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

Usability and Origin of Geothermal Water Around Beypazarı Region Ankara, Turkey

Oktay ÇELMEN[1], Mehmet ÇELİK[2]

[1]celmen@mta.gov.tr

[2]celikm@eng.ankara.edu.tr

Keywords: Geothermal springs, environmental isotopes, hydrochemistry, Beypazarı granitoids, Ankara – Turkey.

ABSTRACT

According to hydrochemical analyses four different water types: bicarbonate dominant water (facies-I), sulfate dominant cold brine water (facies-II), sodiumbicarbonate dominant thermal water and thermal and mineralized water (facies-III), and sulfate–chloride dominant thermal and mineralized water (facies-IV) observed in the study area. It is objected that the mineral content/salinity of the water is related to the ions that these waters dissolve from the minerals on the rocks during infiltration and circulation in the saturated zone. Gypsum cover units that exist on the granitoids in the region is the main factor for the ion increase in the facies III geothermal water similar to the cold brine water (facies II). By means of isotopic analyses the thermal springs (Dutlu bath spring, Ayas bath well, Çoban bath well and Kapullu bath spring) are of meteoric origin and receive recharge from precipitation in the Beypazarı granitoids and around gypseous formations with elevations of about 950–1,150 m. On the other hand Karakaya bath well and Ilıca bath spring thermal water points are recharged from the Bilecik limestone hills, Tekke volcanics and Incedoruk Formations. It is observed that Karakoca mineral spring of thermal and mineralized water is recharged from out of the study area. The Ayas resort has been used for balneological purposes since 1892, and the facility currently operates as a spa as well as a physical therapy and rehabilitation center. This is also true for the Dutlu resort. The Coban bath was a spring site in 1970s; however the spring is currently dry. The water of the Karakoca mineral spring is sold in the market under the brand name of Beypazarı; mineral water.

According to oxygen-18 (SO42-) and sulfur-34 (SO42-) contents, sulfate in water samples from Ayas and Dutlu resorts as well as Coban bath is derived from the gypsum of Kirmir Formation as the primary source. Sulfates of the Kapullu bath water and Karakoca mineral water originate from secondary sources such as pyrite oxidation and bacteriological reduction.

Since 1892, Ayas geothermal waters put forwarded to be good for especially rheumatical problems, sciatica, orthopedic and gynaecologic issues balneologically. Now it has doing service with a modern facility and physical therapy center with 380 rooms and 1000 beds where Dutlu bath in the region giving service with 300 room and 700 bed capacity.

1. INTRODUCTION

Beypazarı is between Ayaş, Kapullu and Sarıoba towns, about 100 km west of Ankara. Uğur, Sızma, Ilhan and Kirmir creeks, to the north of the study area, as well as Ankara, Ovaçay and Sakarya rivers to the south discharge to the Sarıyar dam lake to the west of the study area (Fig. 1).

Waters of the Çoban bath well (BT-3), Ayaş bath well (BT-2), Dutlu bath spring (BT-1), Kapullu bath spring (BT-5), Karakaya bath well (AK1), Ilıca bath spring (BT-4), Karakoca mineral spring (BT-6) and Çağlayık bath spring (BT-7) are the thermal and/or mineralized waters in the area (Fig. 1). The Ayaş resorts have been used for balneological purposes since 1982, and the facility currently operates as a spa as well as a physical therapy and rehabilitation center as well as Dutlu resort. Karakoca mineral spring which is mentioned in this study sold in the market under the brand name of Beypazarı mineral water.

In the past many researchers focused their attention to this area; such as Çağlar 1947, Mohr 1956, MTA 1963, Sahinci 1970, Canik 1973, Özbek 1984, Diker 2005, Diker et al. 2005, and Diker et al. 2006, Çelmen 2008. Granitic rock and gypseous units in the region were the subject of several works (Helvacı and Bozkurt 1994, Karadenizli 1995, Zoroğlu and Kadıoğlu 2003, Kadıoğlu 2004). Sulfur isotopes were also used in studies on formation characteristics of gypseous units (Orti et al. 2002, Palmer et al. 2004, Çelik 2007).

By hydrochemical and isotopic investigarions it is understood that thermal and mineralized waters in the region are very related to Beypazarı granitoids and their relation with the rock units.

2. HYDROLOGY AND HYDROGEOLOGY

There are 6 main surface waters consist in the study area. These are Sakarya River, Ankara, Ovaçay, Uğur, Sizma and Kirmir creeks that comprises in the area. Sarıyer Dam lake found at the north of the study area that waters of the Kirmir Creek and Sakarya River are discharged into this Dam Lake.

Acoording to investigations and studies at the study area; it is observed that basement of stratigraphic series consists of Permian-Triassic aged metamorphic rocks which is called as Gökçekaya metamorphics. On the upper zones, Jurassic aged Bilecik limestones overlay the basement rocks. Granitic rocks in the area are found as batholits, which settled down in the area during Upper Cretaceous and named as Beypazarı granitoids. During and after the settling down of these granitoids, many discontinuity planes have been created. These discontinuities are generally normal faults, which lead to the formation of thermal waters.

