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

Hydrogeological Investigation of the Çavundur-Çerkeş Geothermal Field, North-West Turkey

Mehmet Çelik, Oktay Çelmen, Gürhan Rahmi Koçbay

Ankara University, Engineering Faculty, Geological Eng., Dept., Tandoğan 06100, Ankara

celikm@eng.ankara.edu.tr

Keywords: Çavundur-Çerkeş geothermal field, thermal and mineral water, isotope, hydrochemistry, shallow and deep cycled waters

ABSTRACT

The study area is located at Ulusu Fault which is parallel to and some 15 km south of the North Anatolian Fault.

The reservoir rock is the limestone of Dumlupınar Formation of Jurassic-Cretaceous age, constituting the base of the stratigraphic sequence as well. Basalt, agglomerate and tuffs of Miocene age are widely exposed and of low permeability. Marl of Miocene age is a confining unit with very low permeability. This level is overlain by conglomerate, sandstone and mudstone of permeable rocks recharging from the recent ground water.

The groundwater in the study area is divided into two subclasses of shallow and deep cycled. Waters of shallow cycled consist predominantly of Ca^{2+} and HCO_3^-, whereas the waters of deep cycled are Na^+ and HCO_3^- rich waters. Waters of deep cycled emerges usually around Ulusu fault zone. Amongst these hot springs, the Çavundur spa has a discharge rate of 47 l/s and 54^{o}C exit temperature which is utilised as balneological purposes. In the same area, there exist a cold spring with mineral water and a low discharge rate. Isotope analyses suggest that Çavundur spa waters has the interaction of water-rock, whereas the springs of Ulupınar-Balıklıgöl and Kösehamamı are deep cycled and of meteoric origin. The source of heat for the termal and mineral waters is the geothermic gradient as well as volcanic activities. Upon the silica geothermometers, it was predicted that the highest temperature for the Çavundur reservoir is about 92^{o}C.

Physicochemical parameters, pH, EC, and T, were analysed insitu by Hanna instrument. All of the other hydrochemical parameters were analysed in Water Quality Laboratories of Ankara Metropolitan Municipality. Deuterium, oxygen-18 and tritium analyses were done by isotopic laboratories of General Directorate of State Hydraulic Works.

1. INTRODUCTION

The study area is located at the northwest of Turkey in the Çerkeş basin around the Çerkeş and Atkaracalar. The basin which is located at 10 km south of North Anatolian Fault (NAF) and lays parallel to the fault (Figure 1). It increased the importance of investigation through the existance of hot and mineralised water springs as the investigation area is at the circle of the NAF which produces high-magnitude-earthquakes in Turkey. In the investigation area, through the Ulusu fault, there are also young springs that discharged groundwater together with Çavundur spa and Kösehamamı hot and mineralised water springs.

Uluçay and Çerkeş rivers are the most important surface waters of the region. Aim of the study is to (1) determine the origin and facies of deep-circulated geothermal waters and shallow-circulated young groundwaters that are formed parallel to the NAF (2) to find out the relation of the water springs with faults and also geothermal water usage areas and reservoir temperature. With this purpose, a hydrogeological map of the region is made, units are parted according to their permeability features. Young and old springs which have precipitated travertines are interpreted while spotting the travertine at the old and new springs on the map. So far, three surveys are conducted on hydrogeological study in the region by Koçak (1974), Çelmen (2002) and Koçbay (2003).

