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Göynük (Bolu) Çatak Hamamı-Ilıca-Karacalar Fields

Geothermal Geology Investigation in Turkey

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ABSTRACT

The Göynük province is located approximately 250 km NW of Ankara which is the capital of Turkey. There are three different low enthalpy geothermal fields around Göynük named Çatak Hamamı (38.5°C), Ilıca (32.4°C) and Karacalar (27.3°C). Each of these fields have several natural hot water springs. The aim of the investigation is researching the geothermal energy possibilities and determining the drilling locations for effective geothermal fields.

Two different sedimentary deposits of Jura-Tertiary age were observed in the investigation area. The most suitable unit for the reservoir rock is Cretaceous limestone. The Yenipazar formation's marl, shale, Üzümlü formation's tuff and agglomerate, Taraklı and Himmetoğlu formation's clay levels have cap rock features. Although volcanic activity is observed, the level of the temperature is not high enough for geothermal energy possibilities.

The investigation area located in West Pontides tectonic units was affected by Alpine orogenic movement and because of approximately N-W direction compression forces, E-W direction structural shapes were formed.

Detailed geological mapping revision was realized and hydrologic, hydrogeological and hydrogeochemical conditions were determined to evaluate geothermal possibilities of the fields. Radon and CO_2 gas measurements were also realized at different points on the surface to research probable crack and fracture systems. The chemical results of the hot waters also show low temperature. Poor mineral content of the water (except Karacalar field), Na/K ratio and SiO_2 quantity show low reservoir temperature.

The Ilıca spring and especially Karacalar area should be determined with research drillings study in order to examine geothermal possibilities.

1. INTRODUCTION

The study comprising geological and geophysical survey studies for geothermal purposes was realized in three different geothermal areas within the boundaries of the city of Bolu and the county of Göynük in 2008.

Studies carried out previously in the Göynük-Ilıca-Çatak Hamamı-Karacalar geothermal areas were re-evaluated and the revision of detailed geological maps of the above mention areas and their vicinity were made, hydrological, hydro-geological conditions were evaluated in terms of geothermal possibilities. For this aim, radon and CO_2 gas measurements were made in different points on the surface and probable crack and fracture systems were investigated.

In the geophysical survey carried out in the Göynük-Ilıca-Çatak Hamamı-Karacalar geothermal research studies, resistivity and SP methods were applied. Resistivity (vertical electric drilling-DES) in 40 different locations to form profiles and SP derivative measurements having a total length of 5 km in 6 profiles were realized during the research. The area comprising geophysical survey studies is 3,7 sq km in total.

2. GEOLOGY

2.1. Stratigraphy

In the investigated area (Figure 1) a sequence having a thickness of approximately 5000 meters was deposited during Jurassic-Tertiary period on the granitic base forming a part of the middle Sakarya Basin crops out.

Figure 1: The location map of the investigation areas.

These deposits are in the form of two different stratigraphic sequences showing variations before Lower Cretaceous and Paleocene. In the south of studied area, the Soğukçam limestone shows lateral and vertical transitions with the Bilecik limestone and in the north overlies the Mudurnu formation. Besides this, in the south of the basin, Taraklı, Selvipinar and Kızılçay formations and in the north the Halidiye formation were deposited in Paleocene. These two different sequences observed in the investigated area are the result of lateral and vertical transitions of the units with each other within the basin in general. These two different sequences developed in different directions in the basin and the correlations of these sequences are shown in Figure 2 (Besbelli, 1991).

