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Geological and Hydrogeological Investigation of Kozluk-Taslidere (Batman) Geothermal Field

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ABSTRACT

Geological, hydrogeological and geochemical investigation of Kozluk-Taslıdere (Batman) geothermal field was performed in April-May periods of year 2001.

The area in which the spa takes place located on the vicinity of Bitlis-Zagros Suture Zone. The geological units crop out in the study area from older to younger are: Bitlis Metamorphics, Cüngüş Formation, Fırat Formation, Lice Formation, Selmo Formation, Yapraklı Formation and Alluvium.

Taşlıdere thermal fluid is discharging from the well coded Selmo-32 A drilled by Shell Petroleum Company has depth of 2400m.The hot water is colorless, no smelling, scaling, and leavin down yellow-brown colored sediments, has flow rate at 16 l/s with 83 °C temperature.

When the information related to the well Selmo-32A are investigated, it is observed that the well was cased down to the depth of 2172m. The hot water upflows from the below of this depth .But, the lithologies in the drillhole indicate that the reservoir seems to be between 1700-2400 m depths.

Hydrogeologically, the reservoir rocks in the region are; dolomites and limestones of the formations in Mardin Group (moderate-to good) and in Sinan Formation (moderate), limestones of Hoya and Fırat formations (moderate), conglomerate and sandstone levels of Selmo Formation (weak to moderate). Impermeable sedimentary rocks of Antak, Germik, Lice and Yapraklı Formations act as cap rocks of the geothermal system.

Hydrochemical characterization of the thermal water show that it is Ca-Na-SO4-Cl type and has total dissolved solids (TDS) around 2090 mg/l.

1. INTRODUCTION

Taşlıdere thermal water is on the Batman –Sason rail road in the north of Batman and 40 km far from the city (Fig. 1). The hot water is utilized primitively as thermal bath by the local publicity today. In this study the aim is to determine hydrogeological and hydrochemical properties of the hot fluids discharging from the well Selmo-32A and to evaluate the geothermal potential of the region. The works are carried out under the name “Batman-Kozluk Taslıdere Geothermal Project of General Directory of Mineral Research and Exploration of Turkey. At the beginning, previous works made by several authors (Göncüoglu and Turhan, 1984, 1985, 1992; Sungurlu, 1974; Özbek, 1975; Perincek, 1987; Yılmaz and Duran, 1997) are obtained. Previous investigations are mainly concentrated on oil explorations and they generally geological studies. The information about the well Selmo-32 A are obtained from General Directory of Petroleum Affairs. During the studies, 1/25 000 scaled geological map of the study area were made, by the way, geological and hydrogelogical observations and evaluations were performed about the lithologies exposing in the region (DSI, 1979, Dagıstan, 2001, Simsek and Karakus, 2002).

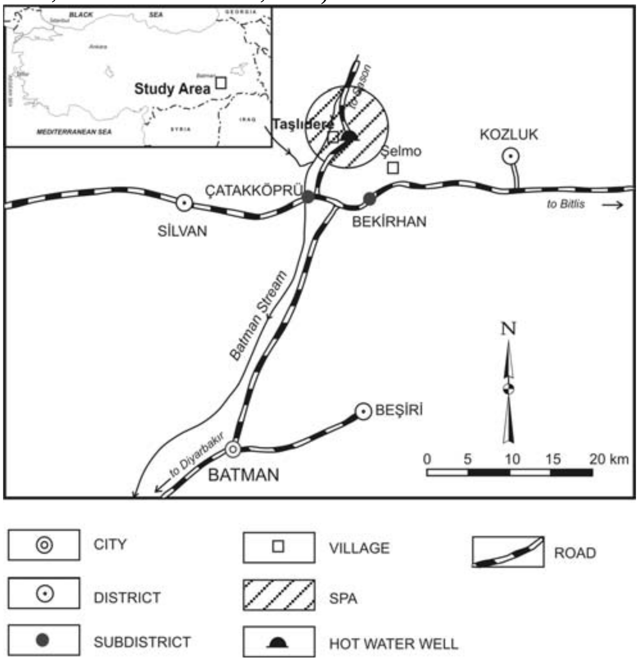

Figure 1: Location of the study area

2. GENERAL GEOLOGY

Turkey is located in the Mediterranean sector of the Alpine orogenic belt. The geological history of the region was influenced by the repeated opening and closing of several oceans, those traces are depicted as suture belt. One of those belts is Bitlis-Zagros suture zone. The study area takes place on the Arabian plate side, very near to this suture zone. The lithologies of Paleozoic to Quaternary in age expose in the region (Fig. 2). Important folding structures which serve as traps for oil deposits, have developed since Upper Miocene during the Neotectonic period because of the N-S trending compressional tectonic regime.

