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Geothermal Energy Research in the Erzurum Province, TURKEY

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ABSTRACT

The Ilica and Pasinler geothermal sites, 28 km and 40 km respectively from the city center, are the only geothermal areas of Erzurum, located in Eastern Anatolia. Erzurum has snow tourism opportunities in addition to of historical sites. It is famous for being one of the coldest locations of Turkey. The International University Winter Olympics will be held in Erzurum, in year 2011, the new geothermal site will occasionally be of meaningful value.

The Hamamderesi Geothermal field is located 8 km northeast, of Erzurum. A spring called Hamamderesi Hot Spring, of 34.4^{o}C has been discharging at a rate of 5 l/s, for almost a century. This geothermal investigation is the first one performed in the area.

Miocene aged andesitic volcanism, overlaying the Jurassic ophiolites, can be seen as the heat source of the geothermal system. Pliocene aged sediments of the Horasan Formation, overlain by Pliocene and Quaternary basalts behave like a reservoir, from which the spring discharges.

Fluid characteristics show Na+Mg+HCO_3 type thermal water. Mineral waters of temperatures ranging between 22°C and 24°C also discharge from the Horasan Formation tectonic zones.

Geological and hydrogeological investigations have been completed, in parallel with geophysical and hydrochemical studies. Radon and CO_2 gas measurements have also been taken.

According to site characteristics, morphological properties of the geothermal system, and the evaluation of investigations, high temperatures are not expected during production. Winter and thermal tourism give value to the Hamamderesi geothermal area. A low degree thermal fluid will then be applicable for the use of thermal opportunities. Such applications will also improve cultural, social and economical structure of the habitants.

1. INTRODUCTION

1.1 Geographic Location

The Hamamderesi region is located on the western part of the Pasinler geothermal area. The Hamamderesi River, discharging at a rate of 70 l /s (annual mean), flows along the exploration site. The studied area is at an 8 km distance from the Erzurum city center, and located at an altitude of 1850 m (Fig 1).

Terrestrial climate is dominant in Erzurum, where summers are dry and winters are rainy and snowy. Precipitation occurs in frequently as snow fall. Vegetation is not developed. Animal cultivation, like cattle, is frequent, as well as agricultural activities, throughout the plain areas.

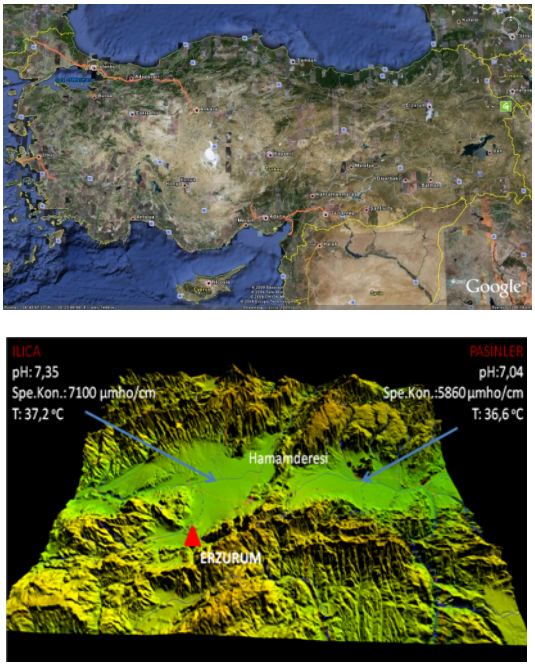

Figure 1: Location of the Hamamderesi Geothermal Site

1.2. Previous Studies

Petroleum possibilities were explored by Akkus, (1965). He prepared the geological map of the area. Later in 1985, Saroglu, examined the neo-tectonical activities and the tectonic evolution of the area. Saroglu adverted that the region experienced a N-S compression regime. Geothermal wells were drilled in Pasinler in 1994 to 2001. Acikgoz, (1994) studied the volcanology of the area in detail. Hot spring analyses were all completed throughout the study. A model of the Pasinler Geothermal basin was also completed by Acikgoz.

2. GEOLOGY

Lithologies start from Upper Cretaseous and end up to Quaternary. Upper Cretaceous aged Sahvelet ophiolites surround the site from the South (Yilmaz, 1989). The ophiolites consist mainly of serpentines, peridotites, gabbros and diabase dikes. Volcanic activity started during Upper Miocene, with the terrestrial deposits, and continued until the Quaternary (Fig. 2, Fig. 3).

