Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Geology of the Denizli Sarayköy (Gerali) Geothermal Field, Western Anatolia, Turkey

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Keywords: Geothermal geology, geophysics, electricity, drilling, alteration, production, scaling.

ABSTRACT

The Denizli-Sarayköy (Gerali) geothermal field is located in the eastern part of the Büyük Menderes Graben, and is characterized by normal fault structures (Figure 1). The stratigraphic sequence of the Denizli-Sarayköy (Gerali) geothermal field consists of metamorphic rocks of the Menderes Massif and sedimentary rocks deposited during the rifting period of the Menderes Massif in the Miocene and Pliocene. This is the first geothermal field studied and drilled by private enterprise for energy production in Turkey. In the field following geological studies, 24 geophysical resistivity measurements had been taken and the location of well number MDO-1 was given (Figure 2., 3). The well has been drilled down to 2120 meters in depth and than completed at this depth. Later the well was deepened down to 2401 due to the request of the owner (Figure 4). During drilling at every 2 meters cuttings were taken and properly labelled.

The well was cased as follows: 0.00 – 100 m 20”∅ casing, 0.00 – 488.50 m 13 3/8”∅ casing, buttress thread, 0.00 – 1452 m 9 5/8”∅ casing, buttress thread, 1452 – 2119 m. Slotted casing.

Geological stratification of Gerali geothermal field from the bottom to top is as follows; at the bottom biotite-chlorite-calc-quartzschist. Above them marble and metamorphic basement of Menderes massif take place. Then Miocene and Pliocene sediments of 1950 meters thickness are found. Geological section is divided into two different hydrothermal alteration zones (Figure 4). At the well log too many fault zones have been seen. Faults cutting sedimentary limestone and marble are the main production zones.

During the drilling, after 600 meters alteration has begun. Loss of mud circulation started after 900 meters. At the 1607-1619 meters, total of 300 m^3 loss of mud circulation has occurred. After this level, the drilling has been continued; partial loss and alteration have been inspected continuously.

After the well completion tests, 125^0C bottom hole temperature was measured by Amerada temp gauge (Figure 5). Production of the well was determined at 50 lt/sec. At productions test deposition of $CaCO_3$ scaling was seen from the surface down to 120 meters in depth.

1. INTRODUCTION

Değirmenci group has obtained the rights for electricity production from geothermal energy at Sarayköy, in the province of Denizli. This is the first private enterprise surveying geological, geophysical and drilling geothermal resources (such as down to 2400 m depth) in Turkey.

Those studies made in Turkey’s geothermal Inventory 1996 were reviewed (MTA., 1996), Detailed studies made at Kızıldere “Erentöz, et.al., 1968”, “Şimşek, 1985”, “Şener, et al. 1986”, “Gökgöz, 1998”, “Westaway, 1993” were taken as basis. Beside the printed studies regional geophysical researches which are showing anomalies made by MTA, were studied as well. In gravity and resistivity reports of Denizli-Sarayköy geothermal energy research “Tezcan, 1967”, general valuation of regional structure was made. In this report, it is shown that there is an anomaly between the south of Sarayköy and Babadag. “Ekingen, 1970”, “Turgay et.al. (1980)”, “Özgüler et. al. (1983)”, “Sülün et. al. (1985)” groups made geophysical resistivity surveys of Denizli Buldan-Pamukkale fields and southern Sarayköy geothermal field seperately. Yavuz Alakuş made a study for apparent resistivity for the length of AB/2 2000. The electric prospected in 24 Vertical Electric Sounding (VES) by the Schlumberger quadripole. In the field, following geological studies and Yavuz Alakuş’s 24 geophysical resistivity measurements, the location of well number MDO-1 was determined (Figure. 2). Before this report; Serpen, et.al., had estimated geothermal potential of the Sarayköy geothermal field in 2000 (Serpen, et.al., 2000). According to their data expected values of accessible geothermal resource base for individual field of Sarayköy anomalie was 4.24 (10^{18}J) (Expected Accessible Geothermal Energy, 10^{18}J).

Previous geological studies are as follows;

“Uysallı, 1967.”, Tekke-Kızıldere, 1/25 000 scale geology.

“Dubertret et. al. (1973)”. 1:500 000 İzmir.

“Pamir et. al. (1974)”. 1/500 000 Denizli.

“Öngür, 1971”. Denizli-Babadağ surrounding geology.

“Bilgin, 1976”. Denizli-Babadağ. surrounding geology.

“Bilgin, 1986”. Metamorphism of Denizli-Babadag

In these studies, the field was shown as a faulted structure. As it is seen from the studies of “Akman, et .al. (2000)”, many faults are situated parallel to each other, in Southern Sarayköy. The minimum resistivity valued measurment point is shown in the geological map (Fig. 2). At this point, MDO-1 well was drilled down to 2401 m. The bottom hole temperature was measured at 125^0C as. Geothermal fluid production was 50 litters/sec. When the main valve was opened completely, the pressure value was measured at whp=0.5 kg/cm^2.g.

Geological data was collected in the field. Temperature and pressure measurements were taken in the well (MDO-1). Mineralogical and petrographycal analyses were made of the rock cuttings. The X-ray diffraction analyses of the clay were made and than Geological cross section of the Sarayköy

(Gerali) geothermal field was prepared as the final report (Figure. 3).

