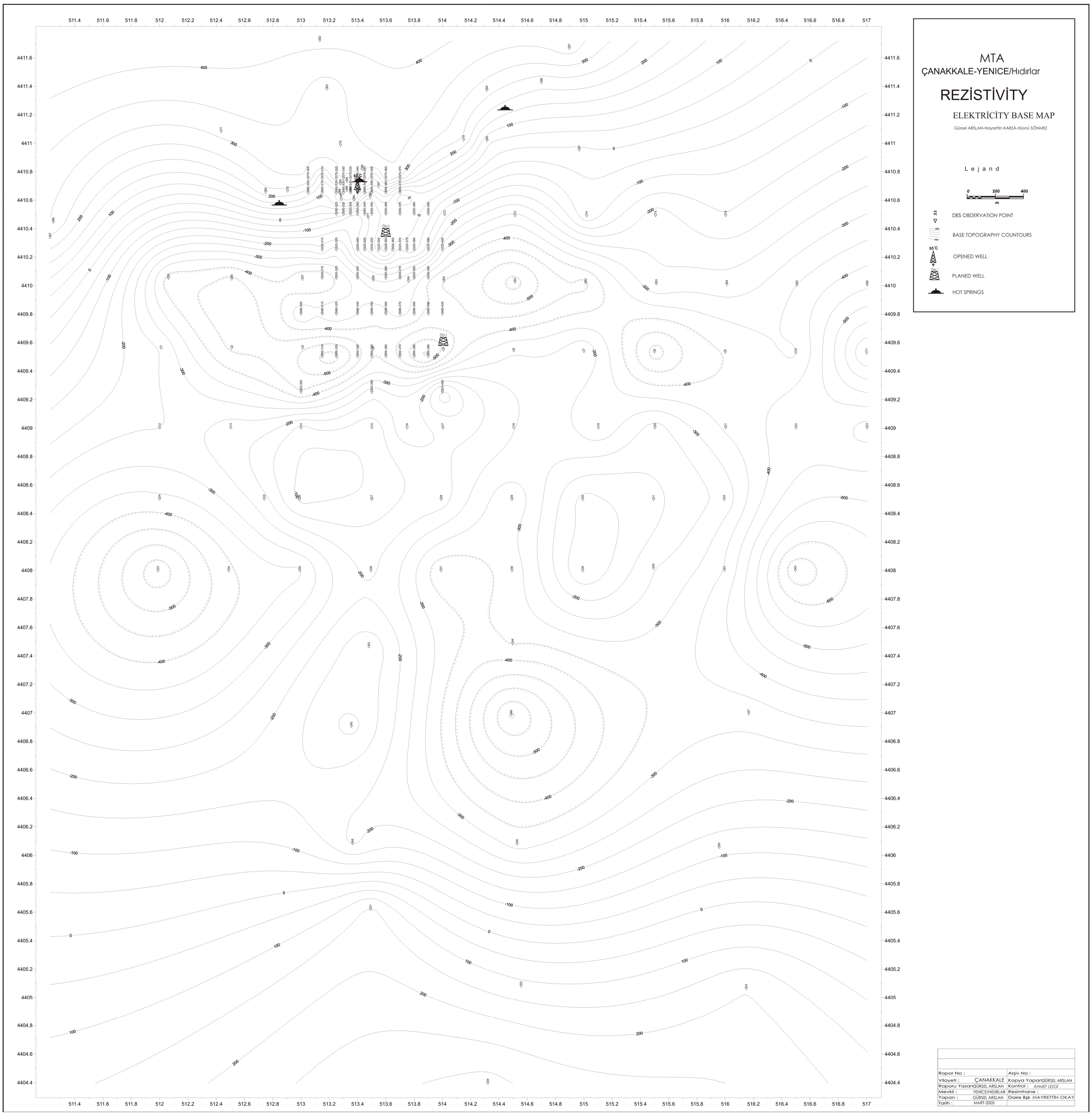

Figure 5: Electrical basement map

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