2.1 Stratigraphy

The lithologies existing in the explored area can be divided into two structural sub units. The first one is the allochtonous units of the Anatolian Plate forming the mountainous suture zone in the north & the second one is the Autoctonous units of Arabian plate in the south. The Allochtonous units thrusted onto the Selmo and Yapraklı formations of the Autochtonous units during Upper Miocene-Pliocene periods due to the continuing N-S compressional tectonic regime (Figs. 2, 3).

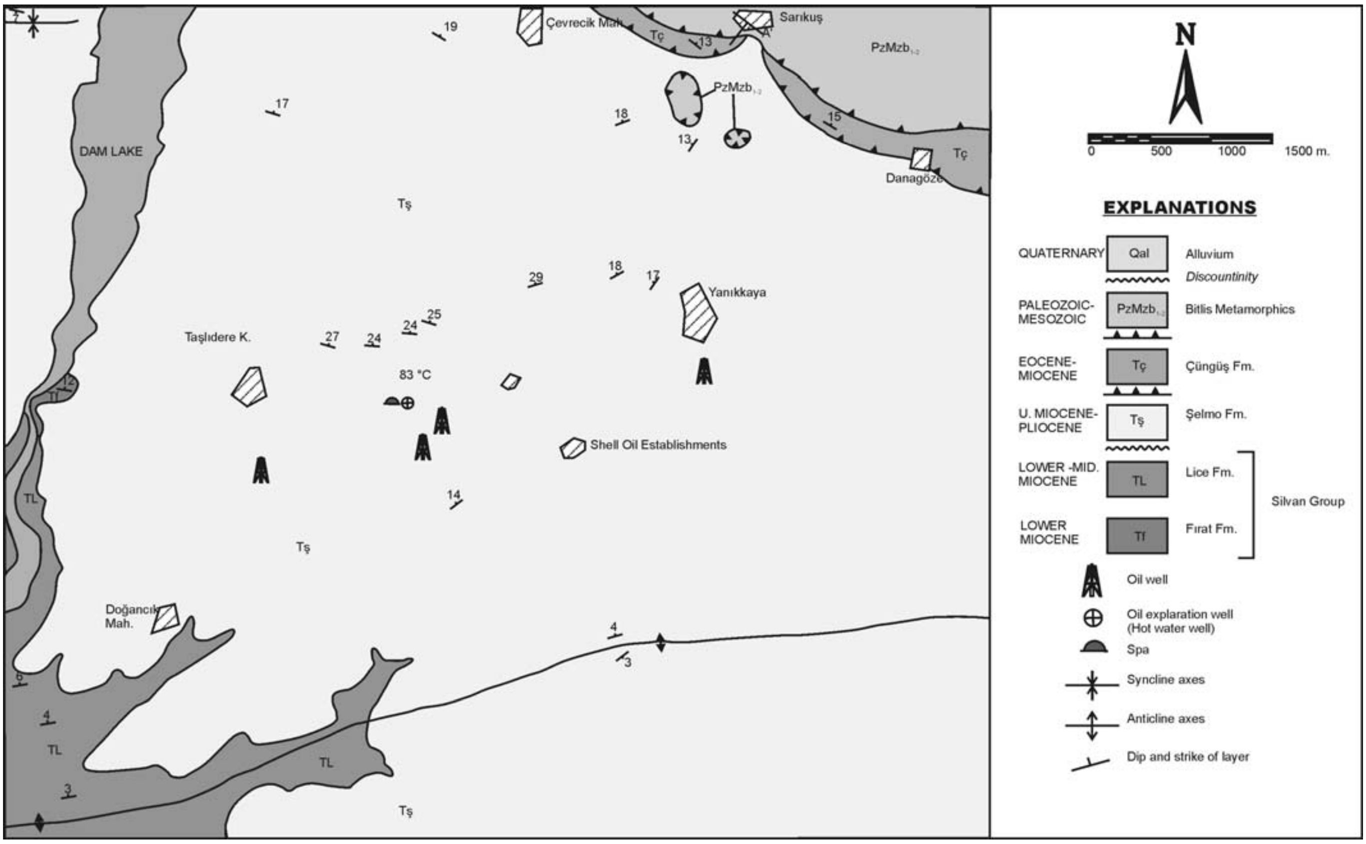

Figure 2: Geological map of Kozluk-Taslidere geothermal area.

2.2 Allochtonous Units

The allochtonous units are; Bitlis Metamorphics and Cüngüş Formations. Bitlis Metamorphics are composed of mainly recrystallized limestones intervening with quartzite, calc-schist, and sandstone layers. The unit is Lower Permian in age (Göncüoglu and Turhan,1984, 1985). Cüngüs Formation of Eocene-Miocene age is a tectono-stratigraphic unit forming the lower slice of the thrust and consists of dominantly shale intercalating with sandstones (Perincek, 1987).Moreover the unit has also blocks of different rock types in various dimensions. The lower and upper contact of the unit is tectonic.

