ORIGIN OF THE HIGH BORON CONTENTS IN THE THERMAL WATERS OF THE RIFT ZONES OF THE MENDERES MASSIF, WESTERN ANATOLIA, TURKEY

Nevzat Özgür
Süleyman Demirel Üniversitesi, Mühendislik-Mimarlık Fakültesi, Jeoloji Mühendisliği Bölümü, 32260 Isparta, TR-Turkey
and
Alice Gallo and Asaf Pekdeger
Freie Universität Berlin, FR Rohstoff- und Umweltgeologie
Malteserstr. 74-100, D-12249 Berlin

ABSTRACT

The thermal waters of Kızıldere and environs in the Büyük Menderes rift zone are marked by boron concentrations of up to 32 mg/l, and flows with rates of about 250 l/s into the Büyük Menderes River, thus increasing the boron contents of the river water up to 4,4 mg/l (e.g., in 1992), for a river-water flow rate of 2 m³/s. These high boron concentrations poison plants, particularly citrus fruits, in irrigated agricultural areas of the rift zone.

High boron contents in the thermal waters can be attributed to (1) unstable boron-bearing mineral phases (e.g., feldspars, muscovites, tourmalines, hornblendes and biotites) in the metamorphic rocks, proven by the experimental leaching tests of various rocks, and (2) a magmatic input, corroborated by isotope analyses of $\delta^{11}B$, $\delta^{13}C$ and $\delta^{34}S$ of the thermal waters. Additionally, Neogene boron deposits in NW Turkey have to be taken into consideration as possible source of boron, which may contribute to these anomalous concentrations by leaching of boron bearing minerals. Meteoric input of boron into the thermal water reservoir must be ruled out because the boron contents of the groundwaters from the Buldan horst in the northern part of the study area are below detection limits (0.01 mg/l). There is no single reason for the high boron concentrations measured in the thermal waters of Kızıldere and environs; rather, a concurrence of several natural factors is likely.

1 Introduction

High temperature thermal waters in the rift zones of the Menderes Massif are distinguished by boron concentrations up to 35 mg/l. Due to toxic effects of boron the economic utilization of the thermal waters is less favorable in the area as long as the geothermal waters are not reinjected in the main reservoirs; therefore, high boron concentrations in this value poison some plants in the rift zones of Büyük Menderes and Gediz, i.e. citrus fruits. The waste waters from the geothermal power plant of Kizildere flows with a flow rate of 500 l/s to the river of Büyük Menderes.

In order to give a reply to the origin of these high boron contents in the thermal waters in the Menderes Massif, we have selected to investigate the thermal field of Kizildere and its environs in the rift zone of Büyük Menderes in combination with the origin and evolution of the thermal waters.

A research scheme carried out from 1994 to 1996, divided in two main fields: (i) geological and geochemical investigations based on detailed geological mapping and rock sampling and (ii) and comprehensive hydrogeological and hydrogeochemical investigations with sampling of groundwaters, thermal waters and river waters of the Büyük Menderes.

2 Geologic setting

The investigated area is located in the northern flank of the eastern part of the rift zone of Büyük Menderes (Fig. 1). In this area, the metamorphic basement build up by Paleozoic gneisses and several schists is overlain discordantly by Pliocene clastic sediments. These sediments show fluvial and lacustrine characters and consist of (i) the 200-m thick Kızılburun formation representing an alternation of red and brown conglomerates, sandstones, shales, and lignites, (ii) the Sazak formation with a thickness from 100 to 250 m consisting of intercalated grey limestones, marls, and siltstones, (iii) the Kolonkaya formation in a range of thickness from 350 to 500 m, which contains yellowish green marls, siltstones, and sandstones, and (iv) the 500-m-thick Tosunlar formation showing an alternation of conglomerates, sandstones and mudstones with fossiliferous clay units (Fig. 2). The gneiss is distinguished by the mineral phases of quartz, feldspar, white and black micas, turmaline and accessory minerals. In comparison, the mica schists contain garnets additionally.

The thermal field is regionally controlled by E-W trending faults. Locally, NW-SE or NE-SW trending faults are active in the field (Özgür et al., 1998a, b). The development of these faults lead to a compression, which was generated by the extension during the formation of the rift zone of Büyük Menderes (Özgür et al., 1997; Özgür, 1998).

In the thermal field of Kizildere, the metamorphic and sedimentary rocks are distinguished by intensely hydrothermal alteration which is represented by phyllic, argillic, and silicic ± haematitization alteration zones. The carbonatization must be considered as a new type alteration in the thermal field of Kizildere additionally.

