HYDROGEOLOGICAL AND GEOTHERMAL FEATURES OF THE RESADIYE (TOKAT) SPA AND ITS ENVIRONS.

S. PASVANOGLU[1] & B. CANIK[2]

[1]Faculty of Engineering, University of Kocaeli, 'Izmit, Turkey
[2]Faculty of Science, University of Ankara, Ankara, Turkey

SUMMARY: Thermal and mineral waters of the Resadiye spring were studied in terms of origin, source characteristics and physico-chemical features. Two boreholes are proposed to increase production. Late Jurassic-Early Cretaceous age Zinav limestone is fractured and contains vuggy porosity and likely acts as an aquifer for thermal water. The overlying marly units of the Nebiseyh and Kapakli Formations act as seal. Thermal water emanates from a N25W-N65W fracture which is located within the North Anatolian Fault Zone. Temperatures are between 38° and 49° C and the discharge rate is 3 l/s. These hot waters are meteoric waters that have been warmed up due to the geothermal gradient. Total dissolved solid solids range fi-om 3563 to 5990 mg/l. To protect these springs three separate reserves have been proposed.

1. INTRODUCTION

The study area lies within the Tokat-Resadiye town boundaries and encompass 2 km^2. Resadiye spa is immediately west of Resadiye town (Figure 1). The town was established within the Kelkit Valley. The North Anatolian Fault Zone (NAFZ) passes through the Kelkit Valley and has prime importance for our study. The hot waters of the Resadiye discharge from the branches of the NAFZ in this area. In this study, thermal waters–. from **the** Resadiye spring were studied in terms of origin, source characteristics and physico-chemical features. Two boreholes are proposed for increasing production (Figures 1 and **2).**

2. GEOLOGY

The Mesozoic and Cenozoic age sedimentary sequence is shown in Figures 1 and 2. Formation names and ages are from Seymen (1975) and Kocak and Erzenoglu (1987).

2.1 Zinav Limestone

This unit crops out on the western bank of the Kelkit River. The unit is 150-200 m thick. The unit is laminated, brecciated, and fractured-filled with calcite and silica. Whitish micritic, biomicritic, sparitic and detritic limestone makes up the unit. The lower boundary is not exposed while the upper boundary forms an unconformable contact with the Nebiseyh formation. The Zinav Limestone unit is Upper Jurassic-Lower Cretaceous in age.

2.2 Nebiseyh Formation

This unit also crops out on the western bank of the Kelkit River. This formation is 150-200 m thick, fractured, and is made of clayey limestone and marl interlayered with tuffaceous beds. The upper boundary is conformable with the overlying Kapakl Formation. The occurrence of Globotruncana fossils indicates an age of Turonian to Eariy Campanian.

2.3 Kapakli Formation

This unit is widespread in the study area and is 200 to 1000 m thick. Pelagic facies contain lava and pyroclastic layers. Within this unit, andesitic volcanic rocks are reported. Common occurrences of bentonite seem to be alteration products of these volcanic rocks. The age of this formation is Early Maastrichtian.

2.4 Yolustu Formation: This is made up of lavas from numerous eruption centres which has blanketed most of the area. The composition of the lava is basalt. The age is Late Miocene-Early Pliocene.

2.5 Old Aluvium: This unit is observed to the east of Resadiye town and is about 100 m thick. Gravel, sand, and silt deposits of the Kelkit Creek make up this unit. Its age is Plio-Quaternary.

2.6 Travertine: Along the Kelkit Valley and elsewhere along the NAFZ, travertine deposits exist. The largest of these **is** the Cermik travertine deposit, which is associated with modem spring activity. The age of these deposits extends back to the Quaternary, and the maximum thickness is 50-60 m.