2. MATERIALS AND METHODS:

Relatively detailed cutting analyses along with various borehole logs were used to assess the geothermal system into which MDO-1 was drilled. During drilling, rock cuttings were taken at every 2 m depth interval and than properly labelled. At the well site, a binocular microscope (Nikon 64114) was used for the analyses of the rock cuttings. The mud circulation losses and the rate of penetration were recorded for each drill pipe sunk. Rock cuttings of thin sections were analysed at MTA Laboratories. After the regular X-ray difractometer analyses of the 2 to 40^0, the samples were glicoloted and than heated in the oven. The X-ray diffractometer analyses were made both at the MTA, and the Sivas Republic University.

The Temperature logs were taken in order to locate aquifers and assess the condition of the wells for drilling. (Temperature logging equipment was provided by Amerada Logging tools). This provided important information on temperature conditions, flow paths and feed-zones in the geothermal systems. Temperature logs have also been recorded after the drilling and the production.

3. GENERAL GEOLOGICAL SETTING OF TURKEY AND THE MENDERES MASSIF:

Turkey is located within the Alpine-Himalayan orogenic belt. The distribution of seismicity and active regimes are concentrated along high strain zones; many of which are major strike-slip faults, such as the North Anatolian fault "Ketin, 1968", East Anatolian transform fault "Dewey and Şengör 1979" and graben zones (e.g. Büyük and Küçük Menderes grabens, Gediz, Simav, Manyas, and Kızılcahamam grabens) "Angelier et al., 1981, Şengör, et al., 1985". The broad tectonic framework of the Aegean region and the Eastern Mediterranean region are dominated by the rapid westwardly motion of the Anatolian plate relative to the Black Sea (Eurasia) plate, and west to south-westwardly motion relative to the African plate "McKenzie, 1972, Dewey and Şengör 1979".

The Menderes Massif is one of the largest metamorphic massifs in Turkey, with a length of about 200 km N-S between Simav and Gökova grabens, and about 150 km E-W between Denizli and İzmir in Western Anatolia "Ketin, 1983". "Philippson (1910)" described the Menderes Massif as a dome-like structure, broken by faulting during the Alpine orogeny; whereas "Dixon and Pereira (1974)" regarded the Menderes Massif as one of a number of the ***"zwischengebirge"*** massifs; essentially microcontinental blocks, made up of pre-Mesozoic basement rocks having some of the characteristics of the cratons but displaying evidence of Alpine tectonic and magmatic involvement.

The crystalline Menderes Massif is divided into two major units: the core and the cover series. The core series consist of Precambrian to Cambrian high-grade schist, metavolcanic-gneisses, augen gneiss, metagranites, migmatites and metagabbros. The cover series are composed of Ordovician to Paleocene micaschists, phyllites, metaquartzites, meta leucogranites, chloritoid-kyanite schists, meta carbonates and meta olistostrom. In many places, metabauxites (probably upper Jurassic to Cretaceous in age) occur in the upper levels of the metacarbonate sequence "Dora et al., 1995". "Candan et al. 1992" observed that high-grade metamorphic rocks are located along tectonic contacts within the schist, phyllite and marble series which envelope the core. This is enforced by the field data and drilling data comprised by the Germencik-Ömerbeyli geothermal system "Şimşek et al. 1983; Karamanderesi and Özgüler, 1988a; Karamanderesi et al., 1988b".

In a large scale, regional suture means this post-metamorphic compressional phase conjugated with the paleotectonic evaluation of the Western Anatolia is in N-S direction; but the pushing is in northward direction. This compressional force has given rise to an extreme cataclastic structure. The post metamorphic granite plutons in Early Miocene are extremely subjected to this compressional tectonics, and the allochtonous units are cut across by the graben systems of neo-tectonic phase started in The Tortonian. According to these data this effective compressional tectonism in Menderes Massif must be Early-Middle Miocene period. Neogene sediments overlie the allochthon and autochthon grouping rocks with angular unconformity at the south of the study area. The Neotectonic period of the Menderes Massif and surrounding areas have been the subject of regional research for many years "Ketin, 1966; McKenzie, 1972; Dumont et al. 1979; Angelier et al. 1981".

Extensive tectonic activity and formation of east-west grabens have formed the shape of Western Anatolia. Of these, Büyük Menderes and Gediz grabens host the main and the most important geothermal fields of Western Turkey. The distribution of geothermal fields in Turkey, closely follow the tectonic patterns. All of the hot springs with temperatures above 50^0C-100^0C in Eastern and Western Anatolia are clearly related to young volcanic activity and block faulting. The post-collosional volcanic activities, lasting from the upper Miocene to modern time have been responsible for heating up the geothermal fields in Turkey "Demirel and Şentürk, 1996". The high thermal activities are reflected in the forms of widespread acidic volcanic activity with much hydrothermal alteration, fumaroles, and more than 600 hot springs with temperatures up to 100^0C "Çağlar, 1961".

Two different views have been proposed for the timing of the development of the East-West grabens. According to one view; the grabens began to develop during Late Oligocene-Early Miocene times and have progressively enlarged since then "Seyitoğlu and Scott, 1996". The other view proposes that the grabens have been forming from the Late Miocene period to The Present time "Şengör et al. 1985; Görür et al. 1995". Resolution of this question requires a fuller understanding of the geology of the region, as well as the detailed geology of the graben areas.

Most of the thermal waters, of which hosted rocks are Menderes Massif metamorphics, discharge from the rims of East-West trending faults that form Büyük Menderes, Küçük Menderes, Gediz and Simav grabens. The circulation of thermal waters is closely related to major faults and fractured zones. Fractured rocks of the Menderes Massif, such as quartz-schists, gneiss and granodiorite and karstic marbles, the shale and sandstone and limestone megablocks of Bornova melange and nonmetamorphic Mesozoic carbonates are the reservoir rocks. Relatively impermeable Neogene sedimentary units occur in different facies in the Northern and Southern parts of the Gediz graben and Northern parts of Büyük Menderes graben. These rocks cap the geothermal systems. Increasing geothermal gradient by the effects of graben tectonism may be the heat resource of geothermal systems. Thermal waters from Gümüşköy, Germencik, Kızıldere, Tekkehamam, Ortakçı, Bayındır, Salihli, Turgutlu, Simav, Saraycık, Gediz, Uşak-Emirfakı and Gecek fields are hosted by Menderes Massif rocks.

