Geothermics 65 (2017) 99–112

Contents lists available at ScienceDirect

Geothermics

journal homepage: www.elsevier.com/locate/geothermics

Hydrogeological and hydrochemical studies of the Kaman-Savcili-Büyükoba (Kirsehir) geothermal area, Turkey

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ARTICLE INFO

Article history:
Received 17 November 2015
Received in revised form 30 July 2016
Accepted 7 September 2016

Keywords:
Geothermal
Hydrogeology
Hydrogeochemistry
Kaman
Kirsehir
Turkey

ABSTRACT

The Savcili-Büyükoba (Kirsehir) geothermal area is located in Central Anatolia, about 150 km southeast of Ankara and 5 km north of the Hirfanli Dam. The Savcili-Büyükoba geothermal area is controlled mainly by NE-SW and NW-SE faults. Thermal waters emerge at the intersection of faults. The temperature of the thermal waters in the field varies from 30.0 to 34.6 °C and the electrical conductivity ranges from 513 to 565 μS/cm. The hydrochemical facies of the thermal waters are of the Na-Cl type and those of cold waters are of the Ca-HCO_3 type with respect to the ion concentrations. The thermal waters of the study area plot along the Local Meteoric Water Line (LMWL), and this suggests that the geothermal waters are of a meteoric origin. The low tritium concentrations of the thermal waters show that the thermal aquifer of the Savcili-Büyükoba geothermal area is recharged by groundwater that has a relatively long residence time, which indicates a deep groundwater circulation system. The temperature of the reservoir was calculated to be 68–74 °C using silica geothermometry.

1. Introduction

The study area is centered at 39° 13′N latitude, 33° 40′E longitude and is located in the Kaman province of the city of Kirsehir in Central Anatolia, which is about 150 km southeast of Ankara and 5 km north of the Hirfanli Dam (Fig. 1). The arid climate of the area is characterized by hot, dry summers and cold winters. The mean annual temperature and the total annual rainfall at Savcili are about 11.4 °C and 361 mm, respectively.

Previous investigations have mainly concentrated on geological, geochemical, and petrographic studies. Additionally, research on hydrogeology and hydrochemistry of the thermal waters has been carried out by several researchers (Urgun, 1979; Tekin and Tekin 1986; Onder and Tanidir, 1986; Yurteri, 2014). In the study area, a limited and shallow geophysical resistivity survey has been performed by MTA (General Directorate of Mineral Research and Exploration of Turkey).

The geothermal systems in this area have not been investigated in detail. This study aims to evaluate the potential of the field for future utilization by means of hydrogeochemical characterization. In this context, hydrochemical characteristics of thermal waters in the Savcili-Büyükoba geothermal area are described using results from recent chemical and isotope analysis.

2. Methodology

Isotopic and geochemical techniques, together with geological and geophysical studies, are widely used to define the hydrodynamic structures of geothermal systems. These techniques are vitally important to geothermal investigations, especially in unexplored areas. Geological and detailed hydrogeological investigations were performed first in the Savcili-Büyükoba geothermal area in order to establish the local geological structure and the hydrogeological properties of the lithologic units and to identify possible reservoirs and cap rocks. Then, samples from hot and cold water springs were collected and analysed to determine the origin and chemical characteristics of the thermal waters.

According to the geological map of the study area, at least one spring discharging from each lithological unit was selected as a sampling location (Fig. 2). As can be seen from the sampling map, the cold spring water samples were chosen from the springs that are a part of the local groundwater system, having a high possibility of being located in the recharge area of the thermal springs. Sampling studies were carried out March-August 2014. A total of 24 samples were collected from the study area, representing the aquifers studied (Fig. 3).

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http://dx.doi.org/10.1016/j.geothermics.2016.09.002
0375-6505/

Temperature, pH, and specific electrical conductivity values were measured directly in the field. Water samples were stored in polyethylene bottles for each sampling site. 250 ml of water were collected to determine the anion concentrations, 250 ml for cation and trace element concentrations, 500 ml for tritium analysis, 20 ml for $\delta^{18}O$ and $\delta^{2}H$ isotope analysis. The samples were kept cold until they were sent to the laboratories. Major anion-cation, trace element, and tritium analysis was carried out at Hacettepe University Hydrogeological Engineering Programme Water-Chemistry Laboratory. Major anion-cation and trace element concentrations were determined by atomic absorption spectrophotometry. Sulfate and SiO_2 concentrations were determined by spectrophotometry. Minor and trace element concentrations were determined using ICP/MS (Inductively Coupled Plasma-Mass Spectrometer). Titration methods were used to determine the concentrations of carbonate, bicarbonate, and chloride. Stable isotope analysis was performed by Hacettepe University-UKAM (International Karst Water Resource Research and Application Center), Stable Isotope Laboratory. Standard deviations of the stable isotope analyses were ±0.13‰ for ^{18}O, and ±0.70‰ for deuterium analyses.

Reservoir lithologies were estimated using graphical methods, correlating the relative abundance of ions in individual water samples with those in cold spring waters originating in the different geologic units outcropping in the study area.

Geothermal reservoir temperatures were estimated using silica geothermometers. Stable isotope ratios ($\delta^{18}O$ and $\delta^{2}H$) were used to define hydrological conditions, such as the origin of the thermal waters and the recharge mechanism within the geothermal systems. Based on tritium (^{3}H) data we evaluated recent cold-water contributions to the geothermal fluids and identified local groundwater flow systems.