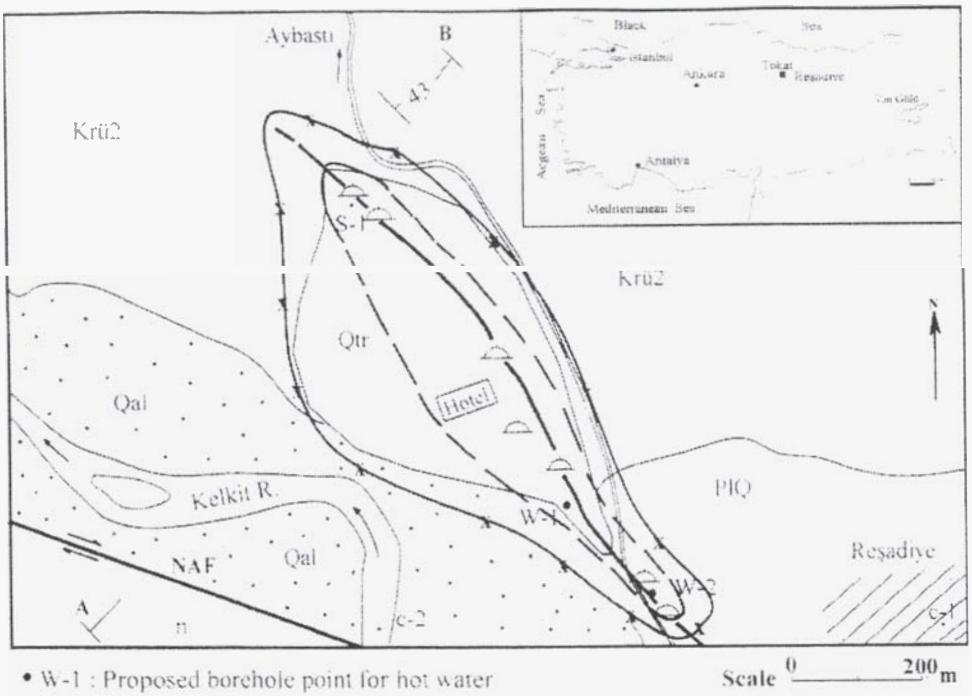

Figure.1- Geological map and conservation area of the Reşadiye Spa and adjacent areas.

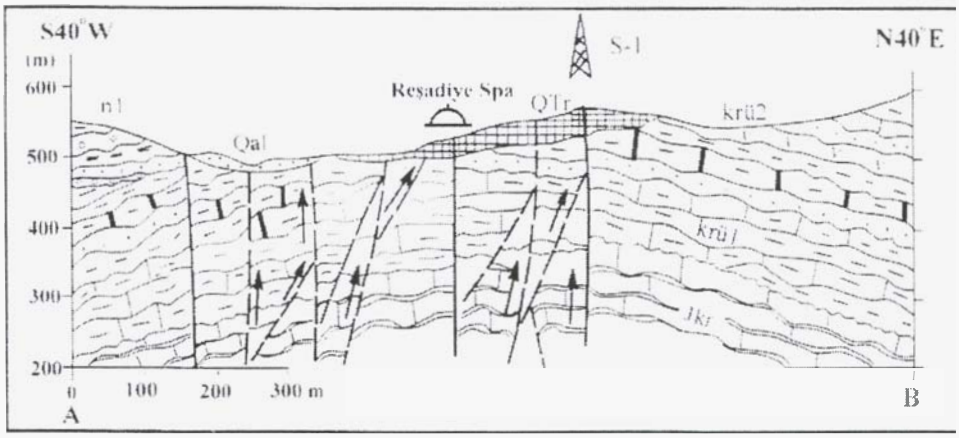

Figure.2- Geological cross section of the Reşadiye Spa area

EXPLANATION

Travertine and alluvium (Qal) Plio-Quaternary

Alluvium (plQ)

Thick lava, tuff, Ammonites and Inoceramus biomicrit, pelagic marn, fragments of limestone and pyroclastic sandstone consecutive (kru2) Kapaklı formation

Nebişeyh formation (kru1) Mesozoic (Cretaceous)

Zinav formation (Jkl) Mesozoic (Jurassic)

Gravelstone, sandstone, mudstone (n1) Karşıkent formation

Conservation area of first degree

Conservation area of second degree

Strike and dip

Formation boundary

Fault (probable etc.)