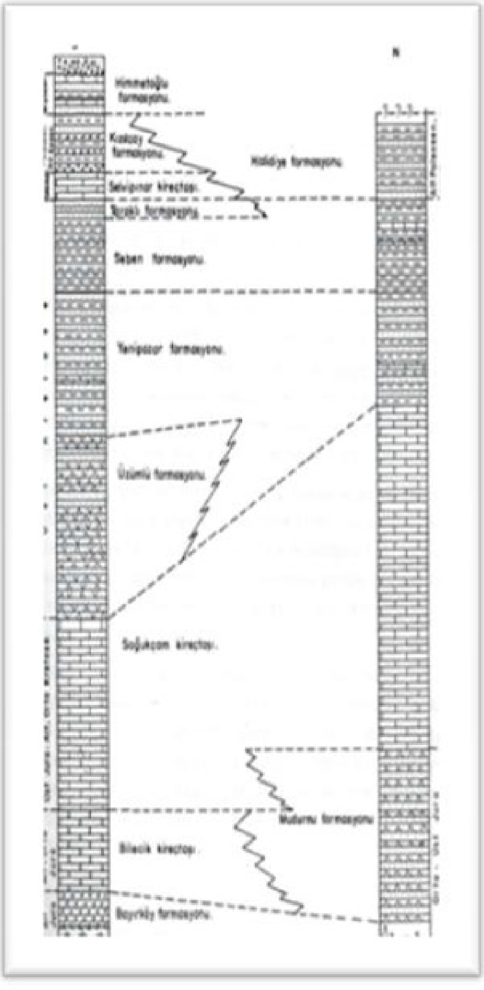

Figure 2: The measured stratigraphic section of Ilıcakoy (Besbelli 1991).

The sequence taking place in the Bolu-Göynük-Karacalar-Ilıca-Çatak Hamamı geothermal areas from bottom to top is as fallows.

2.1.1. Soğukçam Limestone

The unit composed of white, gray colored, middle-tick layered limestone having many cracks and fractures in places and weak zones are filled with secondary calcite (Photo 2, 3).The Soğukçam limestone is widespread in the investigated area. The unit cropping out in anticline axes in E-W directions covers an area of about 80 sq km. As a result of paleontological determination it is seen that the unit was deposited during Upper Jurassic-Lower Cretaceous.

2.1.2. Üzümlü Formation

The lithology of the unit is sequences of volcanogenic sandstone and shale. Tuff, agglomerate and basic lava flow are seen in places within this sequence. The tuffs are generally green and dark red in color. The Üzümlü formation is conformable with the Soğukçam limestone below and shows vertical and horizontal transitions with the Yenipazar formation overlying. Because of its stratigraphic location it is thought to be Upper Cretaceous in age.

2.1.3. Yenipazar Formation

Although, the lithology of the unit shows variations within the investigated area the dominated lithology of the unit is in the form of sandstone, volcanogenic sandstone, conglomerate, shale and marl sequence. Within this lithology there are very tick tuffs in places. The Yenipazar formation conformably deposits over the Üzümlü formation. The unit at the same time shows lateral transition with the Üzümlü formation. In areas where the Üzümlü formation does not deposit, the unit conformably overlies the Soğukçam limestone.

2.1.4. Taraklı Formation

Towards the upper levels the Taraklı Formation is a sequence with increasing grain size and layer thickness. Tick layered mudstone, thin layered sandstone and siltstone sequence showing transition in steps with the Seben formation is seen. It has a vertical transition with the Seben formation below it. Its relation with the Selvipinar limestone and Kızılçay formation overlying the unit shows variations due to the characteristic of the environments of deposit. According to fossils, it is determined that its age rises from Middle-Upper Paleocene to the Lower Miocene.

2.1.5. Himmetoğlu Formation

In the investigated area which shows lacustrine sequence, the Himmetoğlu formation which is the youngest unit cropping out, overlies the Kızılçay formation with an angular unconformity. The Himmetoğlu formation starts with a conglomeratic level. Green colored clay stores overly these levels of the unit which continues with pebbles and sandstone. Still upper clayey lignite and lignite can be seen. There is a bituminous shale zone over these levels. The sequence above the bituminous levels is generally in the form of fine grained sandstone, siltstone, clayey limestone and marl sequence. The age of the unit is accepted to be Upper Miocene.

2.1.6. Basalt

It has lithology of dark gray-black colored basalt with an approximate thickness of 80 m. In the investigated area, it is thought that the unit unconformably overlying the Soğukçam limestone and Yenipazar formation is of Quaternary age.

2.1.7. Travertine

In the investigated area there are travertine formations right in the south of the Göynük county, Kayalıdere village and south and southeast Susuz village in a total area of 6 sq km. Of these, the travertines south of the Göynük county are being operated. It is thought that the origins of the travertines are the Soğukçam formation.

2.1.8. Alluvium

The place where alluvium is spread most in the investigated area is an area where the flow rates of the Çayköy, Ovaçayı, Bölücekova and Mehmetağa streams decreases. In addition, the alluviums formed by the Göynük stream and its arms also cover a wide area.