2.3 Autochtonous Units

The autochtonous units include formations of Mardin Group (Areban, Sabunsuyu, Dardere, Karababa), Sırnak Group (Sinan, Antak), Midyat Group (Hoya, Germik), Silvan Group (Kapıkaya, Fırat, Lice), Selmo Formation and Yapraklı Formation. Among the autochtonous units, Fırat, Lice, Selmo and Yapraklı Formations have outcrops in the field the rest was observed in the drill hole Selmo-32 A.

3. MARDIN GROUP

Mardin Group is mainly composed of dolomites and limestones of Aptian - Turonian age and it is an important reservoir for oil accumulation in the south eastern Turkey. It is observed in between 1920-2400m depths in the well Selmo-32 A (Fig. 4).

Mardin Group comprise the below formations in general.

3.1 Areban Formation

It is made up of Albian aged sandy limestones deposited in coastal environment. It is 50m in thickness and unconformable underlain by Bedinan Formation and conformably overlain by Sabunsuyu Formation.

3.2 Sabunsuyu Formation

The Formation consists of Albian aged dolomites deposited in tidal flat-lagunner environment. The unit has thicknesses between 40-420m in the southeastern Turkey. It unconformable overlies Dardere Formation.

3.3 Dardere Formation

Senomanien aged Dardere Formation comprises limestones deposited in interior shelf environment at its lower level and lagoon-shelf environment at its upper levels. It is overlain by Karababa Formation conformably.

3.4 Karababa Formation

It contains limestones formed in lagoon-shallow sea environment and it is Turonian in age. Karababa Formation unconformable covered by the lower member of Sinan Formation.

4. SIRNAK GROUP

In the explored area, Sinan and Antak formations of Sırnak Group were observed in the drill holes. For this reason, only Sinan and Antak formations are defined in this study.