2.1. Stratigraphy

Even though, many lithological units outcrop in Erzurum and province, only the ones in the site will be described below.

Sahvelet Formation: Consisting mainly of serpentines, peridotites, gabbros and diabase dikes, the formation is principally seen on the eastern and southern parts of the Palandoken Mountains. A thickness of 500 m (Yilmaz,

1989) was observed and Maestrihtian age was given to the formation in previous studies.

Gokcehamam Formation: The formation is represented by silica- carbonates in the upper sections, with gravel, sandstone, and marl (Acikgoz, 1994), overlaying the ophiolites with angular disconformities, and representing deep marine deposits. Due to the large amount of Nummulites fossils, Lutesian age was given to the formation (Acikgoz, 1994).

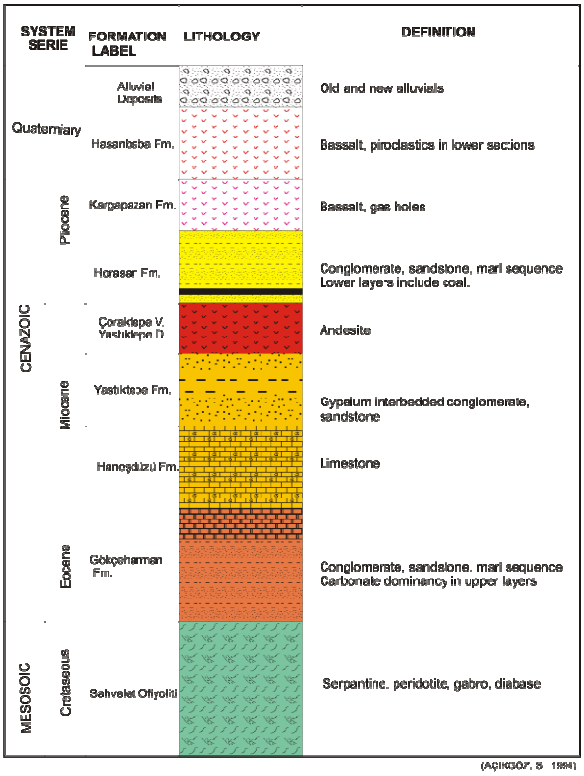

Figure 2. General stratigraphical section of Erzurum and province (Acikgoz, 1994)

Hanesduzu Formation: This formation is seen as conglomerates, sandstones and limestone sequence in the southern parts of the site. The Hanesduzu Formation over lays the Gokcehamam Formation.

Yastiktepe Formation: The formation is mainly formed of Laguna deposits. River bed deposits are also dominant in this formation. Red conglomerates are the dominant deposits, including gypsum. Upper Miocene age was estimated by Akkus, 1965.

Coraktepe Volcanic Rocks: These volcanic rocks are represented mainly by high potassium enriched ignimbrite tuffs, seen mainly near Coraktepe village. Upper sections constitute of olivine basalts, including andesite to rio-dassite compositions. The thickness observed in the site is about 275 m. Upper Miocene age was given in previous studies to these volcanic (Acikgoz, 1994).

Yastiktepe Domes: The dasitic lavas are dominantly observed. Pyroclastics accompany these lavas. It is thought to be formed of high potassium kalk-alkalene character volcanism, as a result of the compression tectonics due to continental movements. These domes overlay the Yastiktepe formation confirmatively. Maximum thickness is 100 m and has an age of Upper Miocene (Acikgoz, 1994).

Horasan Formation: In general, sandstone, marl, conglomerate sequences are observed. The Horasan formation has a thickness of 475 meters. The formation outcrops at the northern and western parts of the site. It is gray, white and yellowish in color and loosely cemented. It is mainly formed of lagoon and river bed deposits, and shows wide sedimentation areas. Gravel is well graded (Pelin, 1980).

Kargapazari Volcanic Rock: Gray, black and pinky andesite – tuff – basalts form mainly these volcanics. The basalts cover all the other lithologies in the site. It is massive, hard and fissured. These volcanics form the principal elevations in the Hamamderesi region. Lava flow traces are observed along flow points. Pliocene – Quaternary ages were given previously to the basalts (Acikgoz, 1994).