The Western Anatolia has a seismically very active crust, which is extending approximately N-S in direction since the Miocene “Dewey and Şengör, 1979; Şengör, 1987”. The upper crust of Western Anatolia deforming under this extensional regime were broken by normal faults controlling E-W trending grabens (Fig. 1). The most important and the largest grabens are: (1) Gediz (Alaşehir) graben and (2) Büyük Menderes graben.

Büyük Menderes graben is a E-W trending depression, 150 km long and 10-20 km wide, bounded by active normal faults “Paton, 1992”. The graben changes its direction in Ortaklar, extends NE-SW through Söke, intersects with Gediz graben in the East of Buldan and turns to Denizli basin from Sarayköy “Westaway, 1993”. The historical earthquakes occurred in B.C. 31, 26 and D.C. 2, 1653, 1895, 1899 and 1955 along the graben bounding faults show that the region is seismically very active “Koçyiğit *et al.*, 2000”.

4. GEOLOGICAL STRATIFICATION OF THE GEOTHERMAL FIELD:

Geological stratification of the field can be given as follows: At the bottom; biotite, muscovite, epidote, chloritoid, quartz schist of Menderes Massif metamorphics (between 2401-2040m).

Above this strata, marble can be seen as the main reservoir (between 2050-1950 m) (Igdecik formation, “Şimşek, 1985a”).

Towards higher ground there is Kizilburun formation going down to 807 m. This strata consisted of limestone, sandstone, conglomerate and siltstone interbedded (1950-1143m). Below Kızılburun formation, limestone strata was found (1950-1775 m). At 1615 meters, a fault zone was cut and the loss of mud circulation was found to be 300 m^3.

Above Kizilburun, there is Sazak formation (between 1143-814 m), consisted of limestone and had a reservoir temperature of 96 ^oC. This zone had been passed by casing. Similar zones had measured at 200^oC in the reservoir at Kizildere and 125 ^oC at Tekkehamam geothermal fields.

At the top of the Sazak Formation, clay strata was discovered (814-60 m). The X-ray diffraction analyses confirmed illite and kaolinite. At all levels, minerals of calcite, secondary quartz, pyrite, pyrrhotite were seen. Fault slicken-side was discovered at all levels.

At the uppermost section of the MDO-1 well (60-00 m), coarse conglomerate, sandstone layers were seen (fig. 4).

In Southern Sarayköy (Gerali) Geothermal Field; low temperature (29^oC) fluid coming from shallow wells at Gerali village as well as sulphur at Kükürt river and Acısu village were clearly seen as surface manifestation.

The geology of the field and the geological section of the well confirm the same faulted tectonic structure (fig 2 and 3). The main fault lines are in the direction of E-W, secondary fault lines are in the direction of N-S, and NE-SW. Fault lines cut with drilling MDO-1, are E-W directed. When the surface measurements from these two faults were correlated with the depth of the two faults drilled in the MDO-1 well (1615, 2050m fault zone), listric faults were easily seen (fig 2-3).

4.1 Borehole geology:

MDO-1 Borehole geology, has been studied in location by both binocular microscope studies and examination of hand-specimens analyses. In the deeper sections, microscopic and X-ray diffractive analyses have been done. The results are as follows;

00-60.00 m Layered with uncemented old terrace deposits, slope debris, and alluvium fans materials as in sandstones pebble, clay, silt etc. In the bottom section up to ten meters there is an aquifer (Figure 4).

60.00-814.00 m Zone is covered with grey clay. The samples from this zone have been analysed by X-ray difractometer at the University of Dokuz Eylül in İzmir. The results showed 2-3 % dolomite, 3-4% feldspar, 7-8% calcite, 8-10 % Quartz and the rest is mainly illite. Hydrothermal alteration zone is illite zone. 584-588 m To 692-698 m various coloured clay, heavy pyrite and as a secondary mineral, pyrrhotite have been detected. Additionally, remains of plant, organic materials, pyrite, calcite, and very small amount of silica have been seen at 798-799 m level. The samples from the level of 806-810 meters showed; gray clay, siltstone and the traces of heavy micro crystalline pyrite, chalcopyrite, secondary calcite and quartz (Figure 4).

814.00- 1143 m. Sazak formation. Light brown and milky brown limestone have been detected by the microscopic analyses. In addition to sparry calcite, heavily fossiliferous ostracoda, vesicular limestone have been detected. The limestone veins contained secondary calcite and quartz as well. Between 878-896 meters, secondary silica and calcite as well as traces of manganese have been detected, under the microscope (Figure 4).

The first loss of mud circulation has been detected at 901 m totalling 3 m^3. Between 984-992 meters, the loss of mud circulation was 5 m^3. Later on between 1002-1010 meters, the loss of mud circulation was measured as 16.13 m^3. Additionally, between 1080-1082 meters the loss of mud circulation was measured as 7 m^3. At the level of 1110-1112 m, the loss of mud circulation was measured as 5 m^3 (Figure 4).

Below the 1143-m level, change in colourization and formation as well as kaolinization was observed. Eight fault zones were discovered in the MDO-1 well.