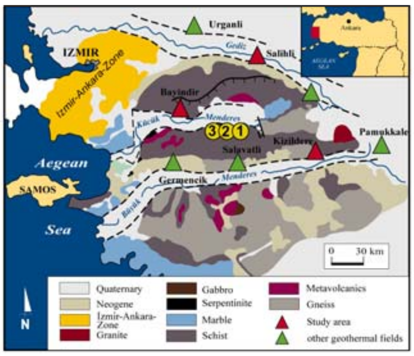

Fig. 1: Geologic setting of the Menderes Massif, location map of the geothermal field of Kızıldere and epithermal Hg (1), Sb (2) and Au (3) deposits of Halıköy, Emirli and Küre.

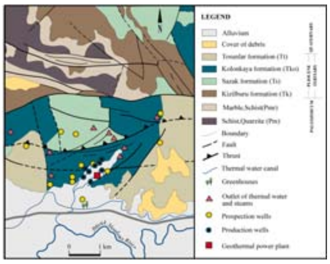

Fig. 2: Geological map of the thermal field of Kızıldere and environs (Şimşek, 1985).

3 Boron Geochemistry

In order to investigate the origin of the high boron concentrations in thermal waters, 250 rock samples within the investigation area were collected. Boron contents in rocks, groundwaters, thermal waters, and river waters were analyzed by photometry (Robert Riele, PM 210) using reagents of calibrating standards, spectroquant ® 14839, and curcumin.

The Precambrian to Cambrian metamorphic rocks differ from the Pliocene sedimentary rocks by their high boron contents (Fig. 3). The Gneisses show boron contents in a range from 6 to 28.151 ppm and a background value of 191 ppm. For comparison, the Igdecik formation, which are composed of mica schists, quartzites and marbles, has a range of boron from 6 to 241 ppm and a background value of 166 ppm. The background values are 53 ppm in Kizilburun formation (range: 9 up to 79 ppm), 16 ppm in Sazak formation (range: 4 up to 24 ppm), 15 ppm in Kolonkaya formation (range: 2 up to 681 ppm) and 48 ppm in Tosunlar formation (range: 15 up to 63 ppm). Recent mineral precipitations in the thermal waters of Kizildere and its environs show a background value of 56 ppm in a range from 5 to 2.846 ppm.

The plot of B versus SiO_2 and Al_2O_3 (Fig. 4) indicates a close positive correlation between boron contents and rock-forming minerals of quartz, feldspar and micas in the study area of Kizildere, which can be confirmed by plot of B versus Na_2O and K_2O (Fig. 5). Boron may be incorporated in the crystal lattice instead of Si and Al (Christ, 1965); besides, the size of lattice depends upon Al-oxide and B-oxide of 1,76 A° and 1,48 A° in ion radius respectively.

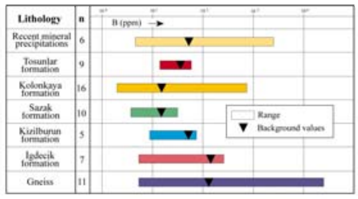

Fig. 3: Range and background values of boron in metamorphic and sedimentary rocks of Kızıldere.

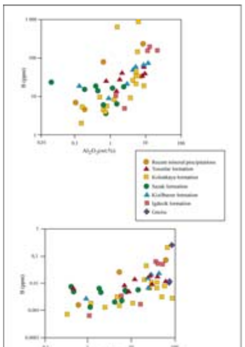

Fig. 4: Plot of B versus SiO_2 and Al_2O_3 in metamorphic and sedimentary rocks of Kızıldere.

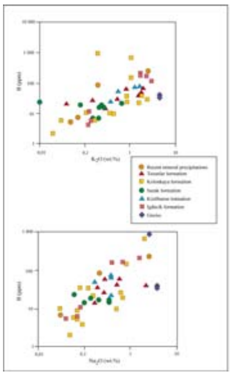

Fig. 5: Plot of B versus Na_2O and K_2O in metamorphic and sedimentary rocks of Kızıldere.

4 Boron hydrogeochemistry of Kizildere

In the thermal field of Kizildere and its environs, boron contents of 200 samples of groundwaters, thermal waters and river waters of Büyük Menderes were analyzed by the above mentioned photometry, especially for March 1996 and October 1996 for at least two different seasons (Figs. 6 and 7). For comparison, 75 samples from the thermal fields of Salihli, Bayindir, Salavatli and Germencik (Özgür, 1998; Özgür et al., 1998a) have been used.

In the seasonal time of March 1996, boron concentrations in the river waters, which are supplied by the thermal waters of the geothermal power plant of Kizildere, dilute up to 0,76 mg/l (Fig. 6). In comparison, the boron concentrations in the river waters increase up to 1,3 mg/l in seasonal time of October 1996 (Fig. 7).

Fig. 8 shows a close correlation between boron contents in various rocks and boron concentrations in leached different rocks. These leaching tests indicate a distinct dependence upon the temperature; besides, the high temperature and buffer effect play an important role.