Alluvial Deposits: The old alluvial deposits are seen, as terrace forms, in the southern regions of the site. According to the irrigation wells drilled, the new alluvial deposits have a thickness of 75 – 100 m.

2.2. Tectonics

Tectonic activities are observed from Upper Miocene till today, in Erzurum and province. The region has been undertaken by a compression regime, which leads to the occurrence of left strike slip faults and normal faults.

Most of the normal faults, which caused the formation of the plains, are buried below the alluvial deposits in the northern sections of the site. Left strike faults are dominant at the western parts, resulting from the partition of the plain.

At the southern part of the area, bendings are observable in ophiolite lithologies, as well as the young deposits, in which the compression effect can be easily seen.

As the result of the investigations, the region shows a “pull-a-part” basin character. The Pasinler basin and the Erzurum basin are separated by the Hamamderesi strike slip fault.

3. GEOTHERMAL ENERGY INVESTIGATIONS

3.1. Previously Determined Hot water Points

Each location observed during the studies, consist of wells and springs. Most of the wells drilled in the site were drilled for irrigation and domestic purposes. A well drilled by local inhabitants, discharges mineral water at a temperature of 24°C.

The Hamamderesi Hot Spring (Fig. 4) discharges at a rate of 5 l/sec, throughout a normal fault, overlain by the alluvial deposits, and at a temperature of 34.4^{o}C. This is the major outflow of the probable geothermal system. As the discharge occurs next to the Hamamderesi River, higher temperatures are expected if cold water mixing is eliminated.

One of the irrigation wells drilled by the DSI (Department of Water Affairs), has artesian discharge, distinguishing it from the other irrigation wells. It is also located 1 km north of the Hamamderesi Spring, near Buyuktuy village.