2.2. Structural Geology

The investigated area forming a small part of the middle Sakarya basin takes places within the West Pontides tectonic union. In the region where Upper Jurassic-Eocene aged deposits crop out, Alpine Orogenic movements have been effective and structural formations extending in approximately E-W direction have developed.

In the region fractural structures formed with the effect of compressional forces developed in approximately N-S directions are observed. Among these structures, the most important ones are reverse faults and thrusts extending in E-W direction and tear faults developed in NW-SE and NE-SW directions forming certain acute angels with these faults. On the other hand, normal faults extending in approximately N-S direction have been formed with the effect of tensional forces of E-W direction developed before and/or after compression.

3. HYDROGEOLOGY

3.1. Rivers

The most important river in the studied area is the Aladağ brook flowing in NNW-SSE direction and fed by Cuma brook and Küsem stream. Other rivers are the Karaçalı stream flowing in E-W direction and fed by Adatarla and Karasu stream; Göynük stream; and Gök stream flowing in SW-NE direction and fed by Değirmendere.

3.2. Underground Waters

The region is quite rich regarding underground waters. The flow rates of cold water resources taking place in the studied area and its vicinity is between 0.1-9 l/s. The Soğukçam limestone containing many fractures and dissolution cavities shows a good reservoir rock property for cold waters. The sandstone level of the Üzümlü formation and the sandy-clayey limestone level of the Yenipazar formation contain underground water.

4. GEOTHERMAL POSSIBILITIES

4.1. Hot Water Resources

Within the studied areas the highest temperature has been measured as 38.5°C in the Çatak Hamamı resources. The temperatures of the waters taking places in the region vary from 18.4°C to 38.5°C. The temperature and flow rate values of these resources measured in the studied field are as follows:

Resources	Temperature (°C)	Flow Rate (l/s)
Ilıca	32,4	3
Çatak Hamamı	32 – 38,5	1,5
Karacalar	27,3	2,3

4.2. The Physical and Chemical Properties of the Waters

In the field, chemical analyses have been made at the resource and soil gases have been measured. Bolu, Göynük is quite rich regarding underground water. In the area, while there are many cold water resources, hot water resources are limited. The electricity conductivity values of the waters found in the Ilıca and Çatak Hamamı areas are between 321-755 µmho/cm and these waters are poor regarding minerals. All the waters found in this region are waters formed as a result of shallow circulation. The pH values of the waters vary from 7,3 to 9,0 and the waters in the region have neutral and basic characteristic. The Cl values of the waters vary from 2,25-30,5 mg/l and their differences originate from circulation periods and probable mixture. The dominant cation in the waters in the region change from Na to Ca but the dominant anion is HCO_3, and it does not change. The B values of the resources found in the Göynük area is between 0,2-12,6 mg/l. Of these resources, the Ilıca and Çatak Hamamı resources waters which are rich in B must not be used directly in irrigation. Mixing of the Ilıca resources water with the irrigation water must also be prevented. In addition, the Ilıca resources found in the area must not be used as drinking water since it bears high Fluorine content (F: 13 mg/l).

On the other hand, in the Karacalar area which is another part of the studied area, the electricity conductivity values of the waters range from 1400 - 1438 µmho/cm and they are mineral waters. The pH values of the hot waters found in Karacalar area vary from 6.2-6.5 and these waters have acidic characteristic. The Cl values of the waters in the Karacalar area are between 3.99-651 mg/l and these waters have been formed as a result of a shallow circulation. In the waters found in the Karacalar area, the dominant cation and anion are Ca and HCO_3 respectively. And these are Ca HCO_3 bearing waters. The hot and mineral waters taking places in the studied area have been evaluated in various diagrams.

According the Schoeller diagram, the hot and warm waters in the Ilıca region bear $NaHCO_3$. The hot, cold and warm waters found in the Çatak Hamamı and Karacalar regions are waters bearing $Ca(HCO_3)_2$ and they are related to limestone aquifer in terms of origin (Figure 3).