Ground water flow direction

Spa

Line of cross section

Drilling localities (production well)

Sampling location

North Anatolian Fault (NAF)

3. HYDROGEOLOGICAL FEATURES OF THE ROCKS

The Zinav Limestone has abundant fractures and dissolution cavities. The pore space is filled with considerable volumes of water making it an important aquifer.

The Nebiseyh, Kapakli and Kirandag Formations are impermeable. The alluvium deposits of the Kelkit Valley may also host good aquifer.

4. THERMAL WATERS

A borehole named S-1 was opened by MTA (General Directorate of Mineral Research and Exploration) 450 m NW of the Resadiye Spa area for supply purposes. From the surface downward this hole intersect **30** m of travertine, **30-60** m of greenish flysch deposits (Kapakli Formation), 60-207 m of greenish gray clay-siltstone with interlayered limestone (Nebiseyh Formation) and 207-219 m gray-whitish Zinav Limestone. The borehole intersected a fault at 218.90 m. The discharge rate of permeable zone was **30** l/s. The temperature of the water ranges from **48"** to 50" C.

Thermal waters also emanate from the E-W NAFZ **(North** Anatolian Fault Zone) and also fiom a **N25W-N65W** fracture immediately west of the Resadiye town. The discharge of thermal waters has deposited a dome of travertine (0.5 km^2; Figure **3).** In places, these travertine deposits are translucent. Depending on the water flow, kidney stone-type morphologies occur.

At present, most of the thermal waters discharge fiom the lower levels of the travertine dome. Near the top of the deposit gas emanates. Travertine deposition blocks fluid paths causing the springs to migrate over time. Spring locations are also sensitive to seismic activity.

The springs discharge at a rate of 3 l/s, and the temperatures range between **38°** and 49°C. Total dissolved solids range fiom **3563** to 5990 mg/l. The waters are colourless and odourless but contain CO_2 gas. At the point of discharge, a deposit of iron oxide is visible. The water compositions are shown in Table 1. The dominant ions are Na and HCO_3. Na may be sourced **from** alteration of Na-plagioclase in subsurface volcanic rocks. Clay minerals also enhance exchange of Na with Ca. HCO_3 is a result of CO_2-rich water interaction with limestone. The source of Cl may be evaporite deposits.

Analyses are plotted on Schoeller diagrams (Figures **4** & **5).** The results show that the Resadiye spa water and the water from borehole S-1 are similar in origin. These waters are Na-Ca-HCO_3-Cl-As-B-CO_2 bearing (AIH, 1979).

Figure 3. **A** view of Resadiye thermal spring and travertine deposit.

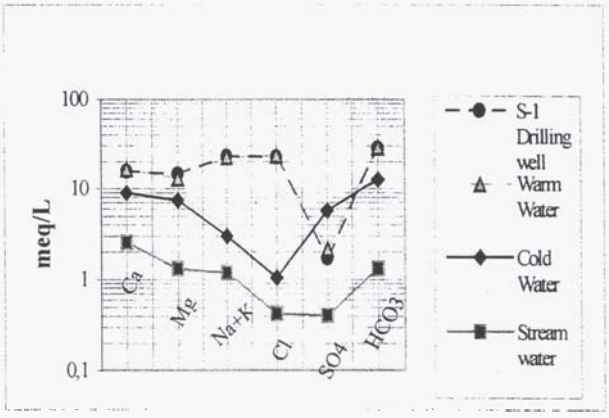

Figure **4:** Schoeller diagram **of** Resadiye geothermal waters.