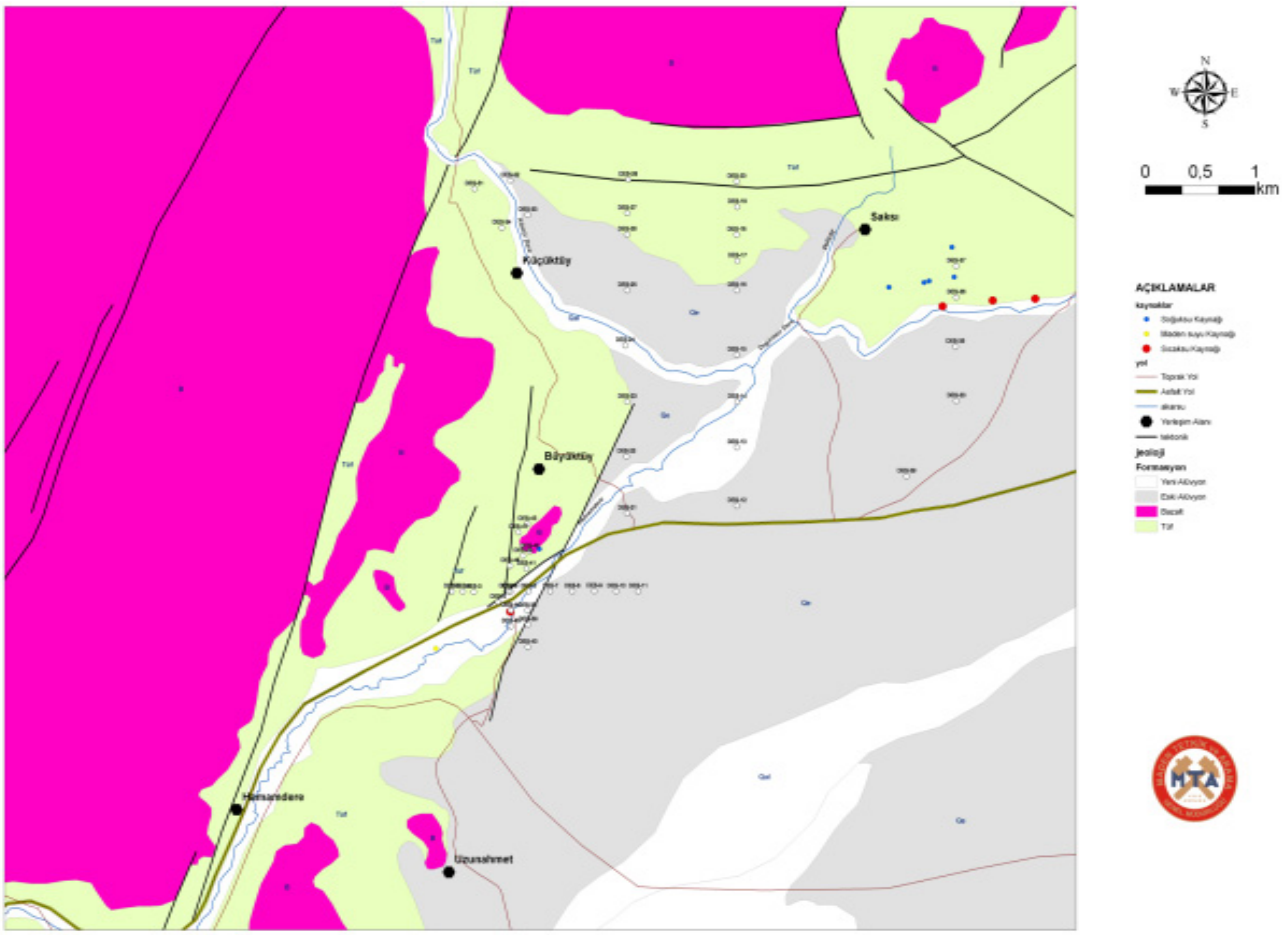

Figure 3. Geological map of the Hamamderesi Region.



Figure 4: The Hamamderesi Hot Spring

3.2. Elements evaluating the Occurrence of the Geothermal System

Bed Rock;

Clay and mudstone layers of the Horasan and Yastiktepe Formations seem to overlay the system, eliminating the heat loss. Unfortunately, as these impermeable layers are intra-bedded with the sandstone, limestone and conglomerate layers, these may act as cold water intrusions to the system, which may lower the heat during production.

Reservoir - Aquifer;

In the wells drilled in Pasinler, the riolytic tuffs and the permeable layers of the Horasan Formations were accepted as the reservoir. In the case of Hamamderesi, the Horasan Formation, is expected to be thicker than the Pasinler region and the limestone of the Hanesduzu Formation, outcropping at the southern sections of the area, is thought to be the reservoir. These limestone layers, outcrop by thrust faults and overlay the Yastiktepe Formation. The carbonate character of the Hamamderesi Hot Spring, leads us to assume that the reservoir is enriched by limestone layers.

Heat Source;

Two different volcanic activities were determined during previous studies. The Miocene aged andesitic activity, seen at the southern parts of the area, and the Quaternary basaltic activity, observed at the northern parts. The andesitic volcanism may have been effective, with the basalt domes outcropping to the north of Pasinler, which have more probability for being the heat source.

4. HYDROCHEMICAL STUDIES

Water samples were collected from hot water points as well as cold waters. The Ilica and Pasinler Geothermal areas were also analyzed, in order to make a comparison with the Hamamderesi Hot spring.

Table 1. Chemical Analysis of the Hamamderesi Hot Spring

pH		7,35			
Specific Conductivity		3990 µmho/cm			
Temperature		34.4 °C			
Salinity		‰0,21			
Total Hardness		37,35 A°			
	mg/l	**meq/l**		**mg/l**	**meq/l**
K^+	47	1,21	**CO_3^{-2}**	<10	
Na^+	662	28,78	**HCO_3^-**	1829	29,98
Ca^{2+}	45	2,25	**Cl^-**	474	13,35
Mg^2	133	11,08	**SO_4^{-2}**	<5	
NH_4	1,35		**F^-**	<0,10	
$B_{(T)}$	>2		**NO_2^-**	<0,07	
SiO_2	142		**NO_3^-**	<4,4	
I	0,38		**PO_4^{-3}**	<1,5	
Fe^{2+}	0,55		**CN**		
Mn	1,45		**COD**		
Pb	0,36		**As**		
Cu	<0,10		**Cd**	0,246	
Ni	<0,05		**Mo**		
Al	<0,10		**Cr**		

According to the Piper Diagram, the cold water (E) and the DSI well (C) show similarities. These have Ca+Mg>Na+K, and are carbonate and sulphate waters, showing carbonate hardness bigger than the non-carbonates hardness.