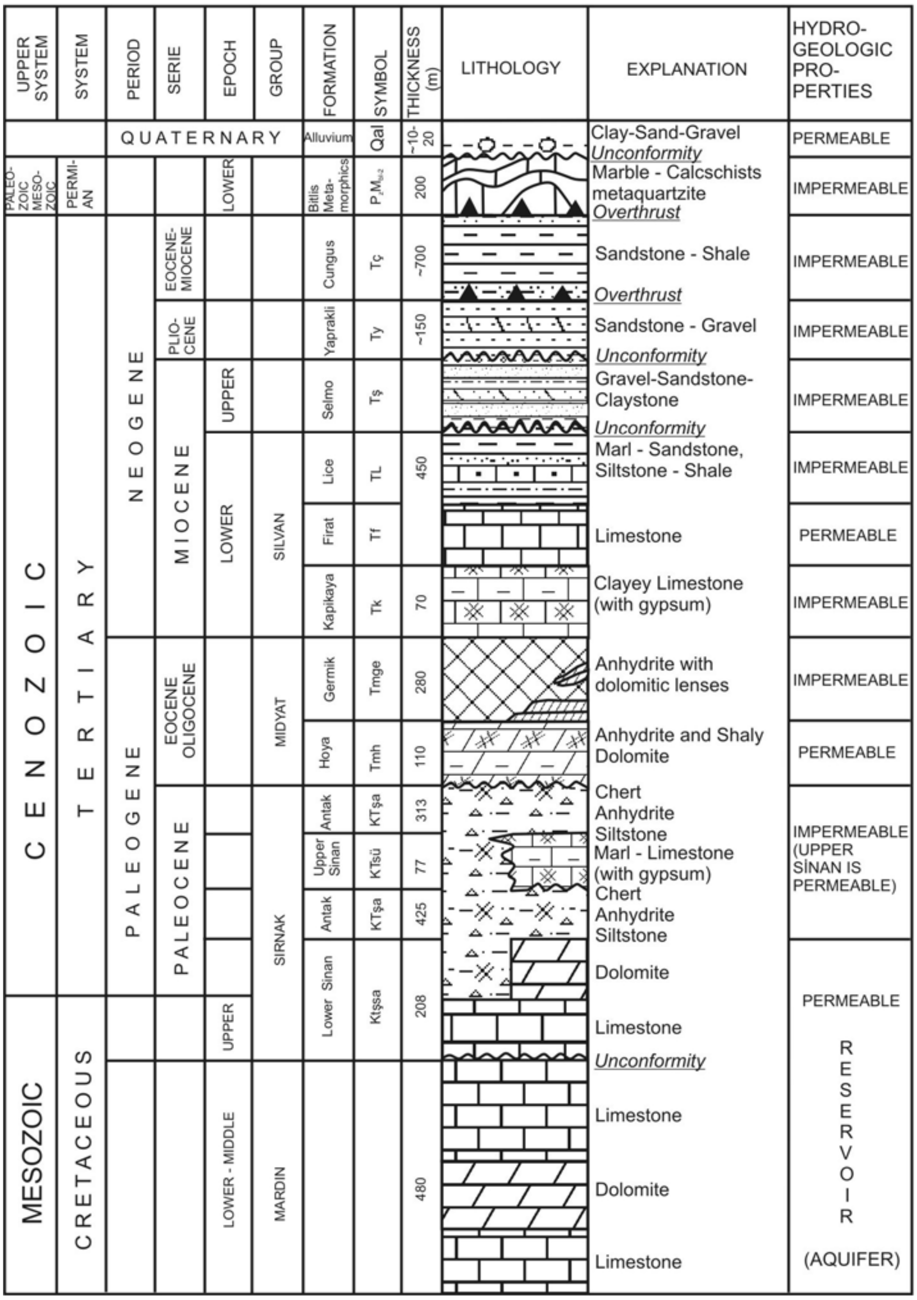

Figure 3: Generalized stratigraphic section and hydrogeologic properties of the units of the study area

4.1 Sinan Formation

The unit was firstly observed in the well Sinan –1 of Mobil Company and named as Sinan reef. Afterwards, the name was changed as Sinan Formation by the authors of TPAO (Turkish Petroleum Corporation). Sinan Formation is divided into two members one is Lower Sinan Member of Maastrichtian age, the other is Upper Sinan Member of Paleocene age.

4.2 Lower Sinan Member

It is composed of clayey limestones at its lower levels, dolomites and limestones at its middle parts and bioclastic limestones at the upper levels. It has a thickness of 208m and accumulated in the shallow platform environment

The lower border of the unit is unconformable with Mardin Group and the upper border is transitive with Antak Formation.

4.3 Upper Sinan member

The Unit spreads along The Diyarbakır- Batman line and its northern side according data obtained from drillholes (Yilmaz and Duran, 1997).

Upper Sinan Member consists mainly of bioclastic limestones, dolomitized limestones and dolomites. It may rarely contain gypsum and clay formations and its depositional environment is terrestrial, tidal-flat and shallow carbonate platforms. The unit is Paleocene age and has a thickness of 77m. It is transitive with Antak Formation in its Upper boundary and unconformable underlain by Lower Sinan Member.

4.4 Antak Formation

The formation is generally is made up of carbonate-cemented conglomerates comprising pink red brown colored unsorted, polygenetic pebbles derived from silicified, radiolarites, ophiolites, volcanic rocks ,dolomites and metamorphic rocks. Foraminiferous limestones, asphaltite, red colored marls and gypsum are also observed in this unit. The formation is Upper Miocene-Upper Pliocene in age and is deposited in alluvial fan, fluvial-lake and stream environments. Its thickness reaches up to 2000m. The lower boundary of the unit is transitional with Sinan Formation but its upper boundary is always discordant with the formations of the Midyat Group and Upper Sinan Member.

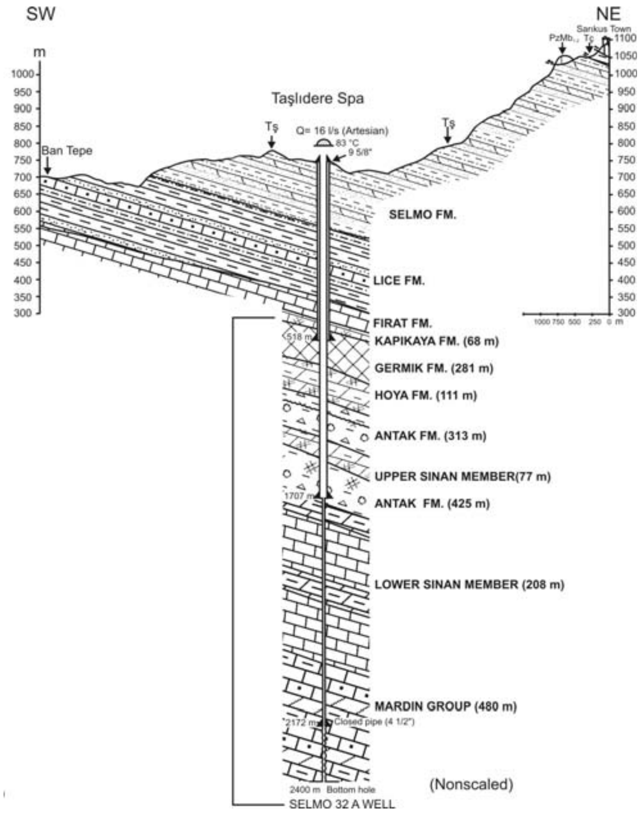

Figure 4: Cross-section and lithologic log of Selmo 32A well.