The ion sequence of the waters found in the region is as follows:

Ilıca : CATION: r(Na+K)>rCa>rMg

ANION: $r(CO_3+HCO_3)>rCl>rSO_4$

Çatak Hamamı : CATION: rCa>r(Na+K)>rMg

ANION: r(HCO3+CO3)>rSO4> rCl

Karacalar : CATION: rCa>r(Na+K)>rMg

ANION: $r(HCO_3+CO_3)>rCl> rSO_4$

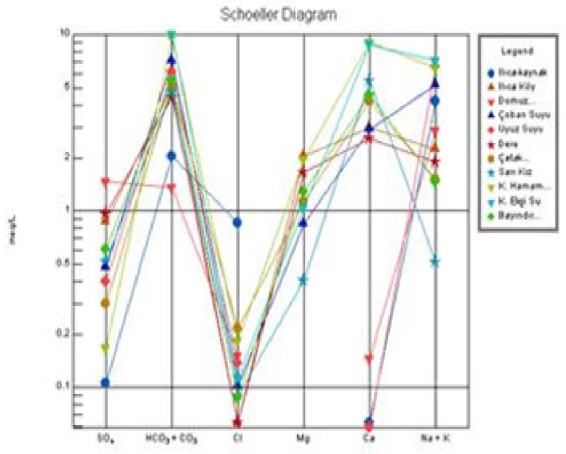

Figure 3: The Schoeller diagram of the investigated area.

According to the Piper diagram, most of the waters in the region are waters bearing $CaCO_3$ and $MgCO_3$ (Figure 4).

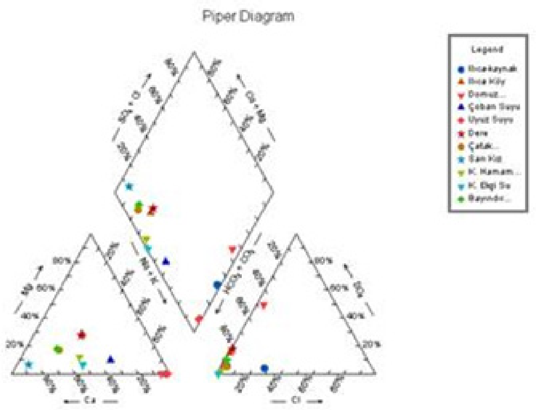

Figure 4: The Piper diagram of the investigated area.

5. GEOPHYSICS

5.1. Applied Methods

In the vicinity of the studied area, resistivity and SP methods and applications have been made in geophysical-electrical surveys realized in order to research and develop geothermal energy possibilities. During the research, resistivity (vertical electrical drilling-DES) studies have been made in 40 different locations and SP derivative measurements in 6 profiles having a total length of 5 km have been taken.

5.2. The Interpretation of the Profiles

5.2.1. Ilıca Area

When the observed and electrical structural cross section of profile A and B are investigated (Figure 5, 6, 7, 8): it is thought that the high resistivity which is west of DES point number 5 originates from the Üzümlü formation. On the other hand, in the eastern parts of the same point, the effect of the Yenice formation is seen as low resistivity. It is thought that the changes in the resistivity values in vertical direction between points B-1 and B-5 originates from discontinuity in N-S directions.

It has been seen that, the SP derivative measurements applied along profile A is conformable with the observed electrical structural cross section (Figure 9, 10).

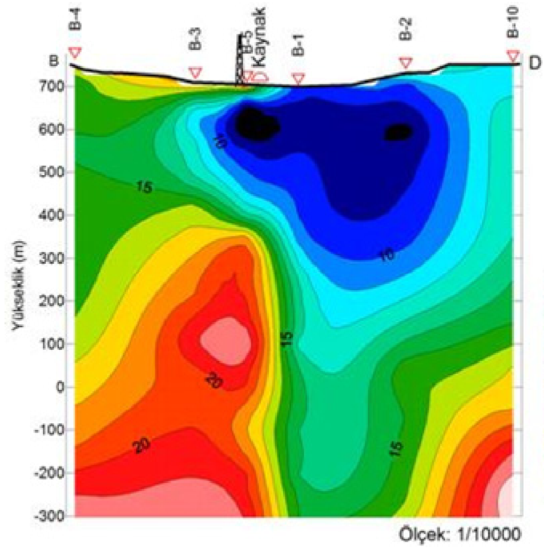

Figure 5: Ilıca A profile observed resistivity cross section.