The Pasinler (A) and Ilica (C) springs are also similar. These are of Na+K>Ca+Mg in chemical character and represent Salt and "briny" waters. Carbonate based alkalinities are higher and show soft water characters.

The mineral water springs belonging to the Hamamderesi area (K), show similarity with the Ilica and Pasinler samples.

The Hamamderesi Hot Spring (I), showing Na+K>Ca+Mg, looks similar with the other hot springs. The spring sample shows a mixture character in chemical composition, but none of the ions exceed 50 % concentration.

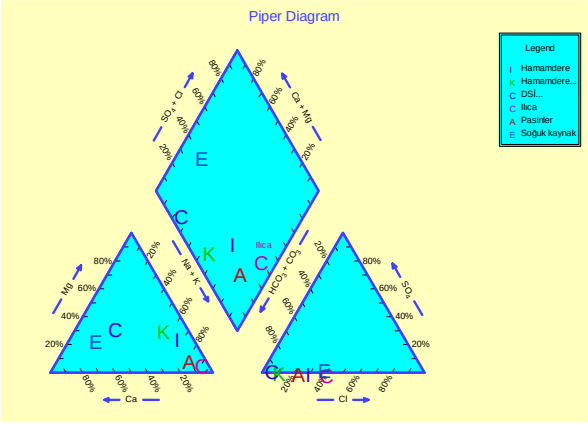

Figure 5: Piper diagram of the Hamamderesi Samples

According to the data of the chemical composition of the Hamamderesi Spring, geothermometer calculations were also realized in order to determine the average temperatures of the reservoir (Table 2).

Table 2. Calculated Geothermometer values of the hot spring.

Geothermometer	**Calculated Temperature (°C)**
Quartz	157.77
Quartz (max. steam loss)	149.90
Chalcedony	133.52
α Cristobalite	107.41
β Cristobalite	58.10
Amorphous Silica	35.59
Na-K	189.28
Na-K-Ca	179.24

5. GAS MEASUREMENTS

In order to determine active faults over the area, radon and CO_2 gas measurements were realized. Radon gas measurement values range between 300 and 750. As the site is under the effect of the neo-tectonic structure of the West Anatolian and the North Anatolian Faults, high radon values are occasionally observed. The East – West directional strike normal faults give the highest values as well as the shearing zones of the strike slip faults with the normal ones (Fig 6).

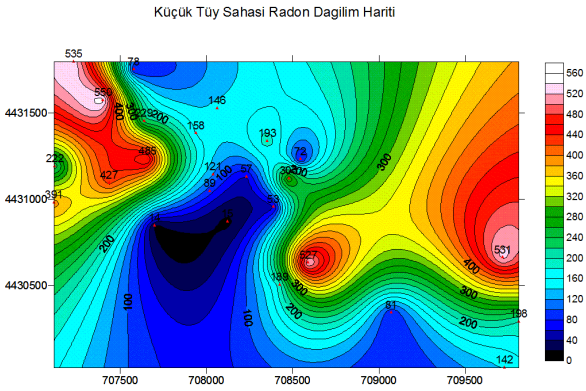

Figure 6: Radon gas distribution of the Hamamderesi Site

High CO_2 gas measurements were only observed in two locations. The highest value corresponds to an irrigation well drilled exactly over the shearing zone in the area. The other high location fits the anomaly obtained during the resistivity studies (Fig 7).

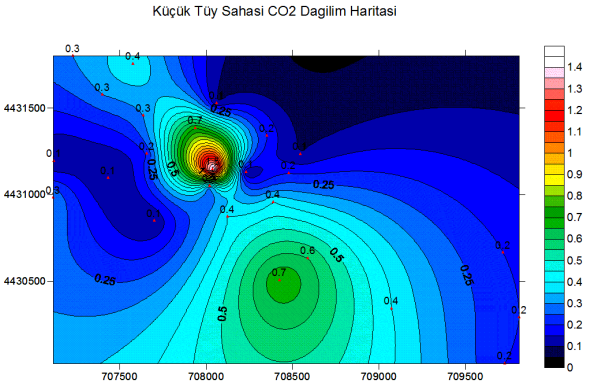

Figure 7: CO_2 gas distribution of the Hamamderesi Site

6. GEOPHYSICAL EXPLORATIONS

Schlumberger technique was applied for determining the resistivity of the layers. Resistivity measurements of the underground layers were carried out, and cross-sections were prepared. The west-east cross section, crossing the Hamamderesi Hot Spring and the normal fault, is shown in Figure 8. A typical low resistivity zone is seen between the point DES48 and DES7. The hot spring (KAYNAK) discharges through this zone.