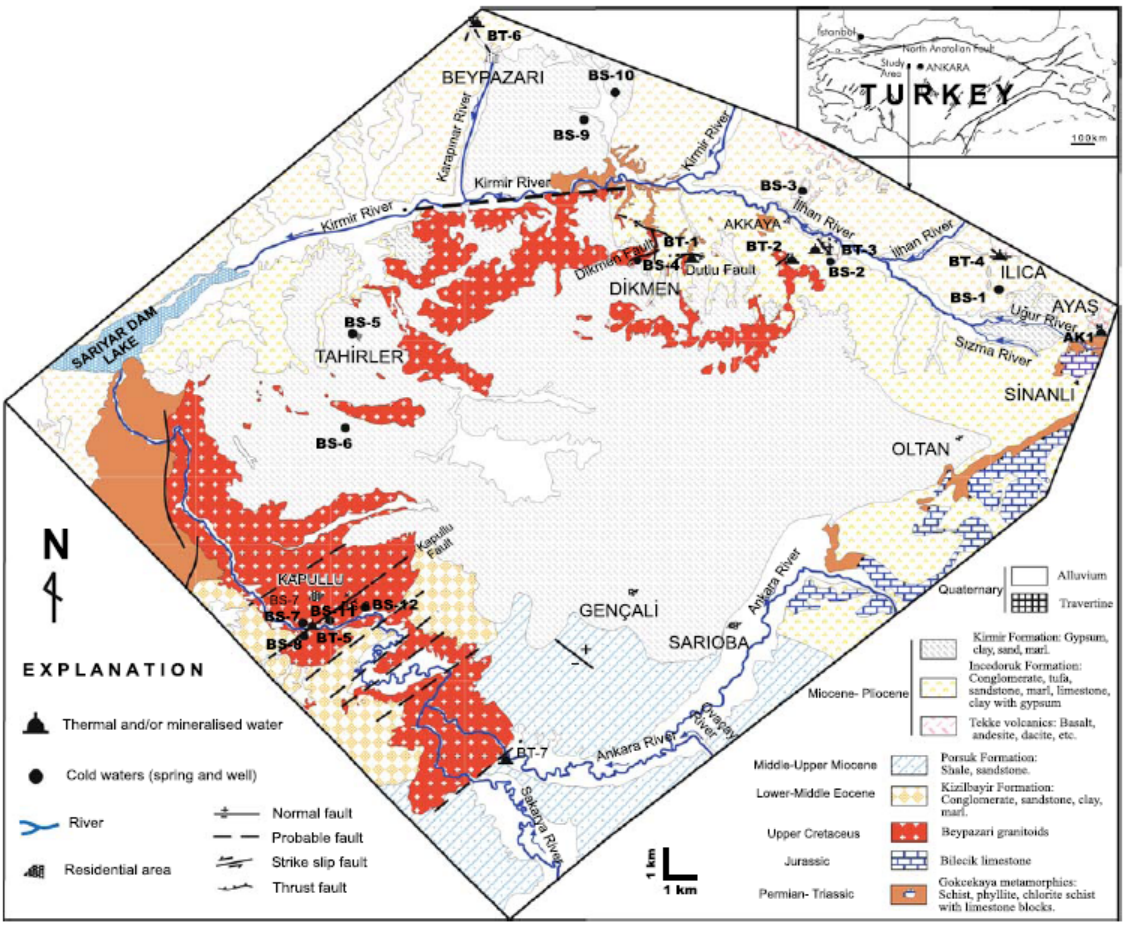

Fig 1: Location and geological maps of the study area (modified from MTA 1/500,000 scale map 1963)

These fault zones are located generally between metamorphic schist and granitoid that are available for groundwater circulation and gathering. Granitoid rocks are very important leading to formation of thermal and cold springs in the study area. Though, thermal springs, BT-1, BT-2, BT-3, BT-5 and BT-7 are discharged on the Beypazarı batholiths.

The young cover units over the granitoids vary between the Lower Eocene and Quaternary. Cover units consist of carbonated and clastic sediments, volcanic and volcanoclastics. Kirmir Formation is made of mudstone, sandstone, gypsum, claystone and marl units. In Kızılbayır and Porsuk formations conglomerate and sandstone and shale, marl and clay exists together. Incedoruk Formation was also formed by the conglomerate, sandstone, limestone, tufa, marl and clay units. Basalts from Tekke volcanites is another cover units exists in the study area (Fig 1, Fig 3) that considered to be possible heaters for the thermal springs.

3. COLD AND THERMAL SPRINGS

There are 12 cold and 8 thermal springs studied in the study area. Cold springs are generally formed along the contacts of different lithologies or along the heterogeneous structure within a rock body with uniform lithology. Bicarbonate dominated BS-1 and BS-3 springs located at the north of the study area are and represent İncedoruk and Tekke Formations BS-4, BS-7, BS-8 and BS-11 cold springs are also bicarbonate dominant waters but related to the granitoids and of belong to facies-I (Table 1, Fig. 2). andBS-10 springs that located at the north and BS-2, BS-5 and BS-6 springs located at the center of the study area are BS-9 sulfate dominant and related to the Kirmir Formation and of type facies-II. BS-5 and BS-6 springs recharged from directly to the layers in the Kirmir formation but BS-9 recharged from magnesiım and sodium salts addition to Kirmir formations gypsums. In addition to this, BS-10 spring compose high Mg ion due for Tekke volcanics.

