Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Geothermal Exploration Survey of Sorgun Geothermal Field (Yozgat-Turkey)

Sakir Simsek[1], Elif Yilmaz[1], Kemal Koc[1], Ozen Turker[1], Huseyin Karakus[1], Nilgun Bakir[2], Abdullah Gulgor, Ziynet Nur Simsek, Gokhan Bulus[3], Ersin Girbalar[3], Ilker Bektas[3], Tuygun Savaci[4], Hüseyin Oguz[4]

[1]Hacettepe University, Geology (Hydrogeology) Engineering Dept. Beytepe, Ankara,
[2]ORME Geothermal Inc. Ankara, [3]Iller Bankasi-Ankara and [4]Yozgat Governership

ssimsek@hacettepe.edu.tr, elifylmz@hacettepe.edu.tr, kemalkoc@hacettepe.edu.tr, ozenturker@yahoo.com, hkarakus@hacettepe.edu.tr, tuygunsavaci@hotmail.com

Keywords: Geothermal exploration, geology, hydrogeology, Sorgun, Yozgat

ABSTRACT

Sorgun geothermal field is located in the east of Sorgun district of Yozgat province. This study is focused on the evaluation of geological, hydrogeological, hydro geochemical, and geophysical studies, and drilling and well performance tests. Previous investigations and exploration wells for productoin of thermal waters and discharging water from coal mines were carried out by MTA General Directorate in this field. Hacettepe University- ORME Geothermal Inc. carried out a joint project on behalf of Yozgat Governorship-Governing of Sorgun District in 2004. Subsequently, Hacettepe University performed consulting services between 2005-2008 related to geological, hydrogeological, and drilling studies and well tests for the SG-1, SG-2, SG-3, SGR-1 and SG-4 wells. Lastly, reports of the well tests that were conducted by General Directorate of Iller Bankasi on behalf of Sorgun Municipality were evaluated.

Production and reinjection wells with bottom-hole temperatures ranging from 69 to 80^oC were drilled to depths of 104-445 m to obtain thermal water from the field. A reinjection well was drilled at the SGR-1 location in the field. Reservoir rocks were hosted by Paleocene granodiorites, whereas Eocene deposits constitute the caprock of the field. Thermal waters are of meteoric origin and classified as $NaCl-SO_4$ waters. The Sorgun geothermal field is suitable for integrated utilizations of thermal waters, specifically central heating, greenhouse heating, thermal tourism and balneology. Geothermal wells provided thermal waters for 1000 residences, a 10,000 m^2 greenhouse and the hot water supply to the thermal resorts.

1. INTRODUCTION

The study area is located 40 km E of the Yozgat province, near the Ankara-Yozgat State Highway (Figure 1).

Initially, the hot water requirement of Sorgun spa was supplied with 5 shallow wells, which have temperatures ranging from 50 to 63ºC. The first geothermal production well (YS-1) was drilled by MTA General Directorate in 1988 to increase the amount of hot water for a local spa (Keskin ve Ozeke, 1988). Following this, the V-1 and BB-1 wells were drilled in the field.

Because of the lignite layer in Sorgun geothermal field, drilling and galleries were opened so that companies could search for coal (Bilfer, Madsan, Yeniceltek Co. et al.). Some galleries were flooded with thermal waters due to fault planes cutting where geothermal fluid is upwelling. For the purpose of decreasing the piezometric head of the thermal water lower to than the coal level in the galleries and for constructing new galleries, hot water drainage wells (YS-3, YS-4, and YS-5) were drilled by MTA General Directorate in 2004. Currently, in the south of the field, Yeniceltek Coal Company produces coal using open coal mining methods. To obtain hot water from the field and determine the western boundary of the field, wells (SG-1, SG-2, SG-3, SG-4, and SGR-1) have been consulted by Hacettepe University 2005-2008.

Figure 1: Location map of Sorgun (Yozgat) geothermal field and its vicinity.