5. MİDYAT GROUP

The unit is well exposed around Midyat town of Mardin city. Midyat Group was firstly defined by Maxon (1936) as "Midyat Limestone". Today it is defined as Midyat Group by Demirkol at all 1979 and 1980 (from Yılmaz and Duran, 1997).

Midyat Group comprises Gercüs, Kavalköy, Hoya, Gaziantep, Havillati and Germik formations. Since only Hoya and Germik formations were observed in the drilling in the study area, only Hoya and Germik Formations are mentioned in this work.

5.1 Hoya formation

Lower Eocene –Lower Oligocene aged Hoya Formation is deposited partly in platform and partly in tidal-flat environment. While the unit generally reaches up to 1200m thickness, in the study area, it was observed 110 m thick in the drill hole Selmo 32-A.

Hoya Formation unconformable overlies Antak Formation and transitionally overlain by Germik Formation.

5.2 Germik Formation

Germik Formation crops out Kurtalan-Siirt, Hatma – Beşiri –Batman regions but doesn't expose in the study area. It is observed as 280m thick in the well Selmo-32-A (Fig. 4).

It is composed up of Middle Eocene –Oligocene aged dolomites interlayered with evaporites (Duran et all 1988 from Yılmaz and Duran 1997).The unit is deposited partly in fluvial and partly in sea –lagoon environment.

The lower contact of the Formation is transitional with the formations of Midyat Group but at its upper boundary, it is unconformable overlain by the units of Silvan Group.

6. SILVAN GROUP

Silvan Group includes Kapıkaya, Fırat and Lice formations. The units of Silvan Group overlie unconformable on the formations of Midyat Group.

6.1 Kapıkaya Formation

It has no outcrops in the study area but it exposes in the north of Malabadi –Silvan and west of Siirt in the southeastern Turkey. Kapıkaya Formation was observed as 68m thick in the drill hole Selmo 32-A and named as "Zokayt Formation "in the lithology log of the well. It is composed of alternations of red-brown colored conglomerates, sandstones, siltstones and mudstones. It also includes clayey limestone, limestone with gypsum and anhydrites in its upper levels.

Lower Miocene aged Kapıkaya Formation overlies Formations of Midyat Groups and conformably underlies the Fırat Formation.

6.2 Fırat Formation

The unit exposes in the west and south west of the study area. It consists of cream-gray colored, hard and brittle reef-bank type limestones of approaching sometimes 50m bed thickness and deposited in the reef and/or bank environments. It is 100-200m in thickness and Lower Miocene in age.

Fırat Formation is unconformable with Formations of Midyat Group and Kapıkaya Formation at its lower boundary and it is transitional with Lice Formation and unconformable with Selmo Formation at its upper boundary.

6.3 Lice Formation

Lice Formation was firstly defined by Schimidt (1958) (from Göncüoglu and Turhan, 1985) and it outcrops along the Malabadi dam lake and in the south of Dogancık village.

Lice Formation is composed of alternations of sandstone, shale, siltstone, sandy limestone, clayey sandstone and gray in color. In this exploration it is observed in the middle of the study area, south of Doğancık village. The unit composes moderate to thin bedded limestones with algaes and foraminiferas at its lower levels and shale and marns intensified with sandstone layers at its upper parts and sandy limestones with fossils at its top. It is nearly 100m in thickness.

Lower Miocene aged Lice Formation is deposited in open –shelf, fore slope and foreland environments.

It transitionally overlies the Fırat Formation and overlain by Selmo Formation unconformable but around Lice region its upper boundary is tectonic.

6.4 Selmo Formation

The unit was firstly named by Balgi (1961) (from Yılmaz and Duran, 1997) and it crops out more than half of the study area. Selmo Formation composes the alternations of conglomerate (varying in colors, weakly cemented with carbonate, containing gypsum lenses and interbeds) sandstones (changing in colors, moderate-thin bedded, weak-moderate cemented, in somewhere cross-bedded and laminated) shale (light gray colored) and marn (yellowish gray, brown, light gray in colors).

Upper Miocene – Pliocene aged Selmo Formation is deposited in transitional zone of coast sand – tidal flat, playa and stream environments. It is generally between 300-900m in thickness. While the lower boundary of the unit is angular unconformity with Lice Formation, its upper boundary is tectonic onto which the Pre-Miocene aged obducting masses were overridden.

6.5 Yapraklı Formation

The unit is firstly defined and named in this study. The formation spreads over in the northwest, south and southeast of the study area.

The formation is essentially composed of red colored muds including loosely cemented horizontal interbeds of conglomerate and sandstone.

It is Pliocene in age according to its stratigraphical position and deposited in fluvial environment. It is underlain unconformable by Selmo Formation and overlain by Quaternary aged alluvium.

6.6 Alluvium

It is composed up of loose uncemented silt, sands, gravels and blocks deposited in the streams and valleys.