Thermal springs, in the study area spread from east to west, whereas to the south of them are found by the Ankara Creek and Sakarya River. Karakaya thermal spring (AK1), which is a thermal and mineralized spring of Na-HCO3 facies (facies-II), is related with Bilecik limestones, Incedoruk Formation and Tekke volcanics.

Ilıca spring (BT-4) is related with different lithologies with Mg-Ca-HCO3 hydrochemical facies. Also, it was stated that this spring could be polluted by the seasonal creek waters (Çetin 2006). BT-1, BT-2, BT-3, BT-5 and BT-7 springs are of Na-SO4-Cl hydrochemical facies. These springs were formed over the Beypazarı granitoids and at the contact of different lithologies.

In the study area cover units reach to 350 m thickness over the granitoids in the BT-3 spring region. These units and granitoids take effect during the formation of these springs. It is also related with their hydrochemical faciesies. The geothermal springs which are only recharged through granitoids are expected to be of Na-HCO_3 hydrochemical facies (Albu et al. 1997). However, the dominant anions at these springs in the study area observed as SO_4^{2-} and Cl^- Shallow cold waters of type facies-I (Ca-Mg-HCO3) and facies-II (Ca-Mg-Na-SO4) are richer in sulfate and bicarbonate as they flow to greater depths.