2. GEOLOGY

The basement rocks in the field are granodiorites, which outcrop at south and southeast parts of the study area. The granodiorites are commonly accepted as having Paleocene age. The upper surface of granodiorites is decomposed, and this unit has joints and fractures in fresh surfaces. Fractures become narrower and the unit becomes more massive with increasing depth.

Eocene sediments overlay the granodiorites unconformable and are divided into three layers. From the Early Eocene, there is a terrestrial-lacustrine facies made up of laminated conglomerate, sandstone, marl with sand and marl. Also, coal (lignite) layers are present in the base conglomerate. From the Middle Eocene, there are marls, sandstones and limestone's that were units deposited in a marine facies. In the Late Eocene, flysch was deposited.

The Pliocene unit that conformably covers the Eocene sediments consists of terrestrial sediments (alternating conglomerate and sandstone) and is visible in outcrop in the north of the area and covers wide portions.

Quaternary alluvium is the youngest unit in the study area and is located along the Egrioz stream in the middle of the area.

Normal slip faults improved depending stress tectonics in Neocene and Quaternary at the field. A buried fault zone was exposed as a result of evaluating data that was obtained from thermal water, coal searches and production wells. The main up-flow paths for waters are WNW-ESE, NE-SW and N-S trending strike-slip faults.

3. HYDROGEOLOGY

The upper 30-50 m of the basement rock (granodiorites) and the deep fault/joint zones are permeable. Units at lower parts have strict fracture intervals and are compact. The alluvium that lines the area of Egrioz and Domuz Stream and includes stream deposits (clay, sand, and gravel) reaches as much as 40 m bed thickness and thus is an important aquifer for hot and cold waters. Pliocene sediments, consisting of conglomerate, sandstone, claystone and marl, are mostly impermeable, but loosely cemented sandstone and conglomerate are permeable and have local importance as an aquifer. Claystone, marl, limestone with clay levels of Eocene sediments are mostly impermeable and are the caprock of the area, but fracture zones of the units and base conglomerate may be permeable.

4. HYDROGEOCHEMISTRY

Thermal waters that were collected from wells in the field have temperatures between 60 and 80°C and electrical conductivities between 2620 and 3075 µS/cm (Table 1).

Based on ionic compounds, the hot waters are Na-Cl type. Semi-logarithmic Schoeller and piper diagrams show that there is a similarity between chemical compositions of hot waters which have relatively high Na-Ca and Cl-SO_4 concentrations in the area (Figure 3a, 3b)