7. STRUCTURAL GEOLOGY

Study area takes place in the Arabian Plate along the south of Bitlis –Zagros suture zone. Recent tectonic framework of the region was governed by continent-continent collision between Anatolian and Arabian plates after the closure of the southern brunch of the Neo Tethian Ocean during the Upper Miocene Period.

This N-S trending compressional tectonic regime having been continuous since Upper Cretaceous overrided the Anatolian Plate onto the Arabian Plate giving rise the Bitlis-Zagros Suture Belt. Relevant to these events, major folding structures providing trap conditions for oil developed at the Arabian Plate near to the suture zone.

7.1 Faults

There is no major fault system observed in the study area. The most famous neotectonic structures are the thrust faults of the Bitlis- Zagros suture zone. Nevertheless, there is a small E-W trending normal fault along the axis of a fold near Bacak village in southwest of the study area (Fig. 2). Because of this fault, gently dipping beds of Selmo Formation are increasing in dip amount.

7.2 Thrust Faults

Since the Taşlıdere thermal water district occur at the south of Bitlis Suture Zone, thrusting events of Miocene Period such as thrusting of Bitlis Metamorphics (Paleozoic) over Cüngüs Formation (Eocene-Miocene),and overriding of Cüngüs Formation onto the Selmo Formation (Upper Miocene –Pliocene) are observed (Fig. 2).

7.3 Folds

The fold structures of the study area are extending nearly parallel to the Bitlis Suture Zone and E-W in direction. The major anticline structure passes through the middle of the study area. The wings of the anticline dip 9-10 degrees and it plunges towards westward.

The small anticline occurring near to Bacak village has an alignment of 6 km and the north wing of the anticline has a dip angle of 15-20 degrees, but its south equivalent has dip angle of 50-55 degrees influenced by the normal fault parallel to the fold axis.

The major synclinal structure having gently dipping wings, lies between Yapraklı and Uzuncayır villages at the south of the study area (Fig. 2).

8. HYDROGEOLOGY

General properties of the surface and ground waters are given below.

8.1 Surface Waters

Batman stream is the major one passing across the Taslıdere region. The stream is dammed up for the purpose of electricity production near the Catakköprü village. The tributaries of the region are joining to this stream and they are drying up in summer mounts. Batman stream connects to the Dicle River at the southwest of Batman city.

8.2 Groundwaters

The study area and its neighborhood are poor in spring water and drill holes are generally used to obtain drinking waters. The only spring water of the exploring area near Dogancık village has total dissolved solids (TDS) value of 894 mg/l and flow rate of 15 l/sq .It is probable that the spring water flows through the rocks including carbonates and gypsum along the deep faults and so it is characterized as sulphate and carbonate rich type water.

8.3 Hydrogeological Properties of the Rocks

According to the under ground geology, the Taslıdere region contains the rocks being partly reservoir and partly cap rocks as characters. That is why, the region is not poor as ground water potential. But, because the geological formations include evaporite interlevels, and the ground waters are brackish ($CaSO_4$, NaCl etc...).

8.4 The Reservoir (Aquifer) Units

The dolomites and limestones of the Mardin Group indicate reservoir characteristics (Yılmaz and Duran, 1997). Through the formations of the Mardin Group, the porosity value of the Sabunsuyu Formation is % 10-15, that of Dardere and Karababa formations is %5-22.

Upper and lover level of the Sinan Formation from the Sırnak Group have the porosity value of %7-20.

Sinan Formation and Mardin Group are the main reservoir rocks for oil production in the southeastern Turkey.

The Hoya Formation having %5-20 porosity value and karstic forms is the main reservoir for ground water production in the southeastern Turkey.

Fırat Formation has %10 porosity value and moderate to weak reservoir character.

The conglomerates, sandstones and limestones levels of the Selmo Formation contain ground waters moderate to weak in proportion but the ground waters are brackish.

8.5 Cap rocks

The formations of Antak, Germik, Lice and Yapraklı are the caprock units in the region. These formations are mainly composed of shale, marl, anhydrite, claystone and mudstone.

9. GEOTHERMAL POTENTIAL

Neither hot water springs nor alteration forms are observed in the study and its adjacent areas. But, around Batman city, some of the wells drilled for oil production purposes have high geothermal gradient values and few of them produces hot waters (Selmo32-A, Dogu Kentalan-1). It is estimated that the Quaternary aged volcanics are one of the elements increasing the geothermal gradient in the region. Kırdagı Basalts those flowed onto the Pliocene aged shale beds in the south of the exploring area is one of the examples for the young volcanic activities. These basaltic lavas had probably flowed along the old valley of the Batman stream. Another gradient increasing factor is the anomolical circle being probably of an endogenic intruding mass observed on the aero-magnetic map of the region. *His anomolic circle lying on the Bitlis Suture Zone is 10km far from the study area in the north.* By using the gradient values of the surrounding oil wells of TPAO (Turkish Petroleum Corporation) The equal-gradient map of the region is performed and the gradient value of the well Selmo-32A (drilled by Shell oil company) is found as 1.46 °C / 33m (= 0.44 °C/10m).