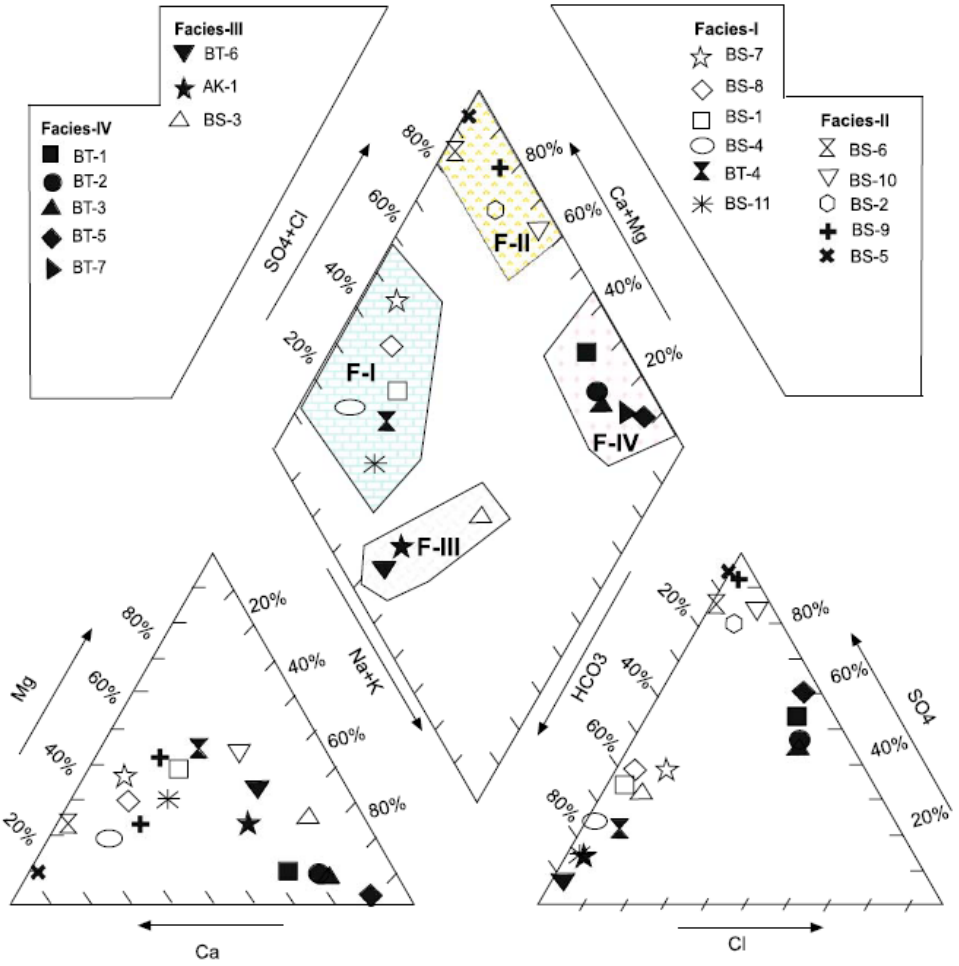

Fig 2 : Piper diagram (1944) for thermal and cold waters

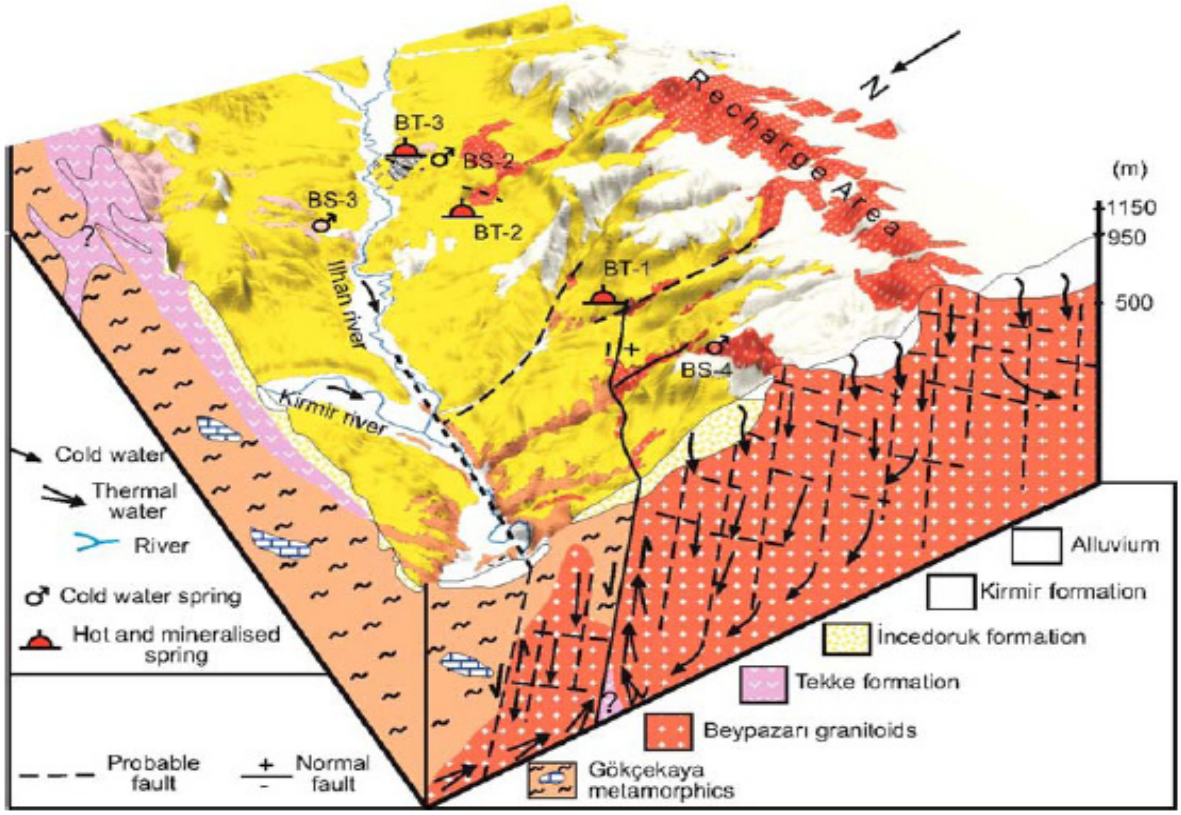

Fig 3 : A hydrogeological model study for some thermal waters in the study area

As facies-I and facies-II type waters flow deep within discontinuities and disintegrated zone of the granitoids that are under the blanket units, they mix with the sodium and bicarbonate in these granitoids. These waters, which are predicted to be hotter due to the geothermal gradient and basalts that are intrusive in deep, surface from the permeable zones formed by normal faults. HCO_3^- is a third degree anion in the BT-1, BT-2 and BT-3 springs in the model (Fig. 3). Among the geothermal waters, waters of the Çağlayık bath well have the highest TDS and EC content

Thermal waters are saturated with respect to calcite, aragonite, dolomite and quartz but undersaturated to anhydrite, gypsum and halite minerals. On the other hand, cold waters are saturated with respect to calcite, aragonite

and dolomite but undersaturated to anhydrite, gypsum and halite minerals. BS-5 and BS-9 cold waters are saturated with respect to gypsum minerals; because they are recharged only by gypseous Kirmir Formation.

Table 1 : Classification of geothermal water in the study area

Sample code	Cations	Anions	Formation	Water types/ hydrochemical facies	Facies (F) code
Thermal and mineralised waters					
BT-1, BT-2, BT-3, BT-5, BT-7	$(Na^+ + K^+) > Ca^{+2} > Mg^{+2}$	$SO_4^{-2} > Cl^- > HCO_3^-$	KBg, TKi, TPi	Na–SO_4–Cl	IV
BT-4	$Mg^{+2} > Ca^{+2} > (Na^+ + K^+)$	$HCO_3^- > SO_4^{-2} > Cl^-$	JKb(?), Tt, TPi	Mg–Ca–HCO_3	I
BT-6	$(Na^+ + K^+) > Mg^{+2} > Ca^{+2}$	$HCO_3^- > SO_4^{-2} > Cl^-$	TPi	Na–HCO_3	III
Thermal water					
AK-1	$(Na^+ + K^+) > Ca^{+2} > Mg^{+2} >$	$HCO_3^- > SO_4^{-2} > Cl^-$	JKb, TPi	Na–HCO_3	III
Cold-brine waters					
BS-2, BS-5, BS-6	$Ca^{+2} > Mg^{+2} > (Na^+ + K^+)$	$SO_4^{-2} > HCO_3^- > Cl^-$	TKi	Ca–SO_4	II
BS-9	$Mg^{+2} > Ca^{+2} > (Na^+ + K^+)$	$SO_4^{-2} > HCO_3^- > Cl^-$	TKi	Mg–Ca–SO_4	II
BS-10	$Mg^{+2} > (Na^+ + K^+) > Ca$	$SO_4^{-2} > Cl^- > HCO_3^-$	TKi	Mg–Na–SO_4	II
Cold-fresh waters					
BS-1	$Ca^{+2} > Mg > (Na + K)$	$HCO_3^- > SO_4^{-2} > Cl^-$	TPi	Ca–Mg–HCO_3	I
BS-3	$(Na^+ + K^+) > Mg^{+2} > Ca^{+2}$	$HCO_3^- > SO_4^{-2} > Cl^-$	Tt, TPi	Na–HCO_3	III
BS-4, BS-7, BS-8, BS-11	$Ca^{+2} > Mg^{+2} > (Na^+ + K^+)$	$HCO_3^- > SO_4^{-2} > Cl^-$	KBg	Ca–HCO_3	I