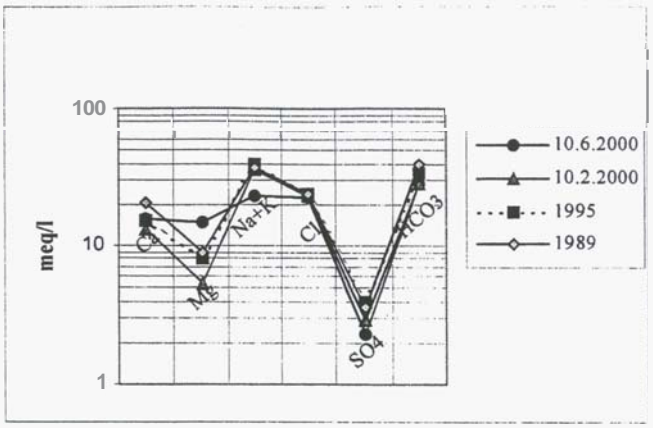

Figure 5: Schoeller diagram of S-1 well in Resadiye Geothermal field

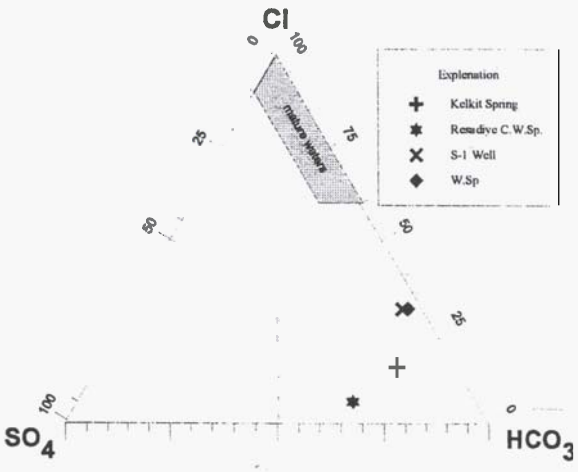

Figure 6: Plot of Cl-SO_4-HCO_3 diagram for the study area

From Cl- SO_4- HCO_3 triangular diagram (Figure 6) Resadiye thermal and mineralised waters and well S-1 are bicarbonate-rich waters. They are near neutral pH, low in chloride and the major cation is sodium. This area on the diagram represents peripheral water in many volcanic-related geothermal fields, where chloride water is the main deeply circulated water-type. However, the reservoir rocks in the Resadiye are composed of limestone. The water emerging from such a reservoir is naturally rich with calcium and bicarbonate ions (Table 1). Also these waters contains slightly high concentrations of sulphate, the source of which may be dissolution of sulfate-bearing minerals like gypsum. We conclude that the relative abundance of SO_4 and HCO_3 in the Resadiye Turkish geothermal water in relation to Cl, is a reflection of the sedimentary rocks in the area.

Based on Figure 7, all of the data plot in the area of immature waters, therefore solute geothermometry is not likely to yield meaningful equilibration temperatures. The only option is to use silica geothermometers. The results are given in Table 2. The estimated subsurface temperatures range from 51° to 94°C.

The thermal waters likely derive From conductive heating and the local geothermal gradient. The recharge probably comes from higher elevation to the north and south of the Resadiye. These waters percolate into the subsurface along fault and fracture zones, get heated and discharge at surface.

5. PRESERVATION OF THERMAL AND MINERALIZED WATER

Considering the geology and the hydrology of the area, three reserves encircling each other have been suggested for conservation of the Resadiye waters (Figure 1; Demirel, 1988).

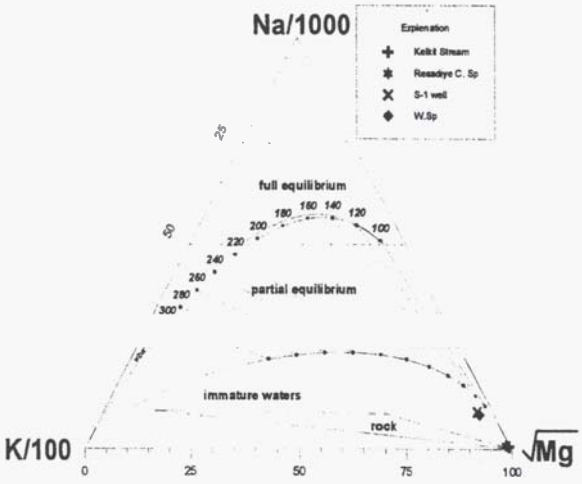

Figure 7: Plot of Na-K-Mg diagram for the waters in the study area

Table 2 Equilibration temperatures for 1995 samples from the study area

Geothermometer (°C)	S-1 well	Resadiye Thermal & mineralised water
$T_{measured}$	50	46
$T_{Qz\text{-}no\ st.loss}$	94	82
$T_{chalcedony}$	64	51

The primary area of conservation includes the fault line and the thermal springs. It also includes fractures, vents and travertine. It covers an area that is 15 by 80 m in size.