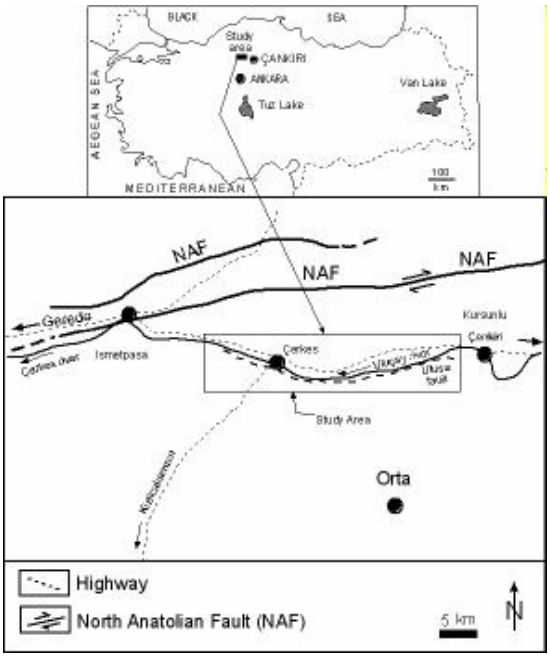

Figure 1. Location maps

2. GEOLOGICAL SETTING

Dumlupınar limestones which are the aquifer of Çavundur hot water springs are outcrope in the west of the region (Figure 2). It is divided into two as unit, clayey limestone and siliceous limestone. Clayey limestone is sequenced as limestone-marl in the west of Bayındır village, and the unit of siliceous limestone is outcrop nearby Ilıca village. In addition to the units, mostly basalt and agglomerate are outcrop. Sivricek Formation is observed at the south of the study area. In the region, volcanism has developed in three phases and lasted until the end of Pliocene age (Barka, 1984).

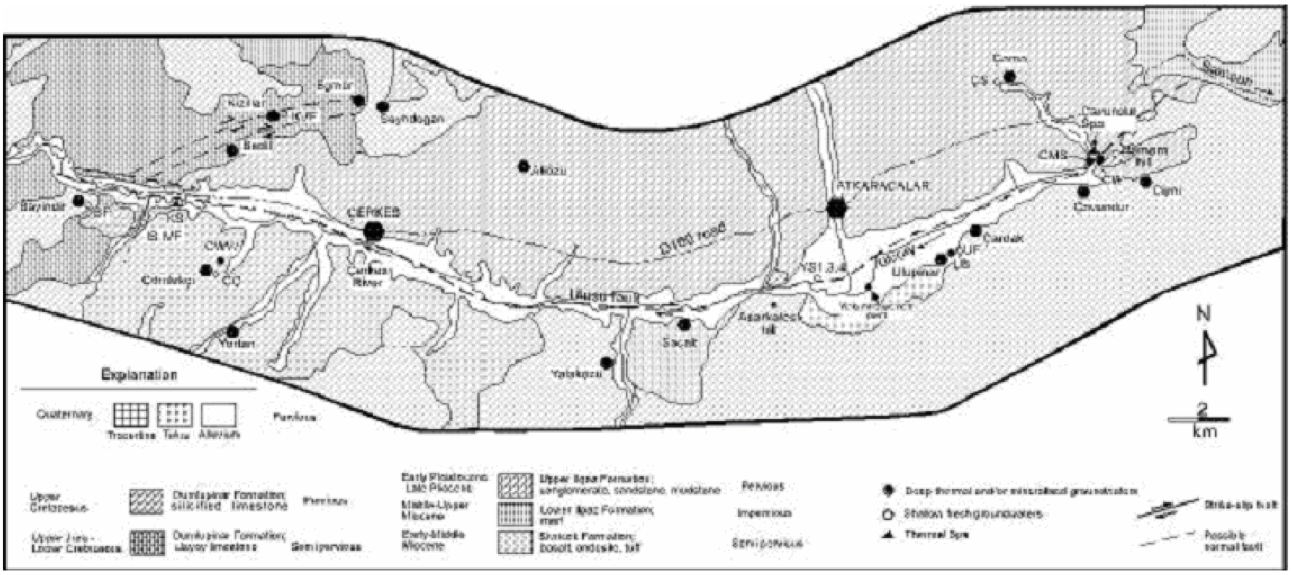

Figure 2. Hydrogeological map

In the investigation area, basalt hills are observed on Upper Ilgaz Formation in Hamam Hill and age of this unit is early-middle Miocene. Ilgaz Formation is scattered especially on the north of the region widely. This formation is divided into two categories according to its lithological features as Upper Ilgaz and Lower Ilgaz Formations. Lower Ilgaz Formation is composed of lacustrine stream units and is represented by limestone and marl. According to Barka (1984) the age of the formation is Tortonien age. Upper Ilgaz Formation is dispersed widely especially at the north part of the investigation area. Its lithological characteristic and geological location lead to a wide and shallow relief topographic scene to the area.

The Formation is composed of mudstone, limestone, conglomerate and sandstones that are precipitated at stream and shallow lake-like facies. Age of the formation is Pliocene-early Pleistocene ages. Alluvium, tallus and travertine units are formed the youngest formations of the region. Travertine deposits, observed at Kösehamam spring, Ilıca spring, and Çavundur hot water spring location surroundings widely (Figure 2). Alluvium units are outcrop at Çerkeş and Ulusu river banks.