3. Geologic and hydrogeologic settings

The basement in the study area is composed of metamorphic rock from the Paleozoic; it is called the Kirsehir Massif (Seymen, 1981). The metamorphic rocks of the Kirsehir Massif are overlain tectonically by ophiolitic melange units which comprise basic volcanoclastic rocks intercalated with pelagic deposits of Late Cretaceous age. These units have been intruded by Baranadag Granitoids, which are of Mesozoic (Late Cretaceous-Paleocene) age. The Eocene units which consist of terrestrial sediments (alternating conglomerate and sandstone) and the Miocene-Pliocene Kizilirmak Formation unconformably overlie Mesozoic units (Kara and Dönmez, 1990). Quaternary alluvium, which is the youngest unit in the study area and located along the Hamamozu stream in the middle of the area, unconformably overlies older formations (Fig. 2). The Savcili-Büyükoba geothermal area is mainly controlled by NE-SW and NW-SE faults.

Thermal waters emerge at the intersection of the faults. Paleozoic metamorphics of the Kirsehir Massif, which are the basement rocks of the study area, are impermeable. However, because of the secondary permeability developed as a result of active tectonics, faults and jointed zones of marbles and granitoids are permeable and exhibit characteristics of a local aquifer in the study area. Eocene and Miocene-Pliocene sediments exhibit cap rock prop-

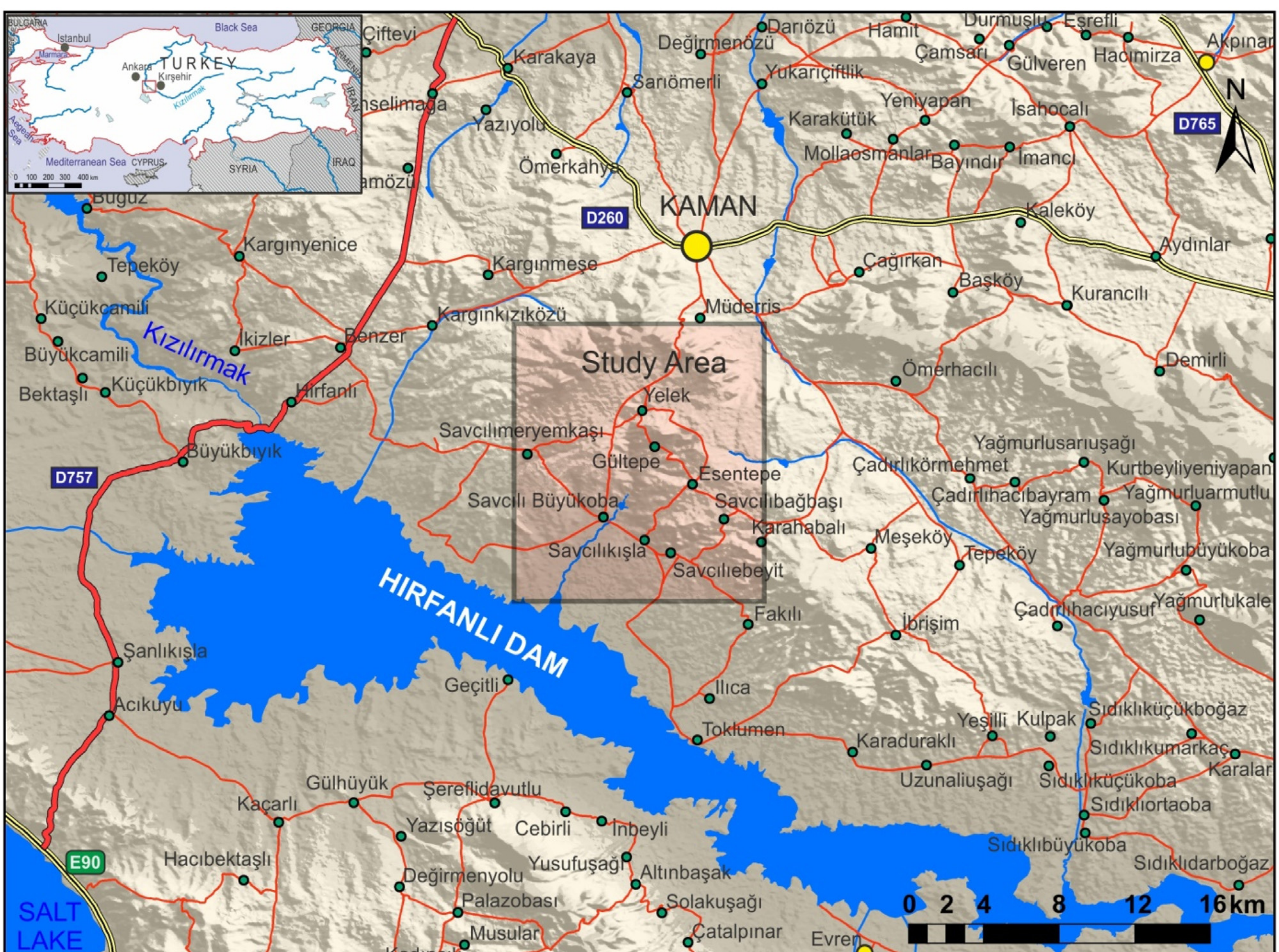

Fig. 1. Location of the Savcili-Büyükoba geothermal area in Central Anatolia.