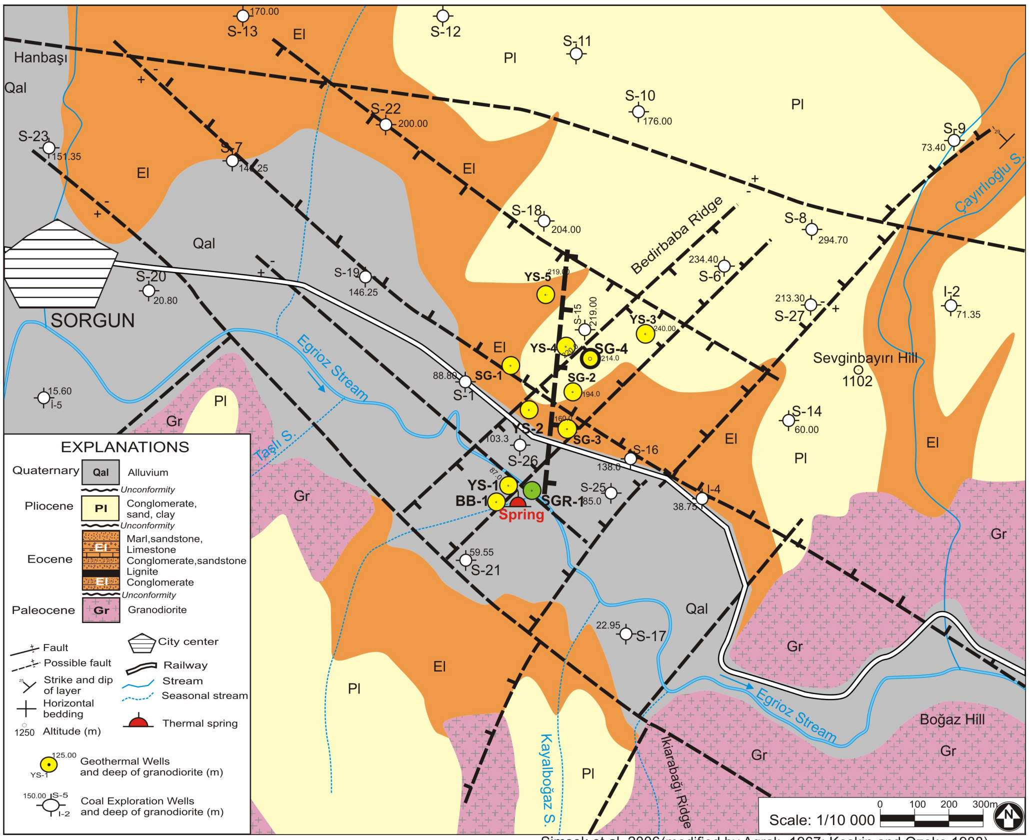
According to Wilcox and U.S. salinity diagrams, waste water from the hot water is not suitable for irrigation. Therefore, direct, uncontrolled discharge of waste water should not be allowed, reinjection must be done instead.

The calculation of mineral saturation index indicates that the thermal waters are extremely saturated with respect to carbonate minerals, such as calcite and dolomite, which are likely to be precipitated as scales in geothermal wells (Figure 3c). Also, thermal water discharged from wells is corrosive.

Based on the isotope analysis, the geothermal system is recharged from meteoric water. However, the thermal waters have high temperature because of isotopic exchange processes. Also, tritium analysis showed that groundwater in the area has a long residence time.

5. GEOPHYSICS

As a result of geophysics studies using MTA and DSI, the thickness of the caprock, which contains Eocene, Pliocene and Quaternary aged sedimentary rocks, and the penetration depth of granodiorites was determined. Normal-slip and steps faults are defined from the thermal spring field to the north and caprock thickness increases toward the north. The seismic survey in the field by Madsan also helped identify fracture lines. After the geophysical studies in the field, the data that is important to determining the location and the depth of production/reinjection wells have been obtained. The borders of Eocene sedimentary and granodiorites are fitted together in drilled wells.



Simsek et al.,2006(modified by Agralı, 1967; Keskin and Ozeke 1988)

Figure 2: Geological map of Sorgun geothermal field and locations of wells.

Table 1: Physical and chemical parameters of Sorgun thermal well waters.

Samp. No	Sample Name	Sampling Date	T (°C)	pH	EC µS/cm	Na ppm	K ppm	Ca ppm	Mg ppm	HCO_3 ppm	Cl ppm	SO_4 ppm
V-1	Hot water well	Aug 2004	63.1	6.96	2620	358.92	11.50	145.05	8.74	185.90	440.82	333.70
BB-1	Bedirbaba hot water well	Aug 2004	59.5	7.14	2690	351.35	12.56	152.35	9.13	185.90	440.52	333.19
YS-4	Madsan hot water well	Jan 2005	80.0	7.98	2920	458.55	15.15	139.64	2.78	18.87	664.73	290.46
SG-2	Thermal water well	May 2005	80.0	8.49	2770	437.78	13.29	113.93	2.58	63.30	612.32	347.79
SG-3	Hot water well	Jan 2006	80.0	8.45	2510	416.10	12.72	126.57	5.17	176.90	495.22	296.77
SGR-1	Reinjection well	June 2006	75.0	8.13	2940	466.84	16.77	140.96	2.40	85.98	750.17	338.25
SG-4	Production well	Dec 2008	79.0	8.07	3075	570.54	20.22	160.74	1.65	36.78	997.92	305.09

