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Hydrogeochemical characteristics of the Ozancik hot spring, Çanakkale, Turkey

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ABSTRACT

This investigation was carried out to determine the hydrogeochemical characteristics of the Ozancık hot spring. The study area is located about 15 km southwest of the town of Çan, Çanakkale. During the investigation, a geological map of the hot spring and its surroundings was prepared, and hot water and rock samples were collected from the study site. The Palaeogene–Neogene andesite, trachyandesite, andesitic tuff, silicified tuff, and tuffites form the basement rocks and they are overlain by the Quaternary alluvial deposits.

The chemical analysis of hot water indicates that it is rich in SO_4^{2-} (575 ppm), Cl^- (193.2 ppm), HCO_3^- (98.5 ppm), Na^+ (315 ppm), K^+ (7.248 ppm), Ca^{2+} (103 ppm), Mg^{2+} (0.274 ppm), and SiO_2 (43.20). The distribution of ions in the hot water on the Schoeller diagram has an arrangement of $r(Na^+ + K^+) > rCa^{2+} > rMg^{2+}$ and $r(SO_4^{2-}) > rCl^- > r(HCO_3^-)$. In addition, the inclusion of Fe^{2+}, Cu^{2+}, Cr^{3+}, Mn^{2+}, Ni^{2+}, and Hg^{2+} in the hot water samples indicates potential natural inorganic contamination.

The water analysis carried out following the ICPMS-200 technique was evaluated according to the World Health Organization and Turkish Standards. The utilisation and the effects of the hot water on human health are also discussed in the paper.

INTRODUCTION

The Ozancık hot spring is located at the village of Bardakçılar near the town of Çan and the city of Çanakkale (Fig. 1). Kaaden (1957), Bingöl et al. (1975), and Ercan (1981) carried out geological studies and Okay et al. (1990) did geological and tectonic studies in this area and its surroundings. Similarly, geomorphological studies were carried out by Erol (1992) and geological and hydrogeochemical studies by Pehlivan (1996).

The major element analysis of rock samples was done in the laboratories of the Geological Engineering Department, Hacettepe University, Turkey. The trace element studies were carried out at the same place applying ICP-30 technique in SGS–XRAL. In addition, the ultra trace element analysis of the hot water samples was carried out using ICPMS–200 technique at the detection limit of 0.01 ppb in the SGS–XRAL laboratories of Canada. Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, and HCO_3^- analysis of the hot water was performed at the Geochemistry Laboratory of İstanbul University.

GEOLOGICAL SETTING

The Çan volcanites occur in most of the study area and consist of andesite, trachyandesite, andesitic tuff, and silicified tuff and tuffite. The Eocene–Upper Miocene Çan volcanites are the product of calc-alkaline volcanism.

At the andesite outcrop of Location ORP6, the hydrothermal activity was not noticed. Trachyandesite is hard but its feldspar is altered to kaolinite. Andesitic tuff consists of plagioclase, biotite, and secondary quartz. Silicified tuff is formed by the extreme silicification of andesites. Tuffite contains the volcanic material, which is replaced in places by thin to medium layers and lamina of clay and silt.

Owing to the proximity of the North Anotolia Fault Zone (NAFZ), the study area is ramified by southwest–northwest trending faults and an active fault (i.e. the Etili Fault) also lies in the north.

HYDROGEOCHEMICAL CHARACTERISTICS

The Koca River and its tributaries drain the study area. The drainage network is developed on permeable rock units formed by the alteration of the Çan volcanites. Therefore, there are no good aquifers in the region. The hot water system is formed in the Çan volcanites including rocks such as andesite, andesitic tuff, silicified tuff, and tuffite.

Circulation of groundwater in the study area takes place within the volcanic rocks, outcropping near the springs. The hot water emerges from a fracture zone after passing through a heat resource underground. The temperature of the Ozancik hot spring at the mouth of the fault zone is 65 °C and its discharge (average flow) is 5.0 l/s.