3. HYDROGEOLOGICAL SETTING

By taking the advantages of the units such as lithological and structural features, water spring yields, fissure and cracks, wells etc. Present units are distinguished as impermeable, permeable and semi-permeable, and mapped (Figure 2). Mesozoic age of Dumlupınar Formation limestones are outcrop in the west of the investigation area widely. A well conducted near Çavundur spa, and limestone is drilled at the 250th meter deep in 1987 by MTA (Uzel and Didik, 1988). It is stated that the limestones are Dumlupınar Formation units and have karstic aquifer properties (Şimşek, 1990). About 20 meter limestone has been penetrated in this well and then there has been no progress at all. Çavundur well is artesian well and have 54^{o}C temperature and 47 l/s yield of hot water.

In the same area (approximately 200 m^2) there are also low yielding Çavundur spa and Çavundur mineralized water spring. At the old discharge area of the spa, a travertine hill as approximately 100 meter long, 50 meter wide and 10 meter high is observed. Çavundur springs come to the surface as long as Ulusu fault. Basalts that comprise of Sivricek Formation have cracked and blocked structure while being permeable. Being layered, agglomerate, tuff and tuffite have to be sequenced by basalt. Having fine particles of tuffs resulted in the diminish of permeability of these units. By taking Sivricek Formation thoroughly, the formation is called as half-permeable.

There have been hot and cold water springs that are recharged by Sivricek Formation. While Çardak fountain is a cold water spring, Ulupınar Balıklıgöl is a hot water spring. Ulupınar Balıklıgöl spring is at 20.5^{o}C temperature and has 15.3 l/s spring yield. Discharging points of this spring is on the base of Balıklıgöl. Lower Ilgaz Formation is represented by marl and clayey limestones. Marls are thick layered and massive, while clayey limestones are thin layered. Due to its lithological properties and geological location, Lower Ilgaz Formation acts as aquiclude below Upper Ilgaz Formation and as confining layer above Mesozoic limestone units. The units of limestone and sandstone of Upper Ilgaz Formation are rather permeable. Loosely mudstone layers are permeable and clayey levels of the units are impermeable. This formation is thought to be permeable horizontally and has feeds Çama and Yoğsan springs. Yields of Yoğsan springs (YS1, YS2, YS3 and YS4) differ from 0.5 to 2.1 l/s while Çama springs' yield are 7.031 l/s.

Alluvium units lay as long as Uluçay and Çerkeş river banks, consists of clay, sand and gravel. It is estimated that recharge of the springs are provided by Upper Ilgaz conglomerate and sandstone permeable levels. Kösehamam spring located in the west of the investigation area, originates from Ulusu fault and recharged by clayey limestones of Dumlupınar Formation. Kösehamam spring group discharge from 5 points through the Ulusu fault. Travertines which are formed parallel to the spring of Kösehamam are thought to represent the former discharge points of Kösehamam spring. It is estimated that piezometric level of geothermal reservoir has been decreased approximately 20 m, until to the nowadays. At the same time, it is estimated that the flow rate of the thermal springs are also waned highly in Kösehamam spring area. Ilıca spring is formed on a secondary fault that

intersects Ulusu fault. It is estimated that having approximately 50 l/s of flow rate, it has also feed by fault zones of the study area.

3.1 Hydrochemical Studies

In the investigation area, there are lots of thermal and cold water springs. At this points, pH, EC and T parameters of springs measured in-situ. Apart from that, full hydrochemical analyses carried out for 9 choosen water samples. Water analyses with an ion-balance error less than 5% were identified. The analysed parameters are of Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, Cl^{-}, SO_4^{-2}, HCO_3^{-}. The chemical analyses of water samples were carried out in water quality laboratories of Ankara Metropolitan Municipality.

3.1.1 Results and Interpretation

Groundwaters are classified as, shallow and deep cycled waters in the study area. Deep cycled waters (mineralised, thermal and mineralised and thermal) show three different properties. According to Piper (1944) diagram, classification of groundwaters are shallow cycled cold waters, deep cycled cold waters and deep cycled geothermal waters.

Shallow cycled waters are of Ca and HCO_3^{-}, deep cycled cold and thermal waters are of Na^{+} and HCO_3^{-} (Figs. 3 and 4). Generally, cold groundwaters moderately mineralised (230-756 µS/cm at 25°C), thermal groundwaters highly mineralised (380-10840 µS/cm at 25°C). Hydrochemical results are shown in Table 1. Ulupınar Balıklıgöl spring which is deep cycled thermal waters are of 380 µS/cm, deep cycled cold water Çömlekci water well 1750 µS/cm, Çavundur mineralised water, 7710 µS/cm and Çavundur well are of 10840 µS/cm. Uluçay and Çerkeş river waters are of 680 and 1011 µS/cm, respectively.