6. INCREASING THE PRODUCTION OF THERMAL WATER

Resadiye Spa greatly contributes to local economy of Resadiye. Thus to support the supply of increasing tourism, more thermal water must be secured, and this depends on the drilling of two new boreholes. Based on field study two locations are suggested.

Resadiye Municipality initiated a geothermal heating project in 1992. This project includes supply of water to 1000 new homes. Together with S-1 borehole, these two boreholes should be sufficient. Used hot water must be re-injected to subsurface at injection wells, which need to be drilled.

7. ACKNOWLEDGMENTS

The authors thank the municipality of Tokat-Resadiye for their help and contribution throughout the study period.

9. REFERENCES

Demiral, **Z.** (1988) Hydrogeological criteria for preservation areas. International lst.

Seymen, **I.** (1975) ***Tectonic specification of North Anatolian fault zone in Kelkit Valley.*** PhD Thesis, I.T.U. Faculty of Mining, Istanbul Turkey.

Pasvanoglu, S. and Canik, B. (1993) Hydrogeological investigation **of** the mineralised and thermal waters of the karstic aquifers around Kirsehir and the possibility of utilisation in Thermal spas. ***International symposium on water resources in karst with special emphasis on Arid and semiarid zones.*** Vol: 1, pp 153 – 167, Shiraz, IRAN

Orme, J. (1992) Technical, economical and feasibility report of central heating of **1200** houses in Resadiye with geothermal water. Presidency **of** Resadiye Municipality. ***Hydrogeological Symposium. Announcements.*** Page 257-269, Ankara.

International Association of Hydrogelogists 1979, ***Map & Mineral and thermal water of Europe. Scale (1:500,000 scale).*** International Association **of** Hydrogelogists. United Kingdom.

Giggenbach, W.F., 1991: Chemical techniques in geothermal exploration. In: ***D`Amore,F. (coordinator), Application of geochemistry in geothermal reservoir development.*** UNITAR/UNDP publication, Rome, **p.** 119-142.

Kocak, **A.,** ve Erzenoglu, Z., 1987 ***Hydrogeological feasibility report of Tokat Thermal waters..*** M.T.A. Rep. No.8294. Ankara – Turkey.

Schoeller, H., 1962. ***Les eaus souterrians Masson et. Cie,*** Paris

Table 1: Chemical composition of thermal and cold spring (in mg/kg) in the study area

Location Name	Sample No	Date	T(C)	pH (25°C)	Ca	Mg	Na	K	Cl	SO4	HCO_3	SiO_2	Li	B
Kelkit Stream	1	10.2.2000	4.56	7.4	51	15.8	26.4	1.5	15.6	19.8	88.4			
Resadiye cold water spring	2	10.2.2000	14.9	6.9	208	52.8	68.3	6.9	49.7	292	640.5			
		22.6.2000		6.7	180	89.8	64.2	8.6	37.3	275	774.7			
S-1 well	3	10.2.2000	48.2	6.6	260	63.7	819	34	830.7	140	1739			
		22.6.2000	49	6.6	314	176	510	40	805.8	111	1739			
		1995	50	6.8	1304	97.5	874	49	843	188	2062	42	0.6	27.2
		18.12.1989	54	6.54	415	107	840	40	837	175	2386	54	1.6	28
Warm Spring	4	10.2.2000	47.3	6.4	260	72.8	799	33	830.7	103	1769			
		22.6.2000	46.5	6.4	330	156.6	500	40	791.6	96	1699			
		1995	46	6.9	280	92	894	59	843	182	2000	32	1.6	27.2
		18.12.1989	45	6.52	288	101	800	40	841	170	1922	49	1.4	32
		1987	45	7	158	90	770	40	799	181	1543	42	1.2	28