1143-1607 m Kızılburun formation was clearly defined. Kızılburun formation consists of coarse or fine grained, well-cemented sandstone, clay and conglomerate layers. Secondary pyrite, calcite, quartz and clay matter can be seen in the conglomerate and sandstone layers. Scattered green layers appear to be relict that resulted after the chlorization.

The cuttings from 1181-1184 m layer show the slickenside, clay and heavy pyrite remnants. Between 1205-1212 meters, second fault line has been discovered. The maroon clay and sandstone layers are mylonitic in nature. The third zone was discovered in between 1243-1245 meters. Between 1267-1268 meters, 8-m3 loss of circulation in mud has been measured. The same fault zone appeared up to 1278 meters. The fourth faulting zone in between 1375-1376 meters. The casing (9 5/8” ∅) has been set at 1452 m and than cemented. Heavy faulting, interbedded clay, siltstone and sandstone (Figure 4) have stratified 1538-1566 meters.

1607-1950-m The most important latest discovery was the limestone stratification in between 1607-1950 meters in the Kızılburun formation. Phenomenally, in the Buldan Horst, this limestone has situated itself as outcrop on top of Menderes Massif metamorphic-schist. These limestone layers contained fossils, ferrous oxide, sferolitic silica, recrystallized limestone, calcium carbonate cemented sandstone, siltstone, fragments of volcanic rock, tuffite, quartzite, opaque rock, smoky quartz and feldspar.

1613 to 1617 meter zone appeared to be the main fault zone. The mud completely disappeared at 1615 m. The total loss of mud circulation was measured as 300 m^3. As a result 1607-1617-m zone have been temporarily cemented. Remnants of the fault was discovered at 1644-1668 m level.

At the 1712-1766 m level, maroon clay fault lines, secondary quartz veins and calcite fragments can be seen in the Kızılburun Formation. The loss of mud circulation was very low (3.5 m^3 at 1732-1758 m and 4.5m^3 at 1758-1766 m in figure 4).

Petrographic analysis of 1774-1780 m cuttings: The main material samples from this level contained, limestone fragments, sparritic, micritic and mosaic patterned quartzite. Traces of muscovite and amphibole were noticed as well. In addition; chert fragmented metamorphic rocks, quartz-mica-schist, quartzite-schist, quartz-calc schist which coloured by ferrous-oxide have been detected in the microscope. In the microscopic sample, quartz (mono crystalline/Polly crystalline), biotite and muscovite have been detected. The biotite must have been coloured green as a result of chloritization.

Petrographic analysis of 1834-1836 m cuttings from this level contain; micritic limestone fragments, chloritization, silicified ferrous oxide fragments, slate, schist, quartzite, quartz, feldspar, garnet and opaque minerals. In the cuttings from 1862-1900 m strata; calcite, dolomite, quartz, feldspar, muscovite and kaolinite have been detected by the X-ray diffraction analysis.

As a result, at the end of the drilling operation at Kızılburun Formation, seven fault zones have been discovered (Figure. 4).

Menderes Massif metamorphics have been studied in two separated zones as follows;

Zone 1 : 1950-2050 m. Marble zone,

Zone 2: 2050-2401 m. Mica schist zone (İgdecik formation, "Şimşek, 1985a, b").

At the 1950-2036 m. Strata, milky white marble have been confirmed as the top level. Additional studies with the X-Ray diffractometer have resulted in minerals such as calcite, dolomite, quartz possible various alkali feldspar (albite) muscovite and kaolinite. Various thin section samples have shown mica-quartz schist, quartz-mica-calc schist, quartzite, and silicified rock fragments as well as carbonitized rock pieces. The X-ray diffractometer analysis have confirmed the same results as above.

At the 2036-2050 m different mineral composition have been noticed. The X-ray diffraction studies have discovered calcite, dolomite, quartz, feldspar, chlorite, simectite (montmorillonite), mixed clay (possibly mica-simectite), amphibole (hornblende), muscovite and kaolinite respectively.

The 2050-2401 m Zone 2. 2050-2041 m mica schist zone (İgdecik formation. "Şimşek, 1985a"). These zone cuttings contained quartz-mica-calc-schist, quartz-calc schist, mica-quartz-schist, quartzite, mica-quartz-schist, mica-schist, and very small amount of epidote schist. The mineral compositions of the cuttings have been discovered as quartz, mica (muscovite/biotite), chlorite, simectite (montmorillonite) and kaolinite. This is the second alteration zone discovered in the drilling operation.

4.2 Drilling History.

MDO-1 well Co-ordinates: X= 97 600

Y= 67 475

Z = 143 m.

Drill-rig; Draw-works and pump bodies of Uralmash have been brought in from Russia and the rig and platform were manufactured in Denizli. The height of the rig is 36 meters. We started to drill on 5.08.2002 and completed at the date of 1.07.2003.

The well was drilled down to 101.55 m by a 26" drill bit. 20" conductor casing pipe was dropped down to 100.45 m.

Through a 20" pipe, drilling continued down to 510 meters by 19" drill bit. The temperature of the hole was measured 9 hours after the mud circulation stopped. K-55 casing was set down to 488.64 m and than cemented up to the surface of the MDO-1 well. 13 3/8" casing was dropped down to 488 m. The weight of the casing was 99.2 kg/m.

Through a 13 3/8" pipe, drilling continued down to 1457 m by a 12 ¼" drill bit. K-55 casing was set down to 1452 m, and than casing was cemented. The cement did not come to the surface of the well, because of the cement loss into the first reservoir. The same mud pumps were used for cementing operation.