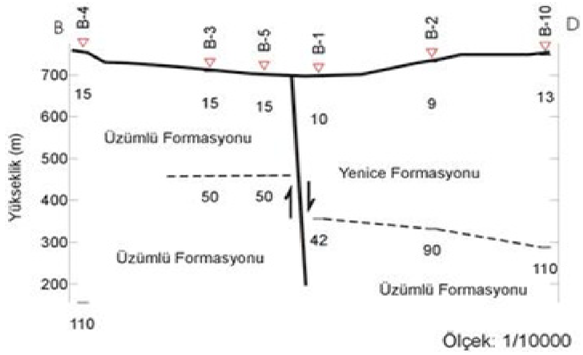

Figure 6: Ilıca A profile electrical structural cross section.

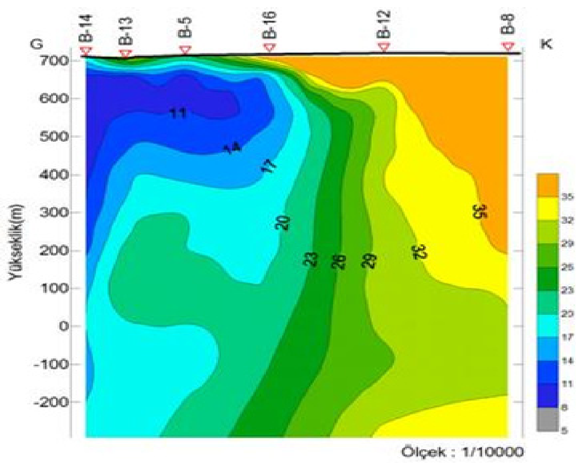

Figure 7: Ilıca B profile observed resistivity cross section.

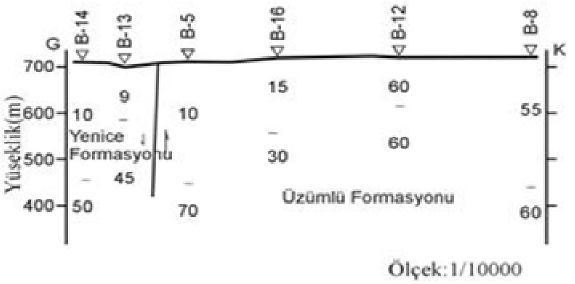

Figure 8: Ilıca B profile electrical structural cross section.

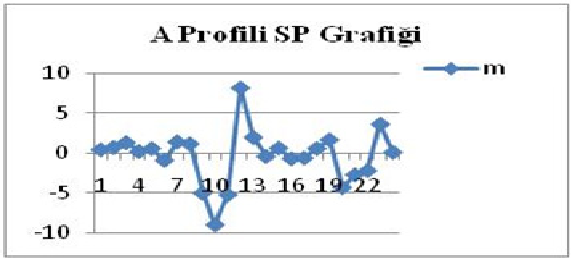

Figure 9: Ilıca A profile SP derivative diagram.

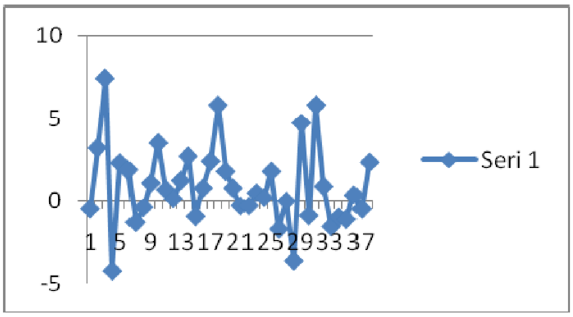

Figure 10: Ilıca B profile SP derivative diagram.

High and low resistivity values are seen as we go towards the north and south of the profile, respectively. In the vicinity of DES point number 5 in the south, there are units of low resistivity which are thought to have originated from hot fluids.

5.2.2. Çatak Hamamı Area

When the observed and electrical structural cross sections of profiles A and B are investigated (Figure 11, 12 13, 14), it is seen that coarse grained units of high resistivity seen at places near the surface overly the low resistivity units. It is thickness increases towards point C-11. It is seen that, there is discontinuity in NE-SW direction between points C-4 and C-5, and C-1 and C-2. This discontinuity and similar structure is the same both profiles. This discontinuity is seen as the continuity of discontinuities in the SW of the studied area.