TKi Kirmir Formation, *TPi* İncedoruk Formation, *Tt* Tekke volcanics, *KBg* Beypazarı granitoids, *JKb* Bilecik limestones

4. BALNEOLOGICAL USE AND UTILIZATION OF THERMAL WATERS

It is known that people have used geothermal water and mineral waters for bathing and their health for many thousand of years. Balneology, the practice of using natural mineral water for the treatment and cure of disease gets people attentions for many thousands of years. In the study area three modern and one primitive bath/spa exists in order to utilize for balneological purposes from geothermal waters. One of the modern spa is calllld as Ayas spa (BT-2) and located at Ayas-Beypazarı road in Ankara . It is known that this bath has been used since 1892 and now it operates with a modern facility and physical therapy center with 380 rooms and 1000 beds.

Dutlu bath (BT-1) is another modern spa in the study area (. It is located about 7 km north-west of Ayas spa giving service with 300 room and 700 beds. Ayas Karakaya bath (AK-1) is another modern spa in the study area which is located at the centre of Ayas region in Ankara.

There is one primitive bath exists in the study area called as Kapullu bath that located at the Kapullu village, south of Beypazarı region.

Geothermal waters in the study area put forwarded to be good for especially rheumatical problems, sciatica, orthopedic and gynecologic issues balneologically.

The water of the Karakoca mineral spring (BT-6) is located at the north of the Beypazarı region. It is sold in the market under the brand name of Beypazarı mineral water.

5. ENVIRONMENTAL ISOTOPE STUDIES

In order to understand origin and evaluation of thermal springs, environmental isotope studies have been taken in the study area. Results of this studies reveals that, thermal springs in addition to thermal and mineralized springs at the study area are of meteoric origin, and as they circulate from the fault zones, these springs are partially cooled by the surface waters and they are exposed to evaporation (Fig. 4) (especially BT-4). According to Oxygen-18 ($d^{18}O$)–deuterium (d^2H) diagram evaporation effects can be seen at BS-2, BS-3, BS-4, BS-5, BS-8, BS-11 and BS-12 cold springs. Especially BS-2, BS-8, BS-11 and BS-12 waters have notably evaporated (Fig 4).

As a result, BT-1, BT-2, BT-3 and BT-5 thermal waters can be classified as deep circulating waters as their tritium contents are close to zero.

In the oxygen-18/elevation graph, it can be seen that BT-1, BT-2, BT-3 and BT-5 geothermal springs, which are located at the same area, are recharged from heights of 950-1,150 m above sea level (Fig. 5). These heights correspond to granitoids and gypsum covered hills that extend in the E-W direction to the south of Dikmen. These areas where granitoids are partially covered by the gypseous Kirmir Formation are used to explain the hydrochemistry of the BT-1, BT-2, BT-3 and BT-5 springs.