Through a 9 5/8" casing, the drilling was continued down to 2119.50 meters by an 8 ½" drill bit. The loss of mud circulation between 1613-1617 m, was 300 m^3. A cement plug was put into this zone in order to continue drilling down to 2119.5 meters; and than drilling of the well was stopped. A 6 5/8" slotted liner (675 m in length of which, 458 m was filtered, 10 mm in thickness) was lowered to the bottom. The well was washed out and started to produce geothermal fluid at 50-liters/sec-flow rate. Bottom hole temperature was 125 ^{0}C (Figure 5).

At the request of the owner, the well was deepened down to 2401 m through a 6 5/8" slotted liner with a 5 5/8" rock bit (Figure 4). After the completion of the well; dynamic and static temperature and dynamic pressure measurements were taken (Figure 5., 6.).

4.3. Well testing:

The compressed air was pumped into the well to fasten the production in the MDO-1 well. The bottom hole temperature was 125^{0}C. The flow rate was at 50 Lt/sec, when the valve was fully opened.

Analysis of the water sample taken from the MDO-1 well is shown below (Table 1).

Table 1. Analysis of the MDO-1 well water (Well head) from the Denizli-Sarayköy (Gerali) geothermal field.

PH (21 ^{0}C)			7.1		
Specific conductivity (21 ^{0}C)			2220 μmho/cm		
Specific gravity (21 ^{0}C)					
Evaporation remains(180 ^{0}C)			Mg/l		
Total hardness			51.9 ^{0}A		
Temporary hardness			51.9 ^{0}A		
Permanent hardness			0.0 ^{0}CA		
	Ma/l	Meq/l		Mg/l	Meq/l
K^+	72.6	1.86	SiO_2	39	
Na^+	240	10,44	HCO_3^-	1361	22.31
NH_4^+	2.96		CO_3^{--}	<10	
Ca^{++}	219	10.90	SO_4^{--}	485	10.10
Mg^{++}	92.8	7.63	Cl	31.4	0.88
$B_{(T)}$	3.1				

4.4 Scaling

As it is known for liquid-dominated resources, the mechanism of depositing $CaCO_3$ scale in a production well depends on carbon dioxide gas released from the geothermal fluid. In Turkey, all of the geothermal fields, including the MDO-1 well in Denizli-Sarayköy (Gerali) geothermal field have scaling problems.

Denizli (Kızıldere) geothermal scaling analysis have shown to be composed of $CaCO_3$ (% 54.96-78.20), $SrCO_3$ (%15.68-19.52) and $BaCO_3$ (%. 19-%0.57) "Arda, 1977". Whereas Germencik (Ömerbeyli-2 well) geothermal scaling analysis have shown to be composed of SrO (% 27) in one sampling, Sr (% 0.2) in another sampling "Karamanderesi et. al.1982".

MDO-1 well has been worked over for one week. The scaling have been observed from 0-120 m level. The resulting samples have been analysed by MTA laboratories as shown below table 2.

According to comparative calculation between the two samples; the results have been recorded as $CaCO_3$ (% 94.94-95.66), $SrCO_3$ (%1.22-1.23), Fe_2O_3 (% 0.64-0.49) and $BaCO_3$ as minimum scaling.

5. Conclusions

Even though there has not been any surface manifestation, the correlation between the geophysical data and geological survey, Sarayköy (Gerali) geothermal field has been discovered as the newest geothermal area in the Denizli Basin.

The exact location has been discovered to be the center of Sarayköy town. It spreads toward Babadag in the direction of N-S.

During drilling, two reservoirs have been discovered. The first one has been drilled at 814-1143 meters and the second one at 1650-2050 meters. In the first reservoir, the temperature was measured as 96-100^{0}C degrees. The Sazak limestone formation has been found to be the main rock formation.

The second (Main) reservoir has been measured at 125^{0}C degrees maximum. Kızılburun formation (Sand stone and Limestone) and Menderes Massif marbles have been drilled.

In the conclusion, the first reservoir is stated to be the limestones of Sazak Fm. and the second reservoir to be the Kzılburun Fm. and the Menderes Massif metamorphics. This statement is in conformity with those in Fig. 4. In Fig. 3, hawever, the first reservoir is shown as the limestones of Kızılburun Formation.

The field has been measured approximately for 3 sq. Km.. Two mineral alteration zones have separated the two reservoirs.

Acknowledgements

We would like to extend our gratitude to Degirmenci Group corporation for their financial support. We are very grateful to MTA and their laboratory staff. We would like to give our special thanks to Hüseyin Yalçın at Sivas Cumhuriyet University for their X-ray diffraction analyses help. Most of all, we would like to give our special thanks to Hakkı's sister, Ms. Emine Karamanderesi Ralston, for her unconditional love in translating and editing this report.