Since the reservoir rocks (formations of Mardin Group and Sinan Formation) for fluids are flowing from west to east along the south vicinity of the suture line according to the oil well data. The burial of them is also one of the heating agents from the point of view of geothermal potential (Figure 5)(Water flow through the rocks of Mardin Group eastward , because of burial, they are heated and they form geothermal water)

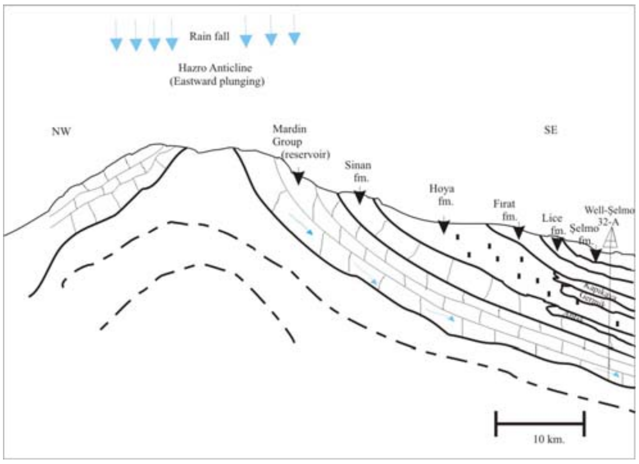

Figure 5: A schematic geological- tectonic cross-section showing possible origin of hot water aquifer (reservoir)

10. GEOTHERMOMETRY

In order to appraise the Taşlıdere hot water by using geothermometry methods, T_{silica}, T_{Na-K} , $T_{Na-K-Ca}$ formulas are used and $T_{silica}= 108^0C$, $T_{Na-K}= 189^0C$, $T_{Na-K-Ca}= 230^0C$ are evaluated. In addition to these, Na/K, Mg/Ca, Cl/HCO_3+CO_3 ratios also show high reservoir temperatures. But, since the hot water are caming from directly the reservoir of 2174 m. depth by means of drill-hole equipped with casing down to the reservoir, high reservoir temperature is not expected so high.

11. HYDROCHEMISTRY

Chemical data for hot and cold waters have been obtained from the samples of springs and well waters. Two samples were collected from each and stored in 1000ml polyethylene bottles. One of the bottles was acidified with HNO_3 and the other was kept unacidified for anion analysis. Some of anions (Ca.Mg) and cations (Cl, CO_3, HCO_3) together with EC (electrical conductivity), pH, salinity and hardness values were measured in the field at the time of collection (Table 1).The major and trace elements in the water samples were analyzed in the geochemical laboratory of MTA (General Directory of Mineral Research and Exploration of Turkey). Results of analyses are included in Table 1. Classification of the waters was made on the principles of the IAH (1979) (International Association of Hydrogeologist). Total equivalents of cations and anions were taken as 100 % and ions more than 20 % (meq/l) were evaluated in the classification.

Taslıdere hot water is characterized as $Ca-Na-SO_4-Cl$ type and has the total dissolved solids (TDS) value of 2090mg/l. The total dissolved values are 870mg/l for Dogancık cold water, 750mg/l for Taşlıdere cold water and 150mg/l for Batman Dam Lake .The increase in the TDS values of the cold waters (Dogancık and Taslıdere) can be explained that the cold waters flow upward along the deep fractures through the rocks including evaporites ($CaSO_4$ and NaCl).Taslıdere thermal water has a pH value of 7.72, the others have pH values between 7.72-9.22. Taslıdere thermal water yields the order of $SO_4>Cl>HCO_3$ as anions and Ca>Na+K>Mg as cations.

As shown in semi-logarithmic Schoeller diagram (Fig. 6), Taşlıdere thermal water and Dogancık cold water give similar signature reflecting their deep circulating characters through the rocks including evaporite formations ($CaSO_4$, NaCl etc..).These waters probably gained this SO_4^- rich nature by leaching of this ion from the gypsum layers present in the Cenozoic sedimentary units of the area.

In the triangular diagram (Fig. 7), when the hot and cold water evaluated with respect to thei anion and cation dispersions, the cold waters are CO_3-HCO_3-rich type waters according to their anion dispersions but Taslıdere hot and cold waters are of SO_4 rich type and Dogancık cold water is a mixture of sea and meteoric waters according to their cation dispersions.

Geothermal water from Selmo-32A is suitable for balneological utilization (Simsek and Karakus, 2002).