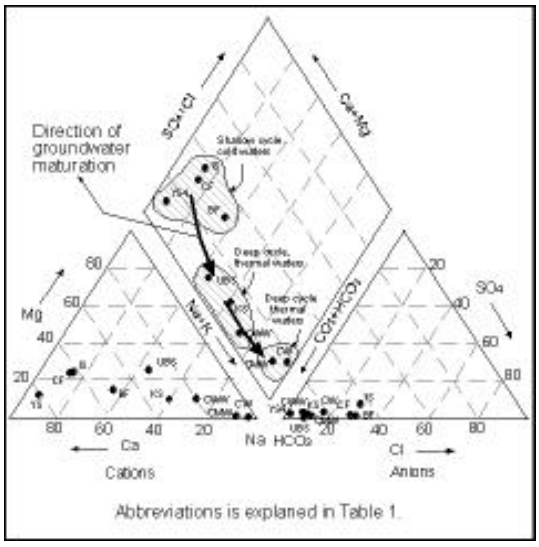

Figure 3. Piper diagram

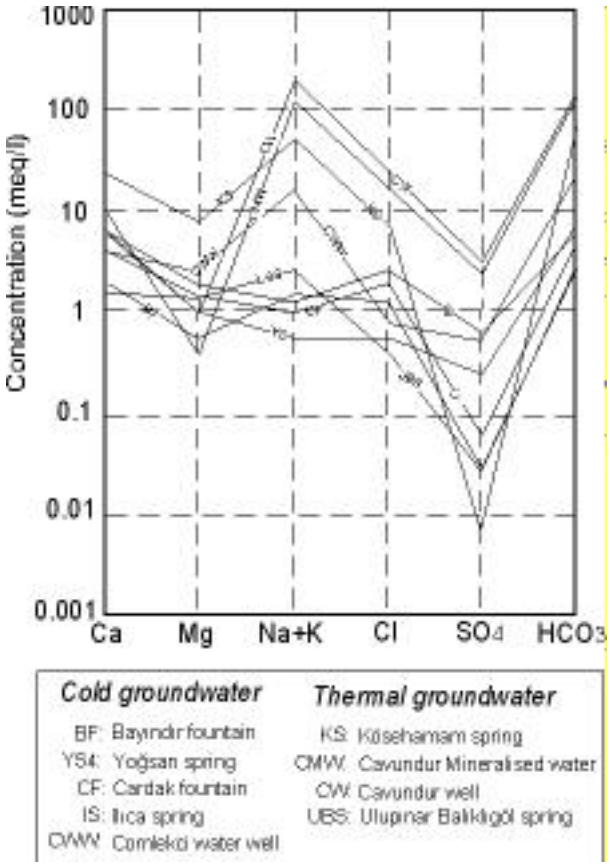

Figure 4. Schoeller diagram

3.2 Isotopic Studies

According to isotopic features of the groundwaters in the investigation area, most of them points are on the Global Meteoric Water Line (Figure 5). Çömlekci water well (CWW), Kösehamam spring (KS) and Ulupınar Balıklıgöl spring (UBS) waters are observed as low oxygen-18 and deuterium values to be claimed in two periods (dry and wet seasons) and interpretated as deep cycled waters by these isotopic values.

Yoğsan springs (YS1, YS3 and YS4) and Çardak fountain (CF) waters are shallow cycled modern waters and have higher isotopic composition than the other meteoric origin waters. Çavundur waters (CW and CMW) indicate oxygen–18 enrichment (exchange with rock minerals). While Çavundur well waters indicate same feature in the dry and wet seasons, Çavundur mineralised waters indicate different properties on oxygen-18/deuterium graph (Figure 5). It is thought that Çavundur mineralised spring has been diluated from modern waters as raising to the ground surface in wet seasons.

Çavundur well have not affected by seasonal differencies. This property indicates that, this waters to be deep cycled and not to be mixed with modern groundwaters while come off from well to the surface.