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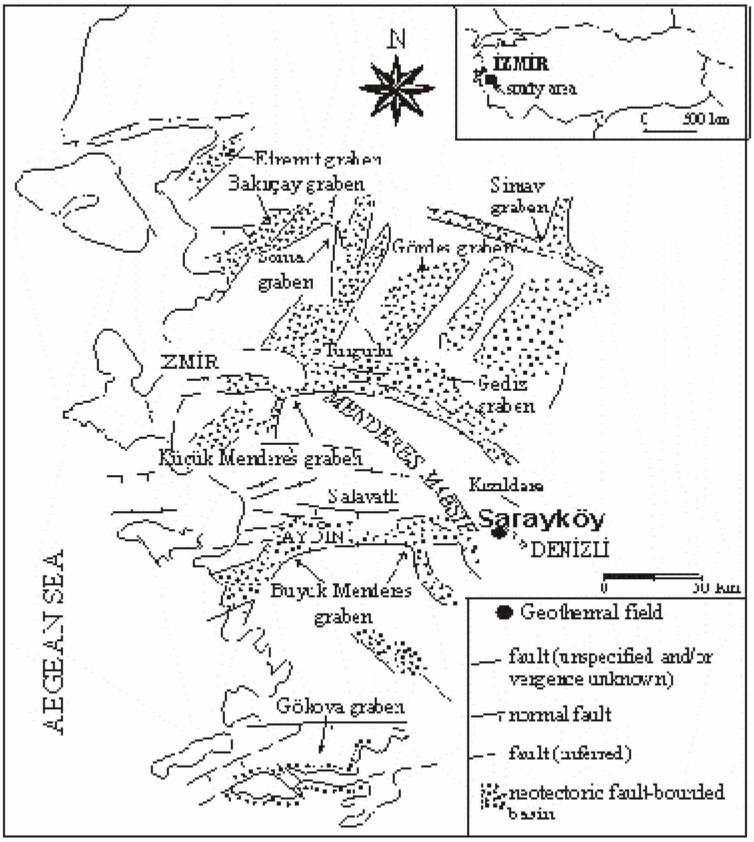

Figure 1 : Main tectonic features of western Anatolia and location map of the Denizli Sarayköy (Gerali) geothermal field.

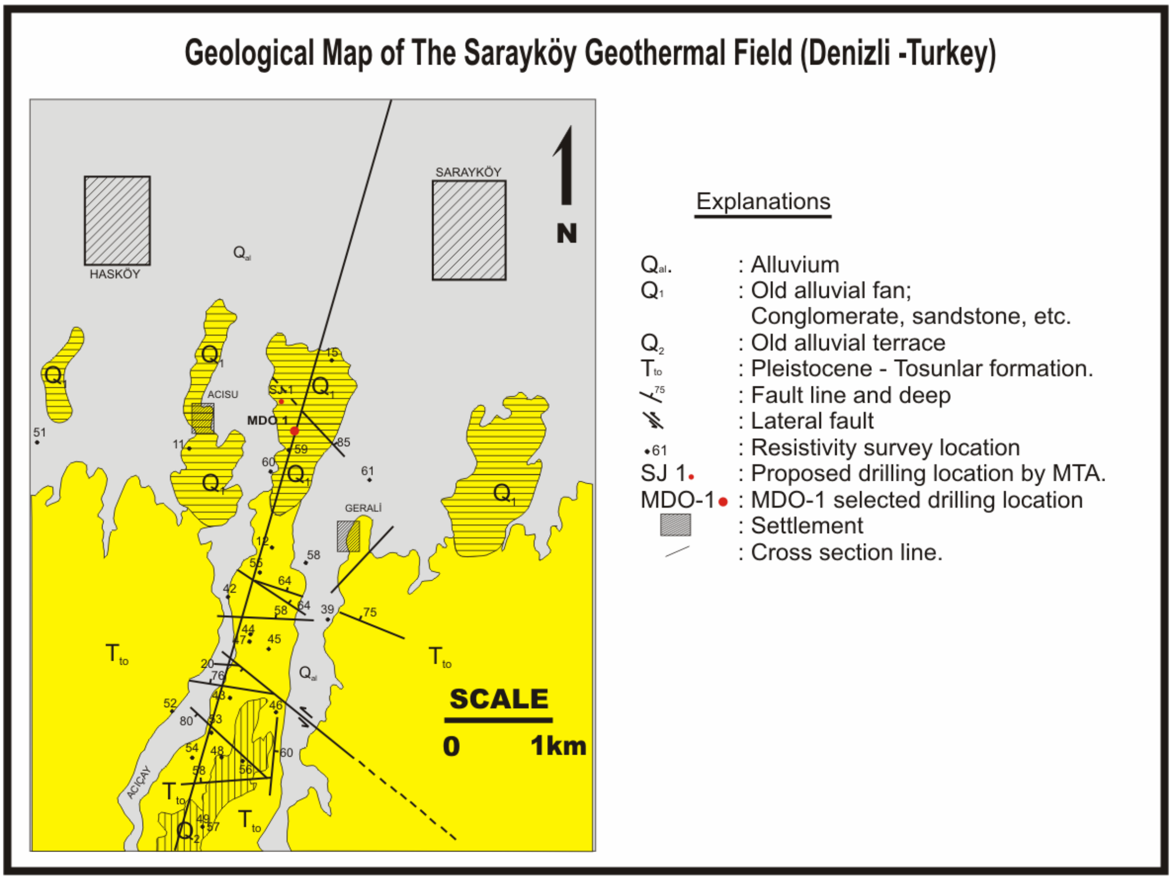

Figure . 2. Geological map of the Sarayköy (Gerali) Geothermal field.