Hydrogeochemistry

The results of chemical analysis of the Ozancık hot spring are presented in Table 1. The hot spring contains mainly the following ions: Na^+ (315 ppm), Ca^{2+} (103 ppm), K^+ (7.248 ppm), Mg^{2+} (0.724 ppm), SO_4^{2-} (575 ppm), Cl^- (193.2 ppm), HCO_3^- (98.5 ppm), and SiO_2 (43.20 ppm). These values were also plotted on the Schoeller Diagram (Schoeller 1962). The diagram (Fig. 2) depicts the following arrangement of anions

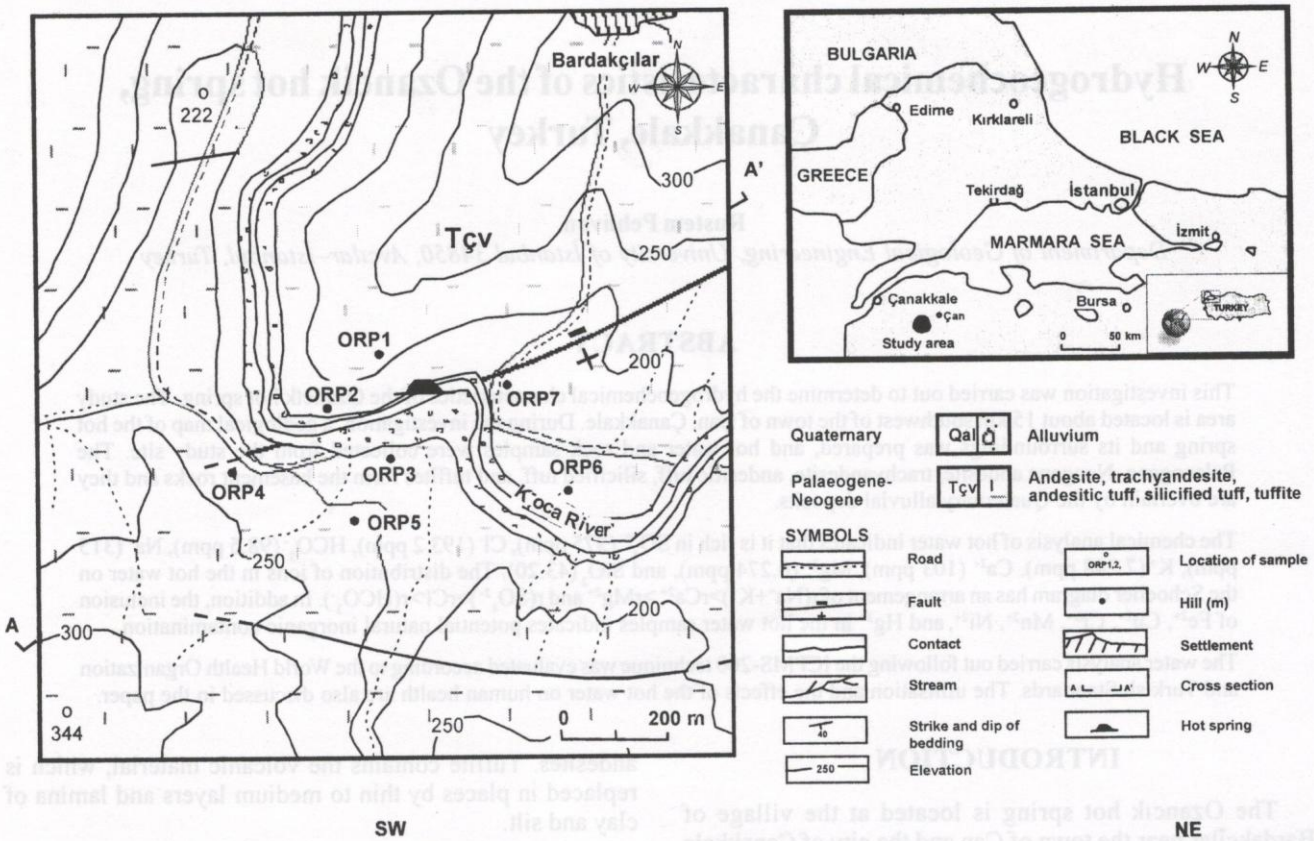

Fig. 1: Location and geological map of the study area

Table 1: Composition of the Ozancık hot spring

Ion	mg/l	meq/l	meq/l (%)
Na^+	315	13.70	71.92
K^+	7.248	0.18	0.94
Ca^{2+}	103	5.15	27.03
Mg^{2+}	0.274	0.02	0.10
Cl^-	193.2	5.44	28.60
SO_4^{2-}	575	11.97	62.93
NO_3^-	0.08	0.001	0.005
HCO_3^-	98.5	1.61	8.46

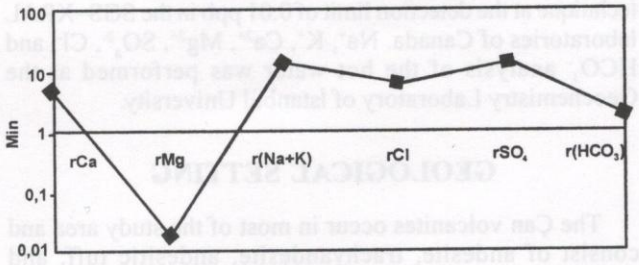

Fig. 2: Schoeller diagram of the Ozancık hot spring

and cations: $r(Na^+ + K^+) > rCa^{2+} > rMg^{2+}$ and $r(SO_4^{2-}) > rCl^- > r(HCO_3^-)$, and it conforms to the following arrangement for the volcanic rocks: $[r(Na^+ + K^+) > rCa^{2+} > rMg^{2+}$ and $r(SO_4^{2-}) > rCl^- > r(HCO_3^-)]$ as given by Şahinci (1991).

The Piper diagram of the hot spring in terms of meq/l (%) is depicted in Fig. 3. In the Piper diagram, hot and mineralised springs are generally arranged as $Na^+ + K^+ > Ca^{2+} + Mg^{2+}$ and $SO_4^{2-} + Cl^- > HCO_3^- + CO_3^{2-}$, and the present hot spring also

depicts a similar trend. The results acquired from the Piper diagram are also compatible with those obtained from the Schoeller diagram.