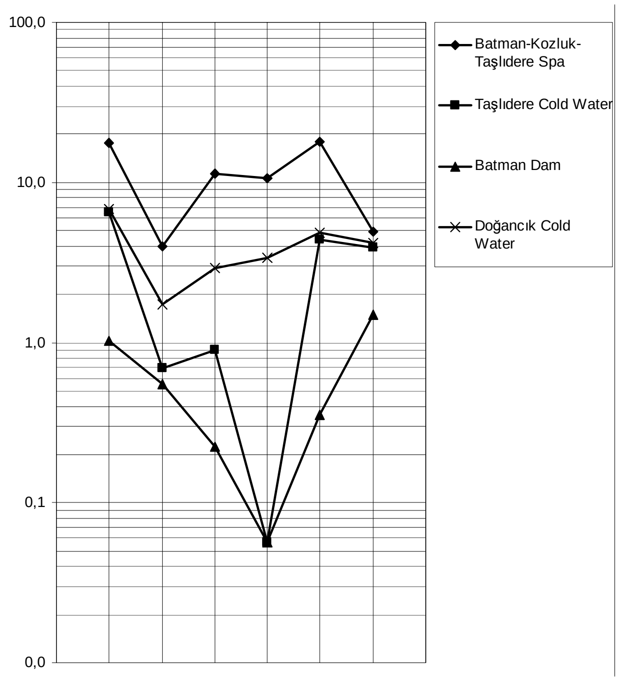

Figure 6: Schoeller diagram of the waters samples

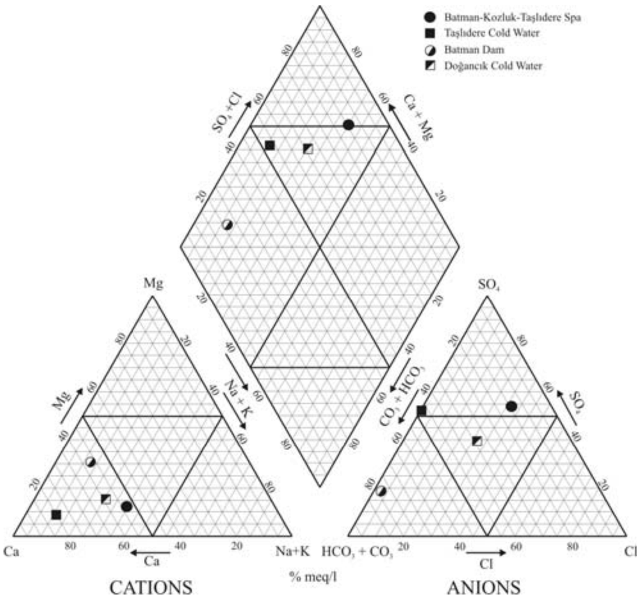

Figure 7: Triangular diagram of the water samples

12. RESULTS AND SUGGESTIONS

The reservoir characteristics of the formations (both outcropping in the study area & observed in the drillholes Selmo-32 A) are investigated and it is founded out, the formations of Mardin Group, Sinan Formations and Hoya Formations indicate good reservoir properties. But Antak, Lice, Yapraklı and partly Selmo formations are cover rocks in their hydrogeological views.

By using oil–well information of TPAO, regional equal-gradient map are prepared and the geothermal gradient of the well Selmo –32 A (drilled by Shell Company) is found as 1.46 °C/33m. Taşlıdere thermal waters discharge from the well Selmo-32 A as artesian; its flow rate & temperature are 16 l/sc and 83 °C respectively. The Selmo-32 A is cased down to the depth of 2172 m and the hot water upflows from the blow level of this depth. The lithologies in the drill hole indicate that the reservoir seems to be between the depths of 1700-2400m and the reservoir rocks are the dolomites and limestones of Mardin Group and Sinan Formation.

In the southeastern Turkey, adjacent to the investigated areas, there are many wells drilled by TPAO for oil purposes do not contain oil but might contain hot waters. In order to find out such wells, it is advised to investigate the drill holes of TPAO from the geothermal point of view.

It is possible to use of geothermal waters in the region for heating (district and greenhouse), balneological and touristic purposes. Those integrated applications will be important for economic incomes and social developments of the region.

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Table 1: Chemical analyses results of water samples of the study area (June, 2001).

Sample	pH	EC	TDS	T	Ca	Mg	Na	K	Cl	SO4	HCO3	SiO2
Taslıdere hot water	7.72	3015	2090	83.0	287	34.3	256	26	325	839	245	56
Dogancık cold water	7.92	1186	873	17.6	137	21.1	65	4.5	120	234	257	17
Batman dam lake	9.22	171	120	21.0	20.7	6.7	4.5	1.1	<10	17	29.9	10
Taslıdere cold water	7.72	782	648	18.0	131	8.4	19.9	1.5	<10	210	239	19