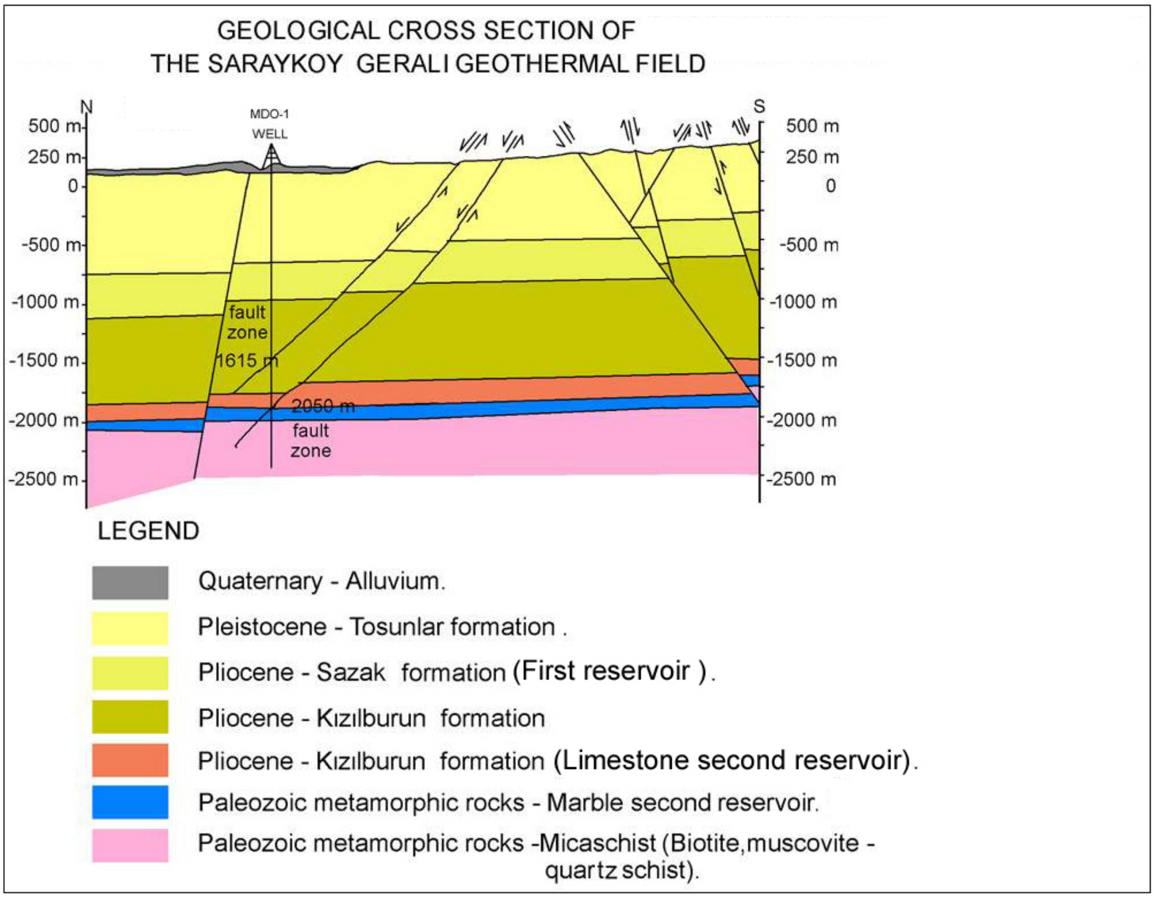

Figure .3 Geological cross section through the Denizli Sarayköy (Gerali) geothermal field.