Fig. 6: Distribution of boron in groundwaters, thermal waters and river waters of Kızıldere and environs.

Fig. 7: Distribution of boron in groundwaters, thermal waters and river waters of Kızıldere and its environs.

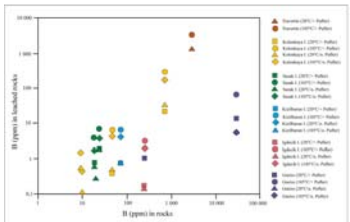

Fig. 8: Plot of boron contents in various rocks vs. boron concentrations in leached rocks.

5 Discussion

The solubility of boron from boron-bearing mineral phases within fluid-rock interaction may contribute to increase of boron in the thermal waters in the rift zones of Menderes Massif. The mineral phases of biotite, white micas, turmaline, feldspars and hornblende can be considered as potential boron carrier. The experimental leaching tests of various rocks in Kizildere and its environs show, that Gneisse and mica schists play as boron source an important role.

Additionally, the magmatic input of boron increase these concentrations in the thermal waters which could be corroborated by the isotope ratios of $^{11}B/^{10}B$ (Giese, 1997; Özgür, 1998) and the values of $\delta^{13}C$ and $\delta^{34}S$ in thermal waters (Özgür, 1998, 2001a, b).

The boron deposits in depth, which occur in connection with young volcanism in the northeastern part of Turkey, i.e. the deposits of Bigadic in Balikesir and of Kirka in Eskisehir, have to be taken into consideration as boron carrier as long as the contrary of existence of such deposits has not been established.

Finally, It can be concluded, that not one single reason is the cause for the high boron concentrations measured in the thermal waters of the rift zones of the Menderes Massif, but a concurrence of several natural factors.

6 References

Christ, C.L., 1965, substitutions of boron in silicate crystals: Norsck Geol Tidsskrift 45, p. 423-428.

Gallo, A., 1998, Borgehalte in der Riftzone des Büyük Menderes im Menderes-Massiv, W-Anatolien/Türkei: Diplomarbeit, Freie Universität Berlin, 59p.

Giese, L., 1997, Geotechnische und umweltgeologische Aspekte bei der Förderung und Reinjektion von Thermalfluiden zur Nutzung geothermischer Energie am Beispiel des Geothermalfeldes Kizildere und des Umfeldes, W-Anatolien/Türkei: Dissertation, Freie Universität Berlin, 201 p.

Özgür, N., Halbach, P., Pekdeger, A., Sönmez, N., Dora, O.Ö., Ma, D.-S., Wolf, M. and Stichler, W., 1997, Epithermal antimony, mercury, and gold deposits in the rift zone of the Kücük Menderes, Western Anatolia, Turkey: preliminary studies: in: Papunen, H. (ed.): Mineral Deposits: Research and Exploration – Where do They Meet?: Proc. 4th Biennnial SGA Meeting, Turku, Finland, August 11-13, 1997, p. 269-273.

Özgür, N., Pekdeger, A., Wolf, M., Stichler, W., Seiler, K.-P. and Satir, M., 1998, Hydrogeochemical and isotope geochemical features of the thermal waters of Kizildere, Salavatli, and Germencik in the rift zone of the Büyük Menderes, western Anatolia, Turkey: preliminary studies: in: Arehart, G.B. and Hulston, J.R. (eds.): Proc. Internat. 9th Symp. on Water-Rock Interaction, Taupo, New Zealand, 30 March – 3 April 1998, p. 645-648.

Özgür, N., Vogel, M., and Pekdeger, A., 1998, A new type of hydrothermal alteration of the Kizildere geothermal field in the rift zone of the Büyük Menderes, western Anatolia, Turkey: in: Arehart, G.B. and Hulston, J.R. (eds.): Proc. Internat. 9th Symp. on Water-Rock Interaction, Taupo, New Zealand, 30 March – 3 April 1998, p. 679-682.

Özgür, N., 1998, Aktive und fossile Geothermalsysteme in den kontinentalen Riftzonen des Menderes-Massives, W-Anatolien/Türkei: Habilitationsschrift, Freie Universität Berlin, 171 p.

Özgür, N., 2001a, Geochemical, hydrogeochemical, and isotope geochemical signatures of the thermal field of Kizildere in the continental rift zone of the Büyük Menderes, Western Anatolia, Turkey: International Geology Review (in press).

Özgür, N., 2001b, Origin of the high boron contents in the thermal waters of the rift zones of the Menderes Massif, Western Anatolia, Turkey: International Geology Review (in press).

Simsek, S., 1985, Geothermal Model of Denizli, Sarayköy-Buldan Area: Geothermics 14, 393-417.