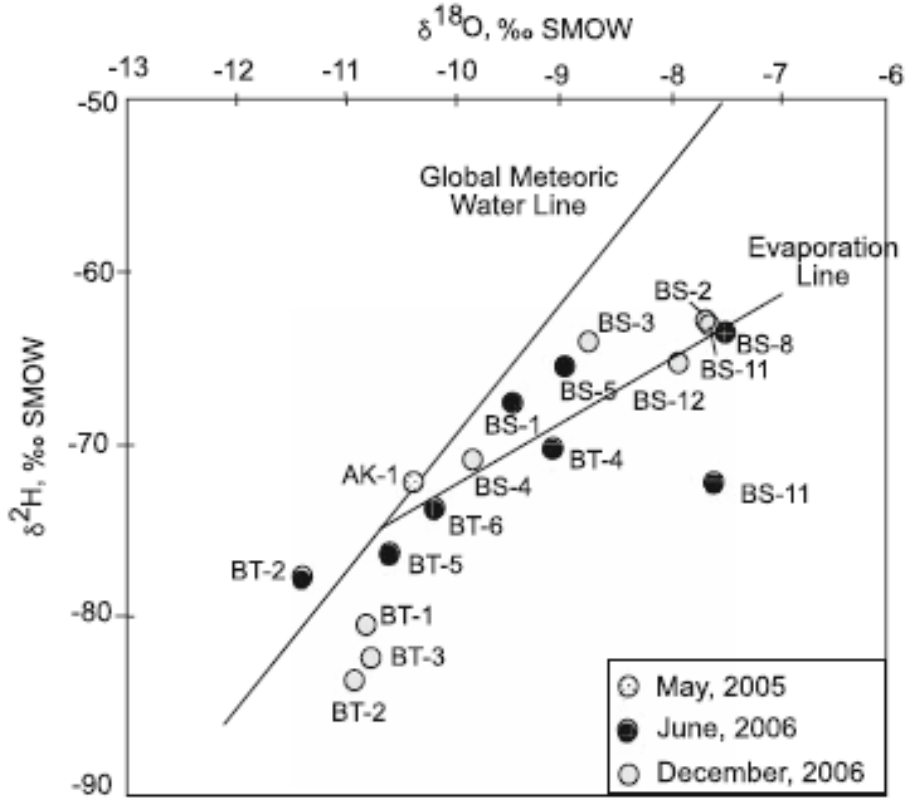

Fig 4 : Oxygen-18 ($d^{18}O$)–deuterium ($d^{2}H$) diagram of the waters in the study area

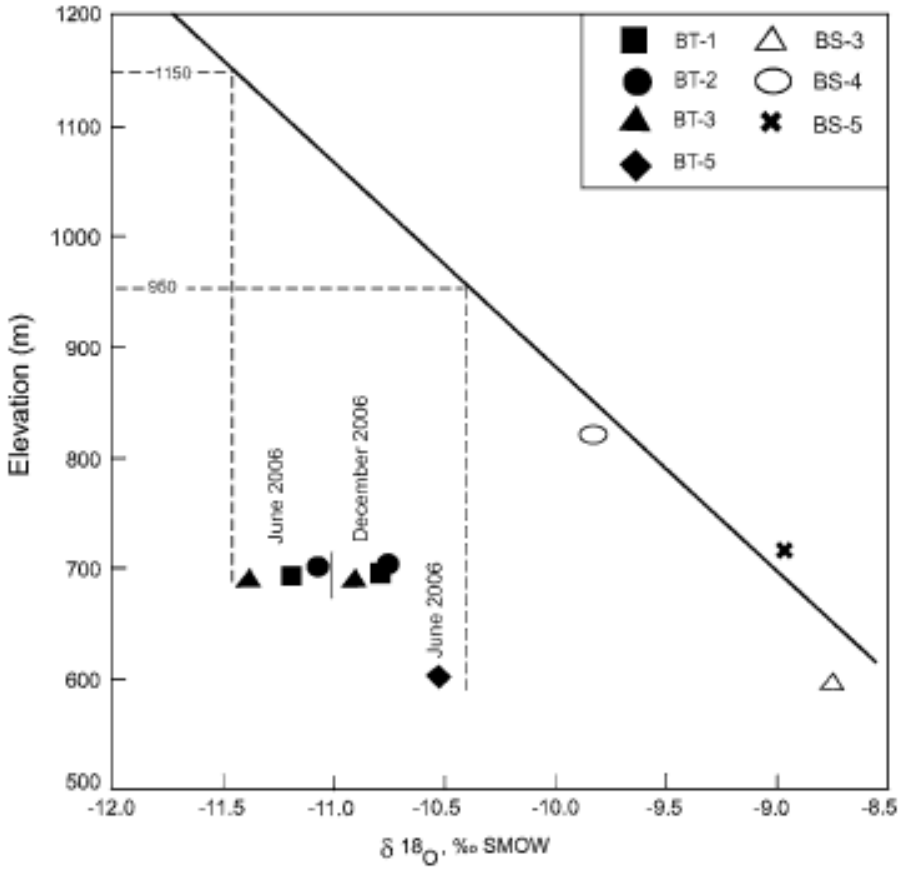

Fig 5: Oxygen-18 (d18O)-temperature diagram of the waters in the study area

6. SULFUR ISOTOPE STUDIES

In order to explain the origin of sulfate in waters and the formation mechanism of geothermal springs, sulfur isotope studies have been carried out in the study area.

Analyses carried out on 5 samples from thermal springs, 2 samples from cold springs, and 1 sample from Sakarya River. Gypsum mineral results were obtained from Orti et al. (2002), Palmer et al. (2004) and this study.

The isotopic composition suggests that BS-3 and BS-5 springs come from the Incedoruk and Kirmir Formations respectively, are within the same range of gypsum minerals. Therefore, the sources of sulfur in the sulfate of these waters are derived from gypsum units of the Incedoruk and Kirmir Formations (Fig. 6 and 7).

As a result of this study, BT-1, BT-2, BT-3 thermal and BS-3, BS-5 cold springs seem to be affected and related with the gypsums of Kirmir formations in the area. These waters are dominated by a sulfate-water system. On the other hand, Karakoca mineral water (BT-6) is seemed to be not affected from gypsums The BT-6 sample is close to the sulfate which has an atmospheric origin (Fig. 10). It is probable that sulfate in the Kapullu bath spring (BT-5) is derived from oxidation of pyrite in granites and, bacterial reduction may also take place due to organic activity in the Sakarya River water. On the other hand sulfate in the Sakarya River water is believed to originate from bacterial reduction and has an atmospheric origin.