According to the cross section, hot water reaches lower depths through the normal fault and penetrates permeable zones as horizontal flow. Alluvial deposits seem to have a thickness of 25 to 50 meters.

7. CONCLUSIONS

According to the geological and hydrochemical studies carried out, the site seems to be a probable geothermal area.

The Hamamderesi hot spring shows similarities to the Pasinler Geothermal field, in chemical composition.

The Hamamderesi Geothermal field is a low enthalpy geothermal area, from which, temperatures not higher than 50°C should not be expected.

Since wells have not been drilled, an exploration well should be drilled, at an appropriate location, in order to gather more exact data.

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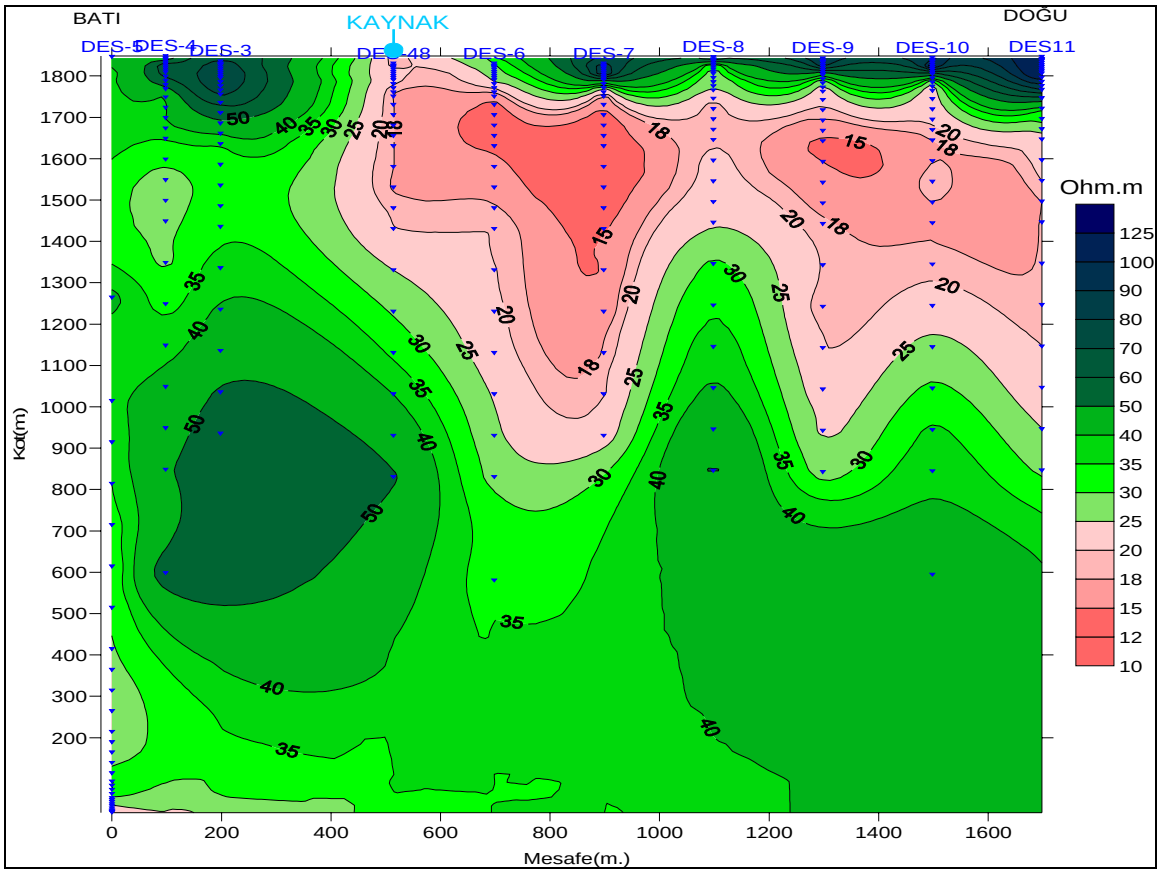

Figure 8. Geophysical cross-section of the Hamamderesi North – South resistivity profile.