Average values of oxygen-18 and deuterium of deep cycled waters (CMS, CW, KS and CWW) are –11.35 and –88.8, respectively. Tritium values are differ from 8.55 to 1.85 Tritium Unit. Avarage oxygen –18 values of shallow cycled waters are of –11.04 and deuterium value of –77.55. Tritium values of Yoğsan springs are of 16.55 Tritium Unit averagely (Table 2). According to tritium contents, Yoğsan springs considered as modern waters.

In addition to this, Cavundur mineralised waters, Çavundur well and Ulupınar Balıklıgöl waters are of predicted to recharging about in 40 years of period (Table 2).

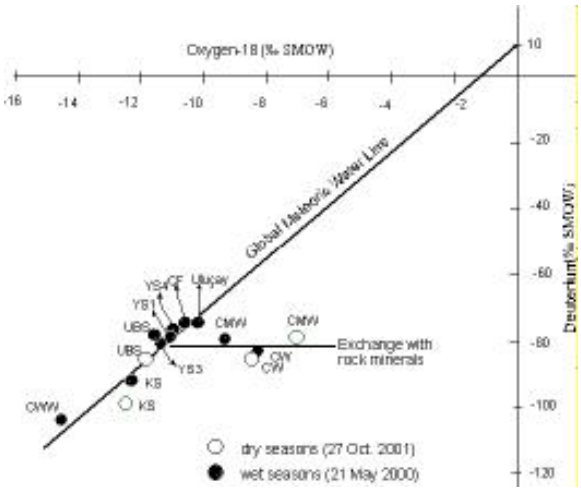

Figure 5. Oxygen-18/deuterium graph

4. CONCLUSIONS

Dumlupınar Formation that outcrop at west of the Çavundur-Çerkeş geothermal area, have an important role of the origin of the thermal and mineralised waters. While clayey limestones of the formation are impermeable, silicified limestones are permeable. This formation missioned as hydrothermal conduit for geothermal springs because of to be sheared with Ulusu Fault and other secondary fault zones.

Volcanic units of the Sivricek Formation are semi-permeable and marls of Lower Ilgaz Formation ise impermeable. Marls have confined layer properties for geothermal system. However, this cap rock has been penetrated by Ulusu Fault. Upper Ilgaz Formation units constitutes are permeable zones that shallow aquifer and recharge young groundwater springs in the area.

Ulusu fault lays parallel to the North Anatolian Fault. Old travertine units lay parallel to the Ulusu Fault around Kösehamamı. Nowadays, there is no spring existance observed around this old travertine points, but some springs observed around Ulusu fault that passes through Çerkeş river. Earthquakes that related with North Anatolian Fault predicted to effect activities of the geothermal springs. In other words, deep cycled geothermal springs to be formed by Ulusu Fault and cold water springs to be formed by independent from Ulusu fault. Ulusu fault zone missioned as hydrothermal conduit for geothermal springs. Geothermal springs are deep cycled, Kösehamam spring (KS), Çavundur mineralised water (CMW) and Çavundur well (CW) waters are of Na^+ and HCO_3^-, Ulupınar Balıklıgöl spring (UBS) waters are of Ca^{+2}, Na^+ and HCO_3^-. Cold Çomlekci water well (CWW) is also deep cycled and are of Na^+ and HCO_3^-. CWW has a high recharging altitude and KS and UBS come after that respectively. An oxygen-18 enrichment has been observed in CW and CMW geothermal waters. With exchange of rock minerals, a variations occur with rock minerals. According to isotopic results, no seasonal distinctions observed in CW, but in wet season $\delta^{18}O$ dilution observed in CMW and enrichment observed in dry season. It is thought that this results proves mixing of young groundwaters.

Due to temperature logs around Çavundur spring, geothermal gradient of the area is calculated as average 80^oC/km. Geothermal gradient is higher than global averages (33^oC/km) in the study area. Reservoir temperature was calculated as 92^oC according to silica geothermometer applications.

In order to obtain more knowledge about probable buried faults and the tectonic structure, more detailed hydrogeological and geophysical study may be carried out in the area.

ACKNOWLEDGMENT

This paper is a final product of a project (no:20010705054) funded by the Scientific Research Projects Fund of Ankara University.

REFERENCES

Barka, A.: Kuzey Anadolu Fay zonundaki bazı Neojen – Kuvaterner havzalarının jeolojisi ve tektonik evrimi, *Ketin Sempozyumu, T.J.K. 38. Bilimsel Teknik Kurultayı*, T.J.K. yayını 209-227, Ankara (1984) (in Turkish).