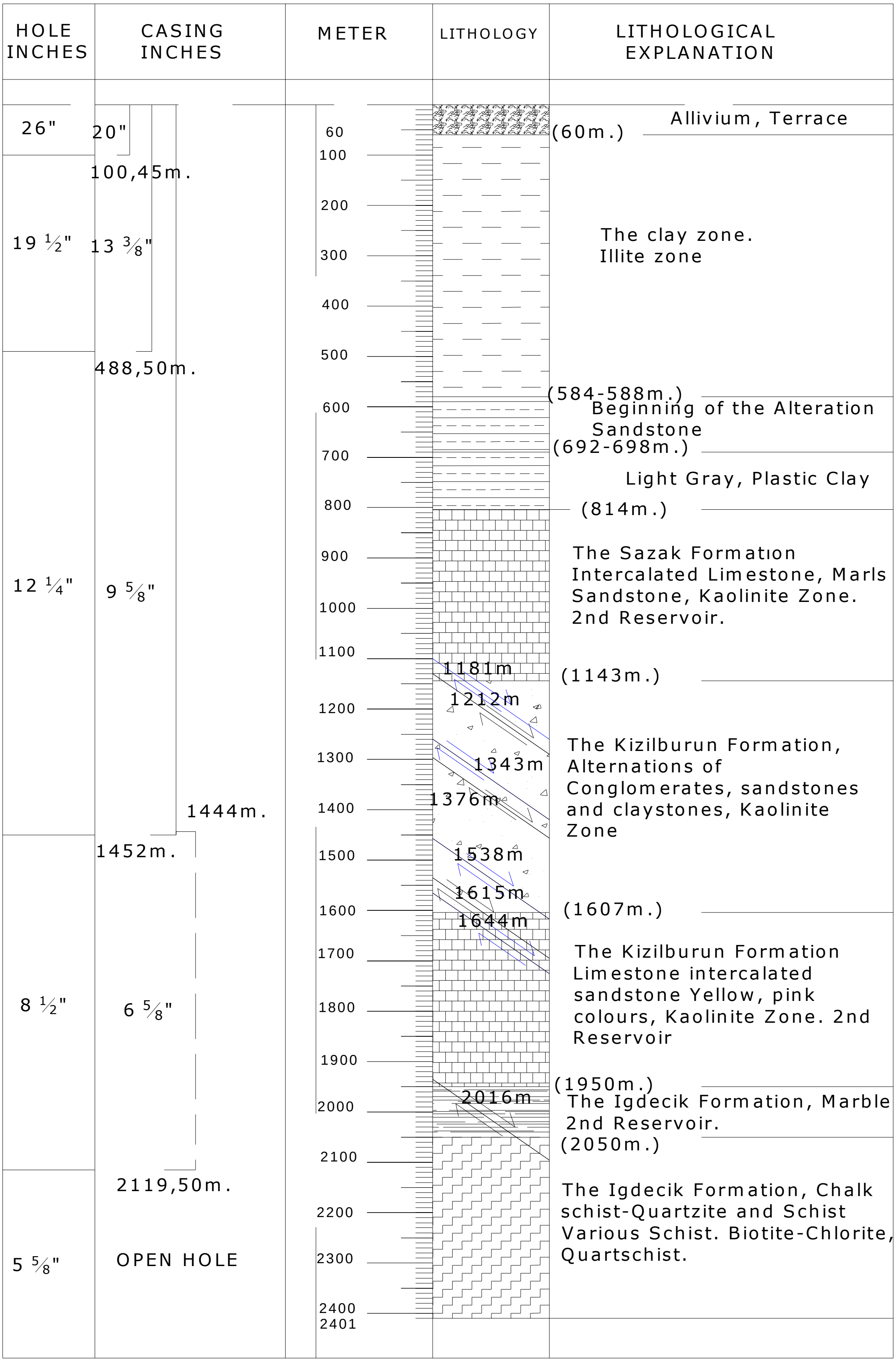

Figure 4. Well log of the MDO-1 well.

Figure 5. MDO weel no-1 Static and Dynamic Temperature values 2003

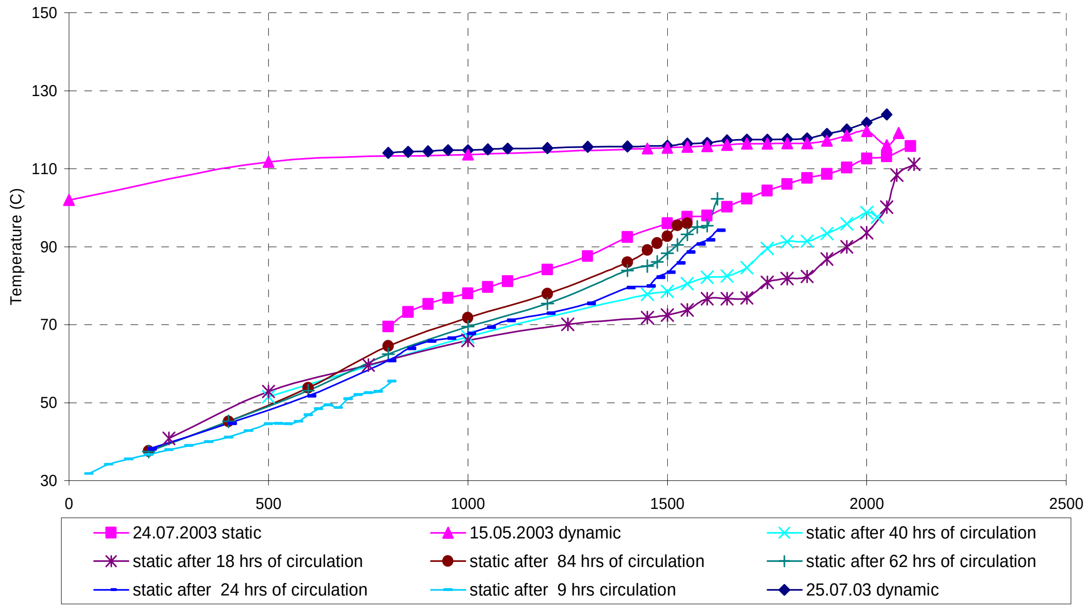

Figure 6 : MDO well no:1 Dynamic pressure values 25-07-2003

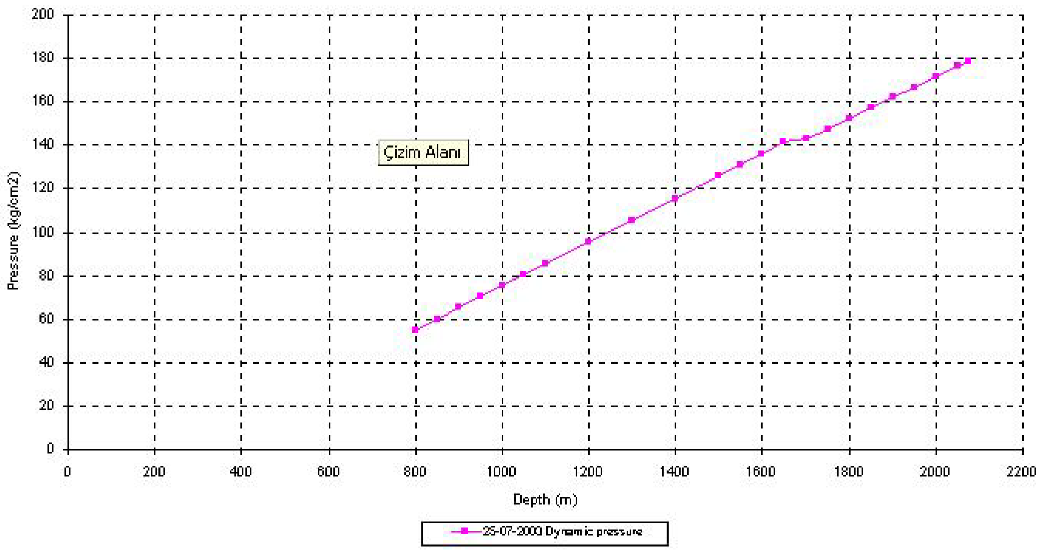

Table 2. MDO-1 well scaling samples analyses result

	% CaO	% MgO	% SiO_2	% Fe_2O_3	% Al_2O_3	.% Lost of ignition	% SrO
Sample-1	**53.60**	**0.10**	**0.40**	**0.65**	**0.45**	**43.10**	**0.86**
Sample –2	**53.20**	**0.15**	**1.20**	**0.50**	**0.25**	**42.60**	**0.87**