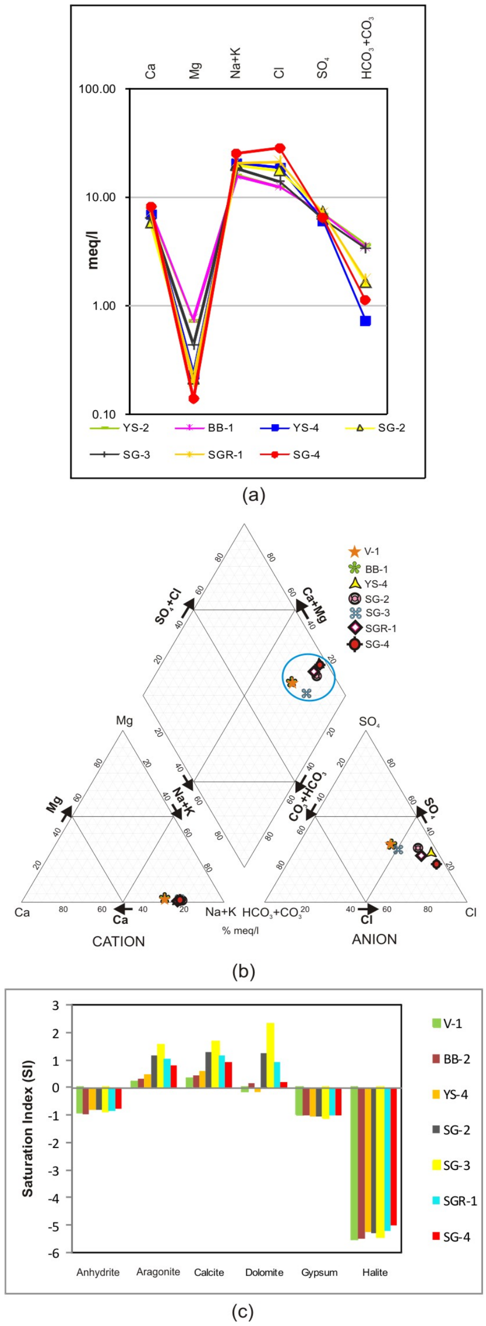


Figure 3: a) Semi-logarithmic diagram, b) Piper triangular diagram, c) Saturation index diagram of Sorgun thermal waters.

6. GEOTHERMAL WELLS

In the Sorgun geothermal field, the first geothermal production well (YS-1; 104.5 m) was drilled in 1988 by MTA General Directorate on behalf of the Yozgat Governorship. Earlier, the hot water requirement of Sorgun spa was supplied with a 5 shallow caisson well with a temperature range between 50 and 63ºC. For YS-1 well, the flow rate and temperature of produced thermal water are, respectively, 15 l/s (with the pump) and 69°C (at the wellhead) (Keskin ve Ozeke, 1988). Later, V-1 (105 m) was drilled near to YS-1, and it has a 17 l/s flow rate (with pump) and 67ºC fluids. Produced water from the V-1 well contributes to Lokman Hekim Spa, Osmanlı Spa and Saray Spa (DEM-SU, 2003). The Bedirbaba (BB-1; 90 m) well was drilled 40 m west of V-1 and has a 3 l/s flow rate and 64ºC fluids. The hot water from this well is used in the Bedirbaba Spa. These wells and others present are listed below Table 2.

Table 2: Characteristics of wells in Sorgun geothermal field.