Çelmen, O.: Çavundur kaplıcası ve dolayının (Çankırı-Kurşunlu) hidrojeoloji incelemesi, *A. Ü. Fen Bilimleri Enstitüsü*, Yüksek Lisans Tezi, Ankara (2002) (in Turkish).

Koçak, A.: Çavundur (Kurşunlu-Çankırı) kaplıca bölgesinin hidrojeolojik etüdü raporu, *MTA Derleme* Rap. No: 6373 (1974) (in Turkish).

Koçbay, G.R.: Kösehamamı kaplıcası ve dolayının (Çankırı-Çerkeş) hidrojeoloji incelemesi, *A. Ü. Fen Bilimleri Enstitüsü*, Yüksek Lisans Tezi, Ankara (2003) (in Turkish).

Piper, A.M.: A graphic procedure in the geochemical interpretation of water analyses, *Trans.Amer. Geophys. Union*, 25 pp., 914-923, 1944.

Şimşek, Ş.: Karstic hot water aquifers in Turkey, Processes in Karst Terranes, *Proceedings* of the Antalya Symposium and Field Seminar; October (1990).

Uzel, Ö. F. and Didik, S.: Çankırı-Kurşunlu-Çavundur (Ç1) sıcak su sondajı kuyu bitirme raporu, MTA Derleme Rapor No. 8398, (1988) (in Turkish).

Table 1. Chemical analyses results of waters in the study area

Observation Points	pH	T °C	Electrical conductivity (µS)	Na^+ (mg/l)	K^+ (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	HCO_3^- (mg/l)
CMS	6.07	14.6	7710	2040.00	135.00	139.00	3.16	483.10	78.18	4660.00
CW	7.72	54.0	10840	3050.00	205.00	36.32	7.58	691.10	110.00	6366.00
KS	6.21	26.8	4340	772.00	110.00	340.00	69.25	187.60	<0.20	2940.00
CWW	8.30	19.0	1753	270.00	30.00	61.20	21.14	20.50	18.18	988.00
UBS	6.77	20.5	380	38.90	6.20	22.70	11.50	10.50	0.91	215.00
YS4	6.94	11.0	510	8.40	0.90	92.32	8.60	13.77	6.90	305.00
BF	7.30	12.7	230	22.30	3.80	27.92	4.66	31.70	1.09	124.00
IS	8.78	14.6	678	18.90	2.90	76.48	17.01	68.90	21.00	264.00
CF	7.55	14.2	406	14.90	1.20	38.80	13.00	49.40	1.90	207.00
YS1	Na	11.7	495	Na	Na	Na	Na	Na	Na	Na
YS3	Na	11.8	528	“	“	“	“	“	“	“
Uluçay river	7.75	15.5	680	“	“	“	“	“	“	“
CVF	9.04	12.1	756	“	“	“	“	“	“	“
IVF	8.78	14.6	678	“	“	“	“	“	“	“
KVF	8.90	12.1	450	“	“	“	“	“	“	“
Çerkeş river	9.32	5.0	1011	“	“	“	“	“	“	“

CMS:Çavundur mineralised spring, CW:Çavundur well, KS:Kösehamamı spring, CWW:Çömlekçi water well, UBS:Ulupınar Balıklıgöl spring, YS4: Yoğsan spring-IV, BF: Bayındır fountain, IS: Ilıca spring, CF:Cardak fountain, YS1:Yoğsan spring-1, YS3: Yoğsan spring-3, CVF: Çömlekci village fountain, IVF: Ilıca village fountain, KVF: Kızıllar village fountain

Table 2. Isotopic analyses results of waters in the study area

Sample No.	Oxygen-18 (‰ SMOW)	Deuterium (‰ SMOW)	Tritium (T.U)	Sampling date
CMS	-9.82	-79.42	8.55+1.30	21 May 2000
CW	-8.28	-83.63	2.85+1.30	“
CF	-10.63	-74.60	Na	“
UBS	-11.59	-78.35	1.85+1.30	“
YS1	-11.10	-78.22	Na	“
YS3	-11.38	-80.32	15.50+1.35	“
YS4	-11.05	-77.07	17.60+1.45	“
Uluçay river	-10.35	-74.85	Na	“
KS	-12.52	-98.67	Na	21 Oct. 2001
CWW	-14.55	-103.93	Na	“
Çerkeş river	-11.85	-85.28	Na	“