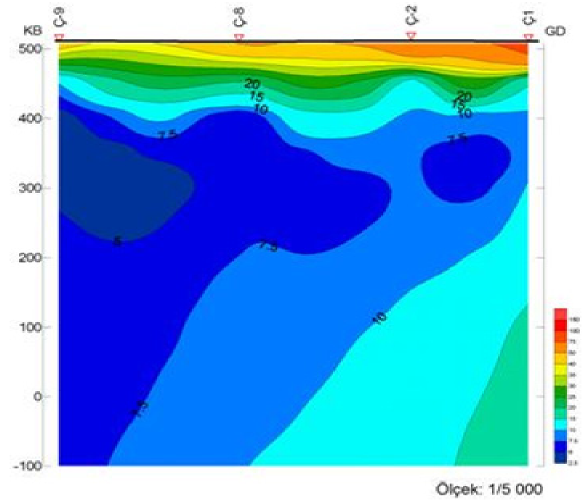

Figure 11: Çatak Hamamı A profile observed resistivity cross section.

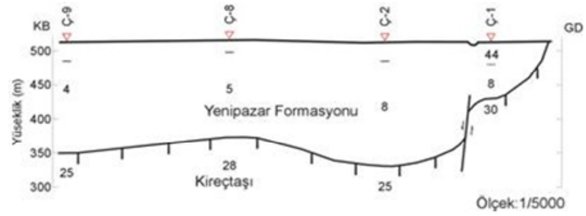

Figure 12: Çatak Hamamı A profile electrical structural cross section.

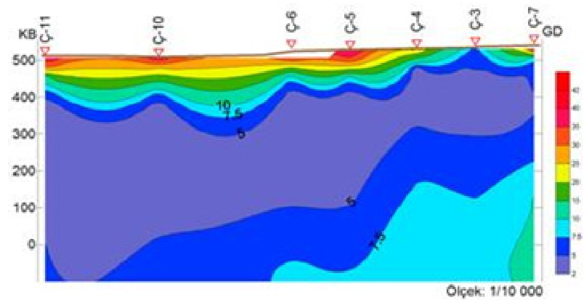

Figure 13: Çatak Hamamı B profile observed resistivity cross section.

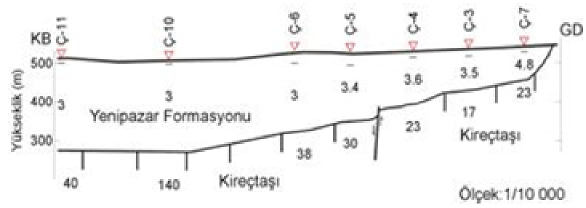

Figure 14: Çatak Hamamı B profile electrical structural cross section.

As we go from the south to the north of the area, the depth of the Yenipazar formation, having high resistivity values near the surface, increases. It consist of sandy and coarse grained pebbly units, the thickness of which ranges from 100-150 meters in places.

Unit of clay and marl covering a large area of the cross section have approximately 5 ohm-m values. High resistivity units originated from limestones constitute the base. The reason for high resistivity values seen in the electrical structural cross section is limestones overlain by the Yenipazar formation.

In the SP measurements realized among 15-25 measurement points taken on profile B, it is thought that the negative and positive transitions originate from probable thrust tectonics (Figure 15).

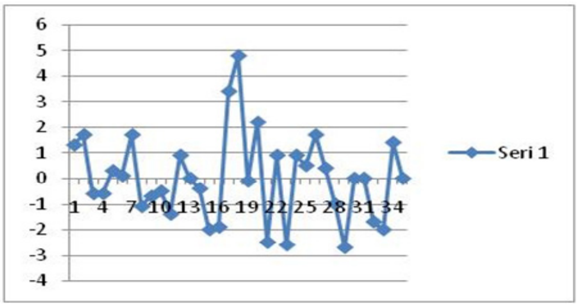

Figure 15: Ilıca A profile SP derivative diagram.

