Geothermal Waters of Urganlı (Manisa) as a Hydrogeological Model, Western Anatolia, Turkey

Nevzat Özgur ¹, Seher Buyuksahin ¹

¹ Suleyman Demirel University, Faculty of Engineering, Department of Geological Engineering, Isparta, Turkey
nevzatozgur@sdu.edu.tr

Abstract: The area of Urganlı is located in the western part of Gediz graben and consists of Paleozoic metamorphic rocks with intercalations of various schists and marbles, Mesozoic limestones and ultrabasic rocks, and Pliocene to recent travertine deposits and alluviums. Mica schists as intercalations in Paleozoic metamorphic rocks form impermeable basement rocks hydrogeochemically. The marble as intercalations in metamorphic rocks is of reservoir rock for geothermal waters. Moreover, these marbles are also aquifer for groundwaters. As impermeable rocks, sedimentary rocks with high quantities of clay contents in Pliocene to recent age play an essential role for enhancement of geothermal waters. Geothermal waters of Urganlı with temperatures of up to 75 °C and reservoir temperatures of up to 180 °C are of Na-HCO₃ type whereas groundwaters display Ca-Mg-HCO₃ type. Geothermal waters of Urganlı were represented as an hydrogeological model within this study. The Kula volcano in the Gediz rift zone with a last eruption age up to 18,000 a is responsible for heating geothermal waters.

1. Introduction
The area of Urganlı in the gedia rift zone was selected for study of geothermal waters by various methods of hydrogeological aspects [Figure 1; 1]. The paper aims (i) to describe geo[thermal fields of Urganlı and (ii) to develop an hydrogeological model of geothermal waters in the study area.

2. Geological setting
In the area of Urganlı, Paleozoic metamorphic rocks form impermeable basement rocks which consist of various schists with intercalations of marbles [Figure 2; 2; 3]. Paleozoic marbles overlie the metamorphic rocks overlain by Mesozoic carbonates and allochthonous ophiolites [3]. Both metamorphic rocks and carbonate rocks and ultrabasic rocks in Paleozoic and Mesozoic age are overlain by Pliocene sediments and travertine deposits and alluviums in Quaternary age discordantly
Figure 1. Geological location map of the study area within the Menderes Massif [1].

Figure 2. Geological map of Urganlı [modified from 2; 3]. Red circles are locations for water samples. For sample KW4 see [1].
3. Material and methods

Field campaigns for measurements of physical parameters and sampling for geothermal waters carried out from 1994 to 2014. In total, 3 samples of geothermal waters and groundwaters were collected [1; 3]. Hydrogeochemical analyses of geothermal waters were carried out by using ICP-OES and IC in the General Directorate of Mineral Research and Exploration, Ankara, Turkey, respectively. Values of stable isotopes and tritium were taken from [1].

4. Results

4.1. Hydrogeology

In the study area of Urganlı, Paleozoic metamorphics have intercalations of marbles and form impermeable basement rocks. These marbles are permeable due to fracture and fault systems and karst spaces can be considered as main reservoir rocks in the area [1; 3]. Vişneli formation in Pliocene age overlies the marbles discordantly and has high quantities of clay contents. Therefore, it can be considered as an impermeable excellent cap rock overlain by Pliocene Yaka formation concordantly consisting of high quantities of clay contents. Therefore, Pliocene Yaka formation is of a second excellent impermeable cap rock in the area. Travertine deposits and sediments in Quaternary age overlie the both Vişneli and Yaka formations discordantly are described as cap rocks as well.

4.2. Hydrogeochemistry

In the area of Urganlı, geothermal waters are of Na-HCO₃ type [Figure 3; 3; 4; 5]. In comparison, the groundwaters in the area are of Ca-Mg-HCO₃ type [3; 5]. Geothermal waters of Urganlı display order of Na+K>Ca>Mg and HCO₃>Cl<SO₄ and immature waters according to Na/1000-K/100-\sqrt{Mg} [Figure 4; 5; 6]. Geothermal waters in the area are distinguished by geochemical reservoir temperatures between 140 to 180 °C in the area corresponding to measured temperatures in various wells [3; 5].

Figure 3. Geothermal waters of Urganlı in Piper diagram. For the data of Kurşunlu and Camurlu see [1; 6].
Figure 4. Plot of Na/1000-K-100-√Mg of geothermal waters in Urganlı. For the data of Kurşunlu and Camurlu see [1; 6].