Lithogeochemistry

Major and trace element analysis of some rock samples obtained from the surroundings of the Ozancik hot spring was carried out so as to fix the influence of hydrothermal activities in the area. With reference to the major element analysis, the rocks are considered to have been transformed into quartzite for the reason that the rock sample ORP1 contains 97.6% of SiO_2.

The rocks sample ORP2 falls into the andesite field (Fig. 4) based on the Na_2O+K_2O-SiO_2 relation in the volcanic rock nomenclature diagram (Le Maitre 1989), and it has a calc-alkaline affinity (Fig. 5) as per Irvine and Baragar (1971) Na_2O+K_2O-SiO_2-FeO^* triangle diagram. The sample ORP3 is rich in SiO_2.

In terms of trace and major element analysis, the silicified tuff samples are enriched with As and Ni, whereas the andesitic tuff samples are enriched with Pb and U. In addition, the sample ORP3 has a high SiO_2 content (Table 2).

UTILISATION OF THE HOT WATER

Hot and mineralised springs can cause positive or adverse effects on human health. Limit values (Table 4) for drinking, mineral, and spring water permitted by the World Health Organization (Uyar 1985; Gray 1994) and the Turkish Standarts (1984 and 1991) as well as for swimming water allowed by the Turkish Standarts (1993) are compared with the analysis results (Tables 1 and 3). It can be seen that, for the Ozancik hot spring, Hg and SO_4 ions exceed the limit values.