5.2.3. Karacalar Area

When the observed cross sections of profile A are investigated (Figure 16), the high resistivity units seen near the surface are due to travertine deposits. Underneath, the effect of the Yenipazar formation on the measurements is seen as values ranging from 20 to 30 ohm-m. The reason for increasing resistivity values as we go deeper than 100 m at DES point K-4 should be either limestones in the form of lenses within the Yenipazar formation or coarse grained and pebbly units. The low resistivity values between K-1 and K-7 correspond to the fine grained clayey units of the Yenipazar formation.

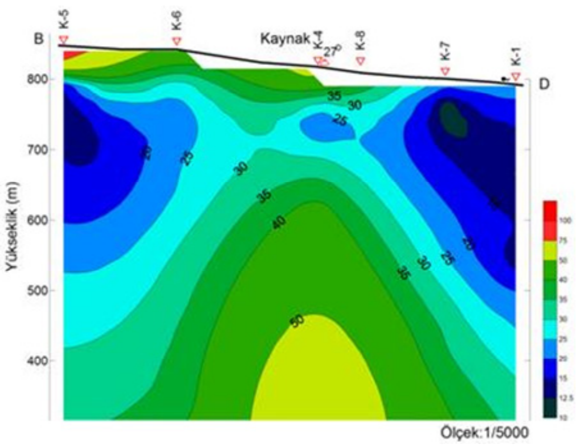

Figure 16: Karacalar A profile observed resistivity cross section.

It has been seen that in the SP measurements on the same profile, the positive and negative transitions at the 3 and 18 does not reflect to the resistivity measurements (Figure 17, 18).

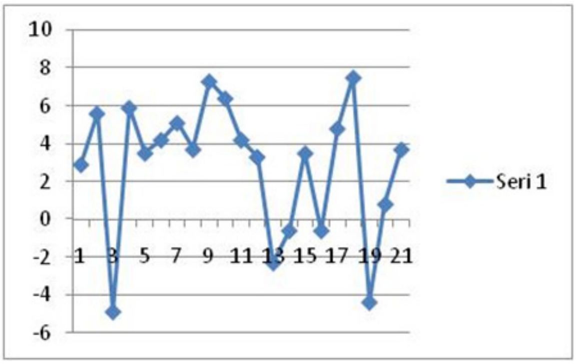

Figure 17: Karacalar A profile SP derivative diagram.

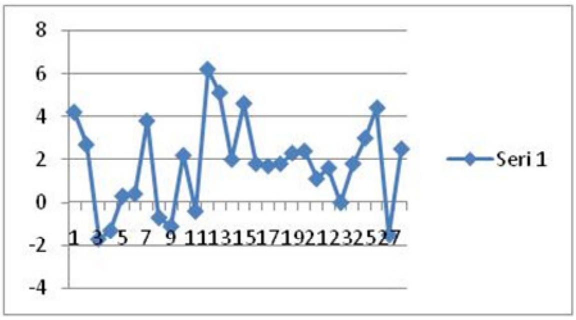

Figure 18: Karacalar B profile SP derivative diagram.

6. CONCLUSIONS AND RECOMMENDATIONS

In this study detailed geological, hydro-geological, geochemical and geophysical resistivity surveys have been carried out in the Göynük county, Çatak Hamamı, Ilıca and Karacalar areas.

The purpose of the survey is to research the geothermal energy possibilities in the above-mentioned areas and to determine drilling locations in effective geothermal areas.

In the investigated areas, although a volcanism period which may be effective in the formation of a geothermal system is observed, it is seen that it is not at sufficient level for high temperature regarding geothermal energy possibilities.

The temperatures of the resources taking place in the investigated area is between 18.4^oC to 38.5^oC; their flow rates are between 0.2 l/s to 3.5 l/s.

In the measurements realized at the resource in the field the electrical conductivities of the waters found in Göynük-Çatak Hamamı and Ilıca geothermal areas are 321 - 755 µmho/cm and these waters are classified as poor waters regarding minerals.

All the waters found in the region are waters forming as a result of shallow circulation and not as a result of deep circulation. The pH values of the waters are between 7.3 - 7.9 and the waters in the region have neutral and basic characteristics. In the waters in the region, while the dominant cation changes from Na to Ca, the dominant anion is HCO_3 and it does not change.

The electrical conductivity values of the hot and mineral waters found in the Karacalar area are more than those of

Çatak Hamamı and Ilıca resources and vary from 1400-1438 µmho/cm.