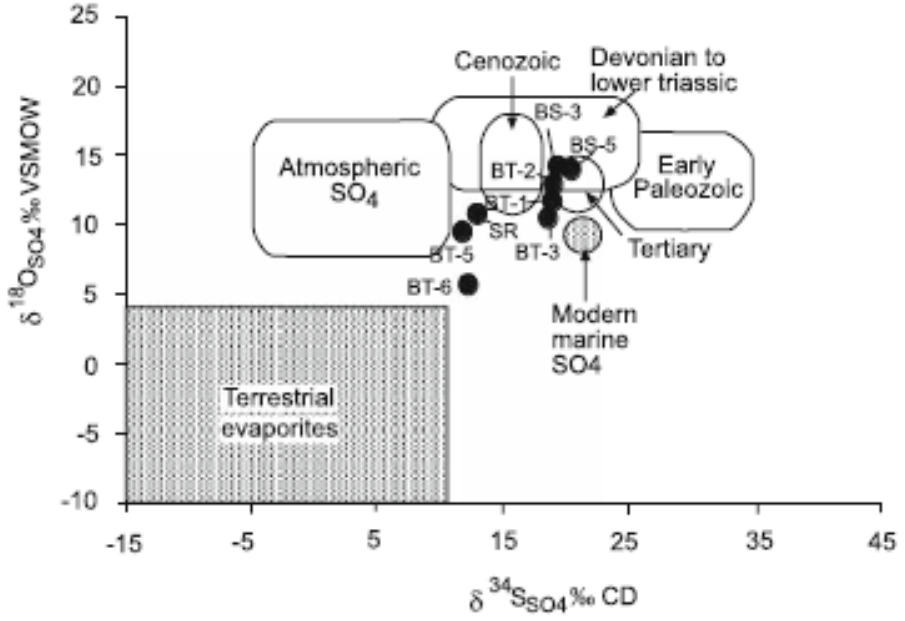

Fig 6 : Sulfur-34 (CD)–oxygen-18 diagram of the waters (Clark and Fritz 1997)

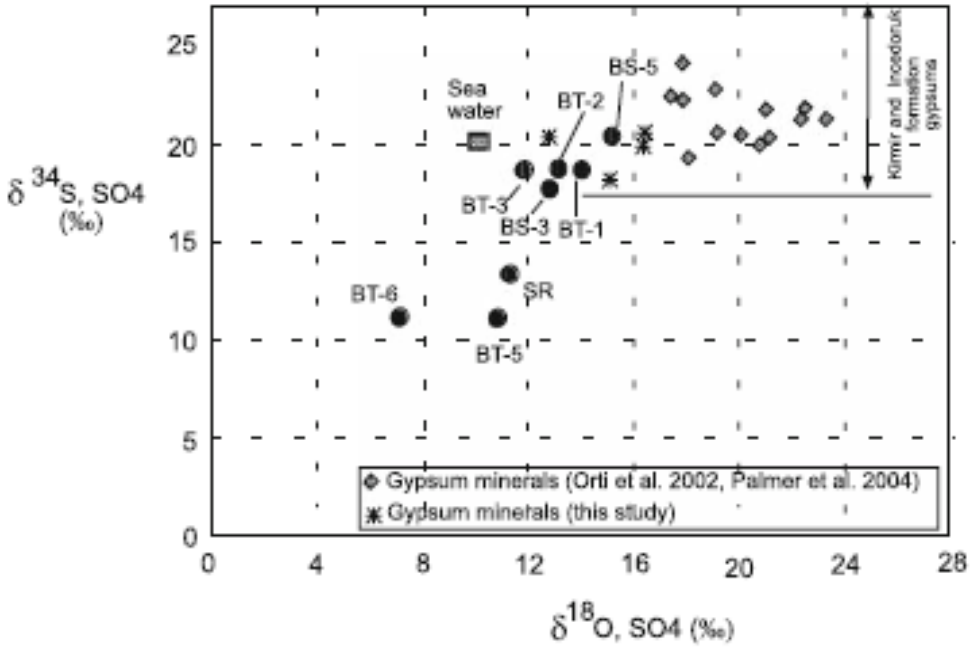

Fig 7: Oxygen-18 (SO4)–sulfur-34 (SO4) diagram

7. CONCLUSIONS

Discontinuities in the area is very important for thermal springs in the area. At this region many discontinuity planes have related with granitoids. These discontinuities are generally normal faults, which lead to the formation of thermal springs. Analyses and studies suggests that origin of sulfates in the cold and thermal waters is related with the Incedoruk and Kirmir formations that contains gypsum minerals.

Hydrochemical analysis results suggest 4 different water types: Facies-I: Bicarbonate dominant waters Facies-II: sulfate dominant cold brine waters, Facies-III: sodium-bicarbonate dominant thermal waters Facies-IV: sulfate-chloride dominant thermal and mineralized waters

Isotopic analysis indicate that the thermal springs (BT-1, BT-2, BT-3 and BT-5) are of meteoric origin and receive recharge from precipitation in the Beypazarı granitoids and around gypseous formations with elevations of about 950-1,150 m. BT-7 spring is believed to be within the same hydrogeological system. AK1 and BT-4 thermal waters are recharged from the Bilecik limestone hills to the south of Ayaş region, and related with Incedoruk formation and Tekke volcanics. On the other hand BT-6 thermal water is recharged from out of the study area.