Well No	Date	Depth (m)	[1]Product (l/s)	[2]Temp. (°C)	Explanation
YS-1	1988	104.5	4	75	(3)Production
V-1	2003	105	17	67	(4)Production
BB-1	1988	90	3	64	4) Production
YS-3	2004	334	6-8	75	(5)Drainage
YS-4	2004	243	20	80	(5) Drainage
YS-5	2004	336	0.1	-	(5) Drainage
SG-1	2005	275	-	50	(6)Nonproduction
SG-2	2005	300	66	80	(6)Production
SG-3	2006	357	40-60	71	(6)Production
SGR–1	2006	444	70	75	(6)Reinjection
SG-4	2008	390	(2)35	79	(6)Production

(1): First production flow rate at production test, (2): Wellhead production flow rate at compressor test, (3): not used, (4): production with the pump (5): Madsan wells, (6): Yozgat Province wells

After drilling and gallery studies for coal research, galleries were flooded with thermal waters due to cutting fault planes along which geothermal fluids are rising. Madsan Coal Inc.

drilled three hot-water drainage wells in 2004 for coal production to get the hot water level lower than the coal level by means of hot water production from granodiorites with wells. The depths of drilled wells, YS-3, YS-4, and YS-5, are 340 m, 243 m and 336 m, respectively The depths of granodiorites are in the order of 240 m - 214 m and 228 m.

A detailed study was performed in the Sorgun geothermal field in July-September 2004 by Hacettepe University and ORME Geothermal Inc. for determination of the potential of hot water and increasing production (HU-ORME, 2004). As a result of this study, the SG-1, SG-2, SG-3, SGR-1 and SG-4 wells were drilled. The SG-1 well was drilled at 275 m depth and has a 5-10 l/s flow rate and 30ºC fluids (Hacettepe University, 2005,) SG-2 was completed at 300 m depth (Figure 4). Thermal water, taken after development tests in the well, has a 66 l/s flow rate and 80ºC wellhead temperature (Hacettepe University, 2005). SG-3 well was drilled to 357 m depth and has 75ºC fluids and a 40-60 l/s flow rate, as determined by the compressor test in the well. SGR-1 is a research/production/reinjection well, resulted in the production and reinjection at 444 meters depth (Figure 4). In the SGR-1 well, a flow rate of approximately 70 l/s, and a temperature of 75ºC were measured in well tests (Hacettepe University, 2006-2008). This well has been used for reinjection purposes since the 2009 heating season. The SG-4 well was drilled to a depth of 390 m. The temperature at the is 79ºC at wellhead and fluid of 35 l/s flow rate has been obtained during production with a compressor (Hacettepe University, 2006-2008).

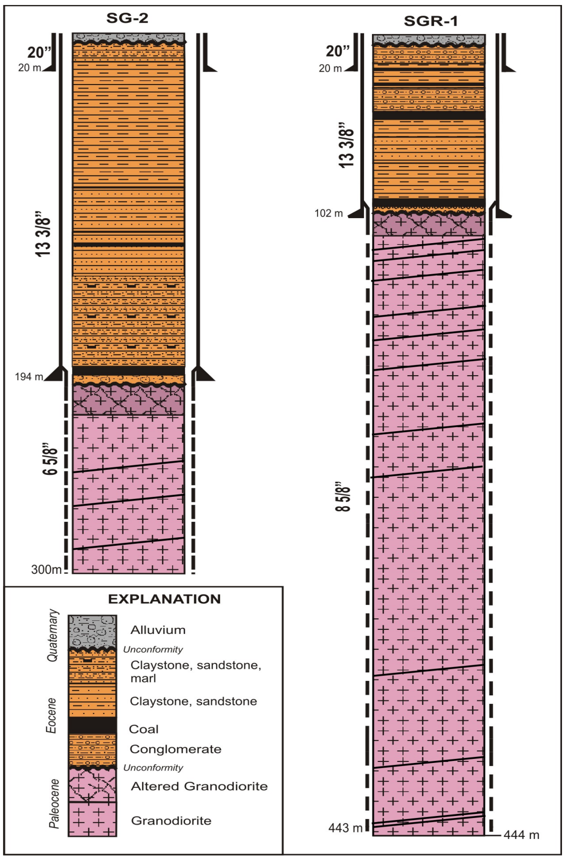


Figure 4: Well lithologic logs and casing plans of SG-2 production and SGR-1 reinjection wells.

