Hydrogeological Conceptual Model of Geothermal Waters in Baklaci (Alasehir, Manisa), Western Anatolia, Turkey

Nevzat Ozgur, Ezgi Yuruk Anilir

1 Suleyman Demirel University, Faculty of Engineering, Department of Geological Engineering, Isparta, Turkey

nevzatozgur@sdu.edu.tr

Abstract. Geothermal waters of Alâşehir are located in the southern part of the Gediz rift zone within the Menderes Massif and form biggest potential in the area with a capacity of up to 200 MWe. Geologically, Paleozoic metamorphic rocks with intercalations of micaschists, quartzites and marbles make the gneisses from impermeable basement in the area underlying Precambriann to Cambrian gneisses. The both rocks are overlain by a Miocene intercalation of sedimentary rocks consisting of conglomerates, sandstones and clay stones and Plio-Quaternary intercalation of sedimentary rocks composed of conglomerates, sandstones and claystones discordantly. In the study area, Paleozoic quartzites and marbles form the main reservoir hydrogeologically. Geothermal waters with Na>Ca>Mg cations and HCO3>Cl anions are of Na-HCO3 type and partially equilibrated waters. Geochemical thermometers show reservoir temperatures of up to 185 °C in accordance with measured temperatures in the production wells. Plot of δ18O versus δ2H in geothermal waters of Alâşehir deviate from the GMWL indication an intensive water-rock interaction. In the area of Alâşehir, geothermal waters are of meteoric origin. Finally, geothermal waters of Alâşehir are distinguished by a 2,0 percent CO2 of productions in geothermal power plants especially which can represent an environmental danger in the area for future unless the steams with CO2 contents do not reinject into the geothermal reservoir.

1. Introduction

Within the Menderes Massif, the continental rift zones were generated due to compressional and extensional tectonic regimes. The one of these rift zones is the Gediz which has numerous geothermal waters such as Alâşehir, Salihl (Kurşunlu, Çamurlu), Pamukkale and Urganlı (Figure 1; 1). This paper aims (i) to describe geothermal waters by hydrogeological, hydrogeochemical and isotope geochemical data and (ii) to develop an hydrogeological model for geothermal waters in the area.

2. Material and methods

During the field campaigns in August 2016, measurements of physical parameters and sampling in two production wells carried out.[2; 3; 4]. Water samples were analyzed for cations and anions in the Laboratory of Mineral Research and Exploration Institute, Ankara, Turkey. For evaluation and plot of hydrogeochemical analyses, the software program AquChem version 3.7 software [5] was used. Stable isotopes of δ18O and δ2H and 3h are derived from [6].
3. Results

3.1. Geologic setting
In the area, metamorphic rocks in Paleozoic age form the basement which are overlain by sedimentary rocks in Early to Middle Miocene age discordantly. The metamorphic rocks consist of intercalations of micaschists, carbonate schists and quartzites [3; 4]. In marble and quartzite intercalations within metamorphic rocks, intense faults, fracture, fissure systems and karst spaces were generated comprehensively. Pliocene Kurşunlu formation overlie the Alaşehir formation concordantly. The both sedimentary rocks are overlain by sediments in Pliocene age discordantly. Travertine deposits and alluvium in Quaternary age overlie all the rock sequences discordantly. In the Gediz rift zone, detachment faults formed. Accordingly, Gediz rift zone is of an half graben.

3.2. Hydrogeology
In the area, there are semi-arid and extremely continental climatic conditions with an annual temperature 16,5 °C and annual precipitation of 478,8 mm. The climatic conditions are very important for formation of geothermal reservoir. The mica schists in the area form impermeable basement and cap rocks. Reservoir rocks are of marbles and quartzites. Moreover, the impermeable sedimentary rocks are of cap rocks.
3.3. Hydrogeochemistry

Geothermal waters in two production wells can be led to Na-HCO₃ type waters hydrogeochemically [4]. In the area, geothermal waters display the cations of Na+K>Ca>Mg and anions of HCO₃>Cl>SO₄. In the diagram of Na1/1000-K1/100-Mg, the geothermal waters are of immature waters [4]. Within the water-rock interaction of the study area, carbonate mineral such as aragonite and calcite besides chalcedony seem to be oversaturated at the discharge temperatures. In comparison, mineral phases of anhydrite, fluorite, dolomite, gypsum and quartz are of undersaturated at same discharge temperatures [4] indicating precipitations of carbonate minerals in geothermal waters which agree with observations in deep production wells causing precipitation during extraction. In the area, The SiO₂ thermometers show reservoir temperatures of up to 230 °C which correspond with calculated temperatures by cation thermometers up to 250 °C.

3.4. Isotope geochemistry

Data of stable isotopes of δ¹⁸O, δ²H and δ³H are derived from [6]. Plot of δ¹⁸O versus δ²H shows that the groundwaters and low temperature geothermal waters correspond with the area between MWLEM (Meteoric Water Line for Eastern Mediterranean) and GMWL (Global Meteoric Water Line) whereas high temperature geothermal waters deviate from GMWL indicating intense water-rock interaction [2; 4; 6]. These results are well corroborated by hydrogeochemical analyses indicating intense water-rock interaction caused by reactions with silicate minerals in the rocks. The tritium values of up to 5.45 TU in groundwaters and mixing groundwaters-geothermal waters are of atmospheric and/or anthropogenic origin.

4. Discussion

In the area of Alaşehir, geothermal waters indicate meteoric origin. The meteoric waters in this catchment area flow through fault, fracture and fissure systems and by permeable rocks into the reservoir which is located in a depth of up to 5 km of the reaction zone of a magma chamber. In the reservoir, meteoric waters can be heated by subvolcanic melt and ascend to the surface due to lower density caused by plate tectonical convection cells (Figure 2). The volatiles of magma reach the geothermal waters where an equilibrium between all components must be taken place.

Figure 2. Hydrogeological model of geothermal waters of Baklacı in the continental rift zone of the Gediz.
In this way, geothermal waters ascend through faults, fractures and permeable rocks in the Gediz rift zone to the surface in form of hot springs, steams and gases. In the continental rift zones of the Menderes Massif, (calcalkaline) basic towards intermediate to acidic volcanic rocks with an age from Middle Miocene to recent occur exist which are responsible for heating of geothermal waters in the area. Geothermal waters in Alaşehir contain 2.0 percent CO₂ contents representing very important environmental problems. Therefore, the CO₂ emissions in geothermal power plants in the area must be reinjected into the reservoir. Finally, geothermal waters of Alaşehir are of very important potential in the area with a capacity of up to 250 MWe in next future.

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