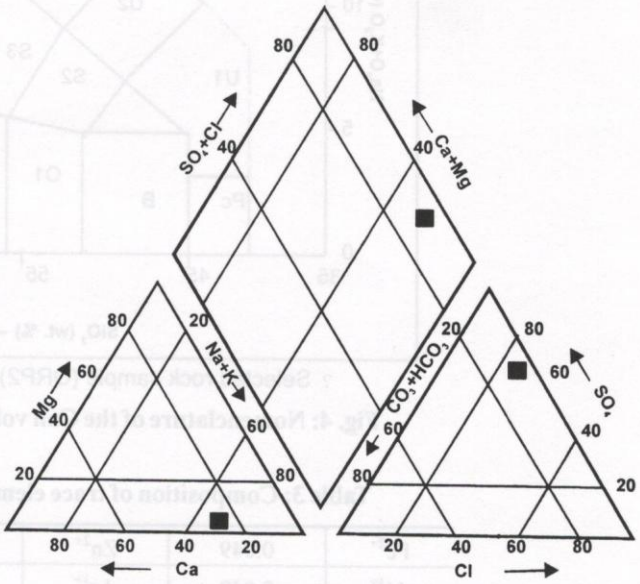

Fig. 3: Piper diagram of the Ozancik hot spring

Table 2: Major oxides (%) and trace elements (ppm) in the selected rock samples

Component	ORP 1 (Silicified tuff)	ORP 3 (Andesitic tuff)	ORP 6 (Andesite)
SiO_2	97.60	64.15	57.43
Al_2O_3	0.24	16.77	20.20
Fe_2O_3	0.64	6.39	6.50
MnO	0.003	0.01	0.20
MgO	>0.01	0.96	2.04
CaO	0.09	0.98	4.25
Na_2O	>0.01	0.73	2.75
K_2O	0.03	2.97	1.08
TiO_2	0.68	0.88	0.78
P_2O_5	0.05	0.06	0.05
LoI	0.12	5.81	4.32
Total	**99.47**	**99.71**	**99.60**
Cr	152	138	80
Mn	21	63	91
Co	5	5	-
Ni	113	43	37
Cu	17	32	25
Zn	6	14	12
Pb	53	110	71
As	60	-	-
U	10	48	26

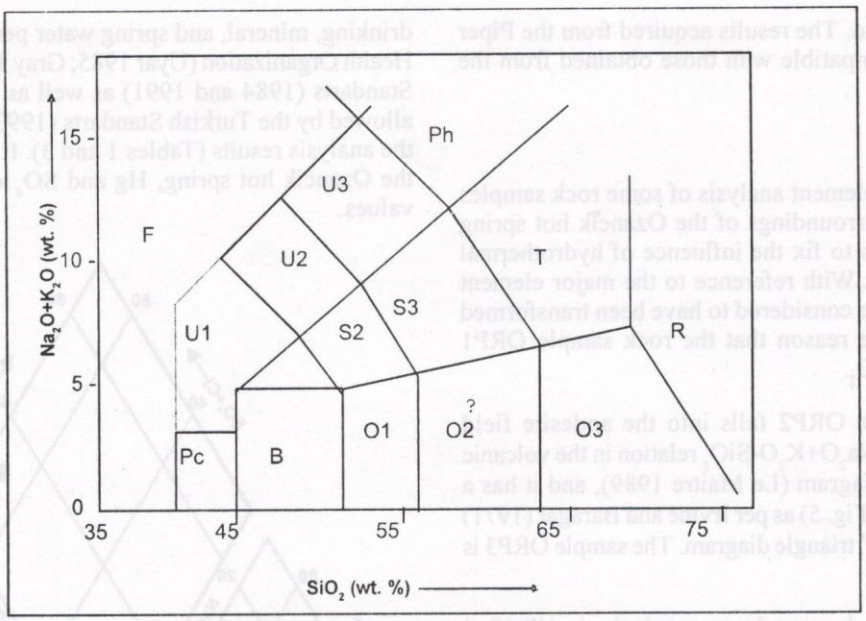

Fig. 4: Nomenclature of the Çan volcanites according to Le Maitre (1989)

Table 3: Composition of trace elements in the Ozancık hot spring (ppm)