According to semi logarithmic Schoeller diagram, the hot and warm waters found in the Ilıca region are waters bearing $NaHCO_3$. The hot and cold waters found in the Çatak Hamamı and Karacalar region are waters bearing $Ca(HCO_3)_2$ and related to limestone aquifers in terms of origin.

With geophysical studies, places where the effect of geothermal activity in the area can be perceived most have been determined and probable fractural zones have been tried to be determined. It has been observed that there are low resistivity units, in the vicinity of DES point B-5 in the Ilıca region.

In the Çatak Hamamı geothermal area, the extension of the fault formed vertically to strike-slip fractures zones in north-south direction have been determined in geophysical studies aiming to clarify the tectonic structure.

Drillings having depths of about 400 m for research purposes should be made in the Ilıca and Karacalar area. Since there is a strong possibility that the drilling machine can not enter the vicinity of Çatak Hamamı, resource development study should be carried out in the region.

REFERENCES

Abdülselamoğlu, Ş.,: Almacıkdağı ile Mudurnu ve Göynük Civarının Jeolojisi, 1959.

Beseme, P.,: Sürümdere Senklinali Bitümlü Kayacının Jeolojik İncelenmesi (Gölpazarı, Bilecik). MTA Rapor No: 25958/16, 1968.

Besbelli, B.,: Adapazarı H 25 b1, b4, c1 paftalarının jeolojisi ve petrol olanakları, 1991.

Demirkol, C.,: Üzümlü-Tuzaklı (Bilecik İli) Dolayının Jeolojisi. Doktora Tezi, İst.Üniv. Fen Fak. Tatbiki Jeoloji Kürsüsü Arşivi, İstanbul, 1973.

Dunham, R.J.,: Classification of Carbonate Rocks According to Depositional Texture, AAPG Special Publ, n.l.

Eroskay. S.O., 1965; Paşalar Boğazı-Gölpazarı Sahasının Jeolojisi İst.Üniv. Fen Fak. Mecm., Seri. B, C. 30,5,3-4, 135-170, 1962.

Folk, R.L.,: Petrology of Sedimentary Rocks. Hammphills, Austin, Texas, 170 s., 1968.

Gevrek, A.,: Gölpazarı Çengeller ve Değirmenderesi Ölçülen Stratigrafi Kesitlerinin Kil Minerolojisi M.T.A Raporu, No: 7245, 1982.

Granit, Y.,et Tintavt, H.,: Observations Prelimin Aices Sur le Jurassique de la Region de Bilecik (Turcjuie). Lab. de Geol., Faculte des Sciences, Dijon, 1960.

Meriç, E., Şengüler.İ.,: Göynük (Bolu, KB Anadolu) Çevresinde Üst Kretase-Pale-osen Stratigrafisi üzerine yeni görüşler. Jeoloji Mühen¬disliği Dergisi, S.29,61-64, 1986.

Miall, A,D.,: Alluvial Sedimentary basin. Tectonic Setting and Basin architecture. In A.D. Miall, ed., Sedimentation and tectonics in alluvial basins. Geol. Assoc. Can. Spec. Paper., 23, 1-33, 1981.

Mutti, E., Lucci, R.,: Turbidities of Northern Apennines. Introductıcn to facies analysis Inter. Geol. Review., 20/2, 125-166, 1972.

Saner, S.,: Geyve-Osmaneli-Gölpazarı-Taraklı Alanının Jeolojisi, Doktora Tezi, MTA Rapor No : 6306, 1977

Saner, S.,: Mudurnu-Göynük havzasının Jura ve Sonrası Çökelim nitelikleriyle, Paleocoğrafya yorumlaması. TJK Bült., 23/1, 39-52, 1980.

Taka, M.,: Himmetoğlu (Göynük-Bolu) Sahasının Bitümlü Şeyi Olanakları ve Sondajları, MTA Rapor No : 8533, 1988.

Turgut, A., Dümenci, S.,: Bolu-Göynük Linyit Havzasına Ait Jeolojik Rapor. MTA Rapor No: 6885, 1980.

Walker, R. G.,: Deep Water Sandstone Facies And Ancient Submarine Fans. Model For Exploration For Stratigraphic Traps. AAPG Bull. 49,12,9-32-966, 1978.