During simultaneous production tests of SG-2, SG-3 and YS-4 wells (118 l/s total production) with a pump, changes in water levels in the SG-2, SG-3 and YS-3 observation wells were observed, with water levels decreasing to around 63 m and becoming stable at this level (Iller Bankasi, 2005-2006). During production in the SG-2, SG-3 and YS-4 wells, YS-3 and Madsan-1 (YS-2) were used as observation wells. Observations and measurements show that YS-2 and YS-3 have been affected by production from the SG-2, SG-3 and YS-4 wells. Also, this situation shows that wells in the north of the Sorgun field are recharged from the same aquifer.

Consequently, using the interpretation of the studies done in the field together with data from the drilled-wells and the geothermal production area, a possible production area and a possible reinjection area have been established. According to this plan, wells to be drilled in the production area will have high temperature and fluid if the drilling penetrates granodiorites (Hacettepe University, 2006-2008).

7. RESULTS

According to the hydrothermal model of the Sorgun geothermal field, meteoric waters (rain and snow) infiltrate underground, warm up with the geothermal gradient and flow up along fractures and faults. Existence of young tectonics in the region shows that the thermal gradient of the field is higher than in other regions. Geothermal waters, rising up through the faults, are stored in the cracks and altered sections of granodiorites and in Eocene basal conglomerates and spread in the alluvium at the top.

Sorgun field's geothermal potential has been increased and developed with joint work by Yozgat Governorship, Sorgun District Governorship, Hacettepe University and ORME Geothermal Inc., and Sorgun Municipality and Iller Bankasi. As a result of those studies and by using 2 production and 1 reinjection wells, at 1000 houses at the city center of Sorgun and a 10,000 m^2 greenhouse are heated by geothermal water. This fluid, besides providing district heating, can be developed further to integrate with greenhouse heating, health and thermal tourism facilities, and fishing and farming culture.

New research/production/reinjection wells should be drilled and the necessary tests and observations should be made for increasing the thermal water production and to provide clean, safe, healthy and sustainable use of thermal water in the region.

ACKNOWLEDGEMENTS

The authors wish to thank to Amir Cicek, Governor of Yozgat, Ertugrul Kilic, Province Governor of Sorgun and Ahmet Simsek, Mayor of Sorgun city for their support to this study and thanks for the analyses of water samples is due to Hacettepe University Hydrogeology Laboratory staff and chemists.

REFERENCES

Agrali, B.: Yozgat-Sorgun Havzasinin 1/10.000 olcekli jeolojik etudu ve 1965-66 yıllarinda yapilan arama sondajlari verilerine gore bolgenin komur imkanlari MTA Rapor No : 3695. Ankara (1967)

DEM-SU: T.C.Yozgat Valiligi Il Ozel Idare Termal Sondaj Uretim Kuyusu Uretim Raporu. Yozgat calismasi raporu, Yozgat (2003-2004)

HU-ORME: Sorgun jeotermal sahasi değerlendirme ve sondaj lokasyonu belirleme calismasi (2004)

Hacettepe University: Sorgun SG-1 ve SG-2 kuyusunda yapilan Jeolojik-Hidrojeolojik-Sondaj ve Test calismalarina iliskin danismanlik raporu (2005)

Hacettepe University: Sorgun SG-3, SGR-1 ve SG-4 kuyusunda yapilan Jeolojik-Hidrojeolojik-Sondaj ve Test calismalarina iliskin danismanlik raporu (2006-2008)

Iller Bankasi: Sorgun (Yozgat) Belediyesi SG-2, SG-3 ve YS-3 Numarali Jeotermal Kuyulari Test ve Olcum Raporu (2005-2006)

Keskin, B., ve Ozeke, H.: Yozgat Sorgun kaplicalari hidrojeoloji raporu. MTA rapor. No: Ankara (1988)