4.3. Isotope geochemistry
Plot of δ18O versus δ2H in geothermal waters are represented [Figure 6; 1, 3]. Geothermal waters of the area are represented by δ2H between -56.0 and -45.9 ‰ and δ18O ranging from -8.88 to -6.72 ‰ [1; 3; 5]. Tritium contents in these waters reach values of up to 8.4 TU. Only one sample of groundwaters corresponds to GMWL. In comparison, geothermal waters display a right shift which is associated with intense water-rock interaction. Tritium values of up to 8.4 TU can be led to atmospheric and/or anthropogenic origin and indicate a mixing process between groundwaters and geothermal waters.

5. Discussion
In Urganlı, metamorphic rocks in Paleozoic age form impermeable rocks at bottom. These rocks are overlain by sediments in Cenozoic age discordantly. The Cambazlı fault in the area is responsible for geothermal waters [2; 3]. In Paleozoic metamorphic rocks of high elevation areas within the catchment area, fracture and fissure systems were generated, which display importance for geothermal reservoir. In study area, the marbles, which are generated in metamorphic rocks as alternations form the most important reservoir rocks due to their features of fractures, fissures and karst formations. Geothermal waters show surface temperatures between 22 and 96 °C. In the Piper diagram from the area of Urganlı, there are deep geothermal waters with Na-HCO₃ type and shallow groundwaters with as Ca-Mg-HCO₃ type. In Urganlı, geothermal waters display order of Na+K>Ca>Mg and HCO₃>Cl.SO₄. SiO₂ thermometers show reservoir temperatures of up to 180 °C [3; 5]. Plot of δ18O versus δ2H shows that the groundwater corresponds to GMWL In comparison, geothermal waters show a right shift from the GMWL which is associated with intense water-rock interactions.
Figure 5. Plot of $\delta^{18}$O vs. $\delta^2$H in various geothermal waters of Urganlı. Yellow circles are the samples from the study area. For the data of stable isotopes and tritium see [1; 3; 5; 7].

The tritium values of up to 8.4 TU are to be attributed to atmospheric and/or anthropogenic origin indicate a mixing process between the both groundwaters and geothermal waters [7;8]. In the area of Urganlı, the geothermal waters were represented as a model hydrogeologically (Figure 6) which has been described by [1; 5] comprehensively.

Figure 6. Hydrogeological conceptual model of geothermal waters of Urganlı [modified from 2;3; 9].
In the system, meteoric waters flow in catchment area through faults, fractures and fissures and by permeable rocks into permeable reservoir rocks in a depth of up to 5 km firstly. There, meteoric waters are are heated by different heat sources, i.e. magmatic melts and heatflow anomalies, and ascend to the surface due to lower density caused by plate tectonical convection cells. In this manner, geothermal waters ascend through faults, fractures, fissures and permeable rocks to the surface in form of hot springs, gases, and steams.

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References
[1] Özgür, N., “Aktive und fossile Geothermalsysteme in den kontinentalen Riftzonen des Menderes Massives, Wanatolien, Türkei,” Habilitationsschrift, Freie Universität Berlin, 171 p., 1998.
[2] Vural, S., “Urganlı (Turgutlu, Manisa) jeotermal alanının jeolojisi ve hidrojeokimyasal özellikleri,” M.Sc. thesis, Graduate School of Applied and Natural Sciences, Kocaeli Üniversitesi, 2009.
[3] Büyükşahin, S., “Urganlı (Turgutlu, Manisa) ve yakın çevresi jeotermal sularının hidrojeolojik modellemesi,” M.Sc. thesis, Graduate School of Applied and Natural Sciences, Süleyman Demirel Üniversitesi, 2016.
[4] Calmbach, L., “AquaChem Computer code-Version 3.7: Aqueous geochemical analyses, plotting and modelling. Waterloo Hydrogeologic: Waterloo, Canada, 1999.
[5] Özgür, N., Büyükşahin, S., Yıldırım, B., Aydemir, E., “Hydrogeological, hydrogeochemical and isotope geochemical features of the geothermal waters in Urganlı and environs, western Anatolia, Turkey, “European Geologists 43.
[6] Giggenbach, W. F., “Geothermal solute equilibria. Derivation of Na-K-Ca-Mg geoindicators. Geochimica et Cosmochimica Acta 52. 2749-2765, 1988.
[7] Yıldırım, B., “Kurşunlu (Salihli, Manisa) ve yakın çevresi jeotermal sularının hidrojeolojik, hidrojeokimyasal ve izotop jeokimyasal özellikleri, “M.Sc. thesis, Graduate School of Applied and Natural Sciences, Süleyman Demirel Üniversitesi, 2016.
[8] Özgür, N., Pekdeger, A., “Active geothermal systems in the rift zones of the Menderes Massif, western Anatolia, Turkey. In: Kharaka, Y.K., Chudaev, O.V. (eds.): Proc. Internat. 8th Symp. on Water-Rock Interaction (Vladivostok, Russia). 529-532, 1995.