According to sulfur isotope studies, sulfate in the waters is largely derived and related from a primary source which is gypsum in the Kirmir Formation rather than sulfide oxidation. Sulfate of BS-3 and BS-5 springs is derived from gypsum in the Kirmir Formation and Sakarya River water sulfate probably originates from atmospheric and terrestrial sources.

BT-5 and BT-6 have different characteristics compared to the other thermal springs. It is thought that sulfate in sample BT-5 is originated from bacterial reduction/pyrite oxidation processes.

ACKNOWLEDGEMENT

This study was financially supported by TUBITAK under grand no. 104Y056 and 108Y108, and Scientific Research Projects Unit of the Ankara University under grand no. 2005-07-45-027.

REFERENCES

Açıkgöz S, Akıllı H, Kurtulus O, Kükük M, Hökelekli E, Taskıran L, Serifoğlu B I, Yıldırım G: Investigation report of Çobanhamamı-Çağa-Güdül (Ankara) geothermal field, MTA Report, Ankara (in Turkish) (2007).

Albu M, Banks D, Nash H.: Mineral and thermal groundwater 405 resources. Chapman & Hall, 447pp, London (1997).

Canik B. : Geology-hydrogeology investigation of the Ayaş resort and bath. Mineral Research and Exploration (MTA) Journal No.80, Ankara (in Turkish) (1973).

Clark I and Fritz P.: Environmental isotopes in hydrogeology. Lewis Publishers, 328pp. (1997).

Çağlar K Ö Mineral waters and baths of Turkey. Mineral Research and Exploration (MTA) Publications, Series B, No.11, Fascicle 1, Ankara (in Turkish) (1947).

Çelik M.: Evaluation of origin of the Ayaş-Beypazarı geothermal waters with sulfur isotopes, Central Anatolia, Turkey. International Symposium on Advances in Isotope Hydrology and Its Role in Sustainable Water Resources Management, (IHS-2007), 21-25 May 2007, Vienna-Austria (unpublished) (2007).

Çelmen O. : Hydrogeochemical and isotopic investigation of the thermal and mineralized springs between Sivrihisar and Beypazarı region (in Turkish). PhD Thesis, Ankara University, Graduate School of Natural and Applied Sciences, Ankara, 239 pp (2008).

Çetin A : Hydrogeologic investigation of Ayaş, Karakaya and Ilıcaköy thermal waters. Graduate School of Natural and Applied Sciences, MSc Thesis, Hacettepe University, Ankara (2006).

Diker S.: Hydrogeological investigation of the Kapullu bath 429 and around (Beypazarı). MSc Thesis, Ankara University, Graduate School of Natural and Applied Sciences, 147pp, Ankara (in Turkish) (2005).

Diker S, Çelik M, Kadıoğlu Y.K.:Formation and hydrogeological characteristics of the Kapullu bath spring (Beypazarı/Ankara). II. National Isotope Techniques Symposium on Hydrology. General Directorate State Hydraulic Works, 26-30 September 2005 Gümüldür-Đzmir, 195-208 (in Turkish) (2005).

Diker S, Çelik M, Kadıoğlu Y.K.: Fingerprints of the formation of geothermal springs on the granitoids: Beypazarı-Ankara, Turkey. Environmental Geology, 51(3): 365-376 (2006).

Helvacı C and Bozkurt S: Geology, mineralogy and petrogenesis of the Beypazarı (Ankara) granitoide. Turkish Geological Bulletin, 37. 2, 31-42 (in Turkish) (1994).

Karadenizli L : Sedimentology of the Beypazarı plain (west 454 of Ankara) Late Miocene-Pliocene gypsum series. Turkish Geological Bulletin, 38. 1, 63-74 (in Turkish) (1995).

Mohr M : Geological and hydrogeological field studies of the Beypazarı region report. Mineral Research and Exploration report no. 2554, 28pp, Ankara (in Turkish) (1956).

MTA (General Directorate of Mineral Research and Exploration) : 1/500.000 scale Zonguldak geological map, Ankara (in Turkish) (1963).

Orti F, Gündoğan Đ, Helvacı C : Sodium sulphate deposits of Neogene age: the Kirmir Formation, Beypazarı Basin, Turkey. Sedimentary Geology, Elsevier, 146, 305-333 (2002).

Özbek T.: Hydrogeological investigation of the Ankara-Beypazarı Dutlu bath around. PhD Thesis, Ankara University, Graduate School of Natural and Applied Sciences 150pp, Ankara (in Turkish) (1984).

Palmer M R, Helvacı C, Fallick A.E: Sulphur, sulphate oxygen and strontium isotope composition of Cenozoic Turkish evaporites. Chemical Geology, Elsevier, 209, 341-356 (2004).

Şahinci A.: Geology-hydrogeology investigation of the Karakaya (Ayaş), Ilıcaköy around. MTA Report No. 4367, 60pp, Ankara (in Turkish) (1970).