Fe^{2+}	0.049	Zn^{2+}	0.0079	Se^{4+}	0.0014
Al^{3+}	0.049	As^{3+}	0.0001	Hg^{2+}	0.0016
Cr^{3+}	0.0009	Rb^{+}	0.036	Th^{3+}	0.00001
Mn^{2+}	0.0003	Sr^{2+}	1.652	U^{3+}	0.00001
Co^{2+}	0.0002	Ag^{3+}	0.0009	SiO_2	43.20
Ni^{2+}	0.0068	Cd^{2+}	0.00001	pH	7.2
Ti^{2+}	0.009	Sn^{2+}	0.00001	T ^{o}C	51
Cu^{2+}	0.0029	Sb^{3+}	0.0001	EC(μ mho/cm)	1000
Pb^{2+}	0.00001	Ba^{2+}	0.018		

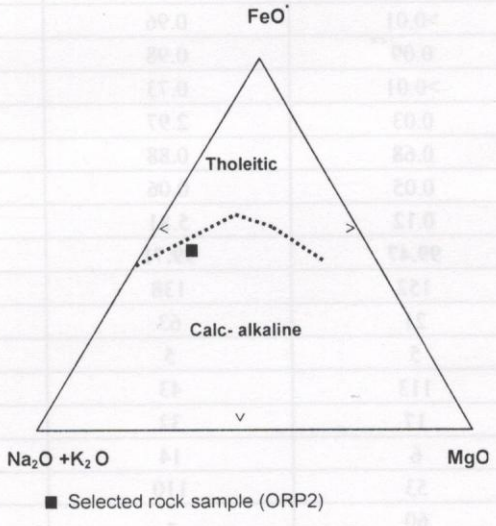

Fig. 5: Classification of the Çan volcanites according to Irvine and Baragar (1971)

Table 4: The limits permitted by the World Health Organization (WHO) and the Turkish Standards (TS) for drinking, mineral water, spring water, and swimming water

Ions	Drinking (WHO) (mg/l)	Drinking (TS) (mg/l)	Mineral water (TS) (mg/l)	Spring water (TS) (mg/l)	Swimming water (TS) (mg/l)
Pb	0.05	0.05	0.05	X	0.01
Cr	0.05	0.05	0.05	X	X
As	0.01	0.05	0.05	X	0.02
Se	0.01	0.01	0.01	X	0.003
CN	0.01	0.01	0.01	X	0.01
Cd	0.01	0.005	0.005	X	X
Ag	0.05	0.05	X	X	X
Hg	0.001	X	0.001	X	X
Fe	1	1	X	0.3	X
Mn	0.05	0.5	0.5	0.1	X
Cu	1	1.5	1	1	X
Zn	5	15	3	5	X
Ca	200	200	X	25	X
Mg	125	150	X	10	X
Ba	1	X	1	X	X
Cl	600	600	X	500	X
F	1	2.4	1.5	1	X
SO_4	400	400	X	20	X
NH_3	x	X	X	X	0.2
NH_4	x	X	0.05	X	X
NO_2, NO_3	45	45	25	25	5

CONCLUSIONS

From the chemical analysis of the Ozancik hot water samples, it was revealed that the hot water is rich in SO_4^{2-}, Cl^-, Na^+, Ca^{2+}, and SiO_2. The inclusion of Fe^{2+}, Cu^{2+}, Cr^{3+}, Mn^{2+}, Ni^{2+}, and Hg^{2+} in the hot water samples indicates a potential natural inorganic contamination. The Ozancik hot spring exhibits the following anion and cation arrangement: [$r(Na^+ + K^+) > rCa^{2+} > rMg^{2+}$ and $r(SO_4^{2-}) > rCl^- > r(HCO_3^-)$], and it is compatible with the following arrangement reported from the volcanic rocks: [$r(Na^+ + K^+) > rCa^{2+} > rMg^{2+}$ and $r(SO_4^{2-}) > rCl^- > r(HCO_3^-)$].

The Ozancık hot spring can be used for swimming purposes. However, the water cannot be used for drinking purposes, as it has a high mercury content.

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