Determining the Geothermal Potential of the Basiskele Field (Kocaeli, Turkey) Using the Soil Gas Method and Hydrogeochemical Studies

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Abstract

This paper covers the outcomes of hydrogeochemistry and gas geochemistry studies carried out to explore the Başiskele (Kocaeli) geothermal field. In the region that includes the Başiskele geothermal field, the strata include metamorphics belonging to the Rhodope-Pontide, Upper Cretaceous flysch, olistostrome, Middle Eocene volcanic units, Pliocene sedimentary rocks, and Quaternary alluvial deposits, respectively. Many faults and associated geothermal resources within the active North Anatolian Fault Zone have been documented in the literature. In situ radon and soil gas measurements have been made using the sniffing method to detect one of these active faults within this study. Maps created according to the soil gas measurements revealed the active fault zones and locations with geothermal potential. Geophysical studies were focused on these high-potential locations and increased the number of measurements. Çiğdem 1 well-drilled in the study area has shown that the marbles, calcschists, and quartzites belonging to the metamorphics starting after a depth of 830 m gained secondary permeability with fractures. Thus, these units formed the reservoir rocks of the system. According to the Piper and Schöller diagrams, the system's water is in the Na-Cl water class. Chemical analysis results of the water sample were evaluated in the Giggenbach Na–K–Mg diagram to use cation geothermometers to determine the reservoir temperatures. Giggenbach diagram shows that Çiğdem 1 well sample is in the class of waters that are in full equilibrium (mature). The reservoir temperature was calculated with the Na–K thermometer, and it was determined that the calculated temperatures vary between 68.64, and 73.42 °C. The water sample taken at 57 °C from the well has a pH value of 9.1. Based on the hydrochemical features and amounts of prominent elements in water, it has been recommended that this resource be used in balneological and hydrothermal therapy.

Keywords

Geothermal survey · Soil gas · Radon · Hydrogeochemistry · Basiskele geothermal field · Balneology

1 Introduction

The study area is within the borders of Kocaeli Province, Başiskele District in Western Anatolia. This district is in the North Anatolian Fault Zone and is, therefore, suitable for forming geothermal systems. Soil gases have been used as an exploration tool for geothermal energy (Cardellini et al., 2003; Corozza et al., 1993; Finlayson, 1992; Tonami, 1970; Werner & Cardellini, 2006). A soil gas survey has been carried out in the study area. ^{222}Rn and CO_2 concentrations were determined. A first evaluation of the ^{222}Rn ($KbBq/m^3$) and CO_2 concentrations was carried out in tectonic activity, and anomalous emissions of soil gases in the particular points were considered. This paper covers the outcomes of soil gas and hydrogeochemistry studies that were carried out to explore the Başiskele (Kocaeli) geothermal field.

1.1 Geological Background

Tertiary units outcrops in the study area (Fig. 1). The basement of the units observed in the study area consists of two different metamorphic successions with tectonic

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contact. Stratigraphically, Iznik metamorphics consist of recrystallized limestone and meta-clastic rocks. Pamukova metamorphics belonging to the Rhodope-Pontid (Istanbul-Zonguldak) zone are tectonically observed over this unit. In addition, upper Cretaceous (Maastrichtian) flysch and olistostromal Bakacak Formation cover each other with angular unconformity as cover successions, Sarısu Volcanics consisting of Middle Eocene-aged volcanic units and Pliocene Aslanbey formation, again with angular unconformity, overlie this group. The youngest unit observed in the study area is Quaternary-aged alluvial deposits (Fig. 1).

2 Materials and Methods

Soil gas measurements were conducted using an infrared gas analyzer. The method consisted of a special probe connected to a portable infrared spectrophotometer (accuracy 2%) that was inserted into the soil to a depth of 80 cm. After 5 min of cleaning, the concentrations of gases reached a constant value. The Markus 10 is a portable instrument for determining the radon content in the soil. A pumping time of about 30 s was chosen to ensure that all fresh air in the system was pumped out. After the pumping phase, the measuring phase began. Radon gases were measured with the same probe after the gas analyses for each point.

For water analysis, the samples filtered for cations were acidified and adjusted to bring the pH below 2. For anions, analysis was made from the filtered sample. The samples were analyzed by ICP-MS.

3 Results

3.1 Soil Gas Survey

As a result of the soil gas study, active faults that are not visible on the surface in the study area were determined. First, soil gas distribution maps of the region were created according to soil gas measurements.

Regions with the highest positive anomalies in these maps were determined as active fault zones and points with geothermal potential (Fig. 2). It has been determined that active faults in these regions have high outputs of radon gas and carbon dioxide gas compounds. According to the soil gas measurement results, geophysical measurements (resistivity-IP) are envisaged in and around the NW–SE direction active fault zone that traverses the license area as a possible potential area.

3.2 Fluid Geochemistry and Geothermometers

According to the Piper diagram, the water sample taken from the region is in the class of Na + K > Ca + Mg (salt and

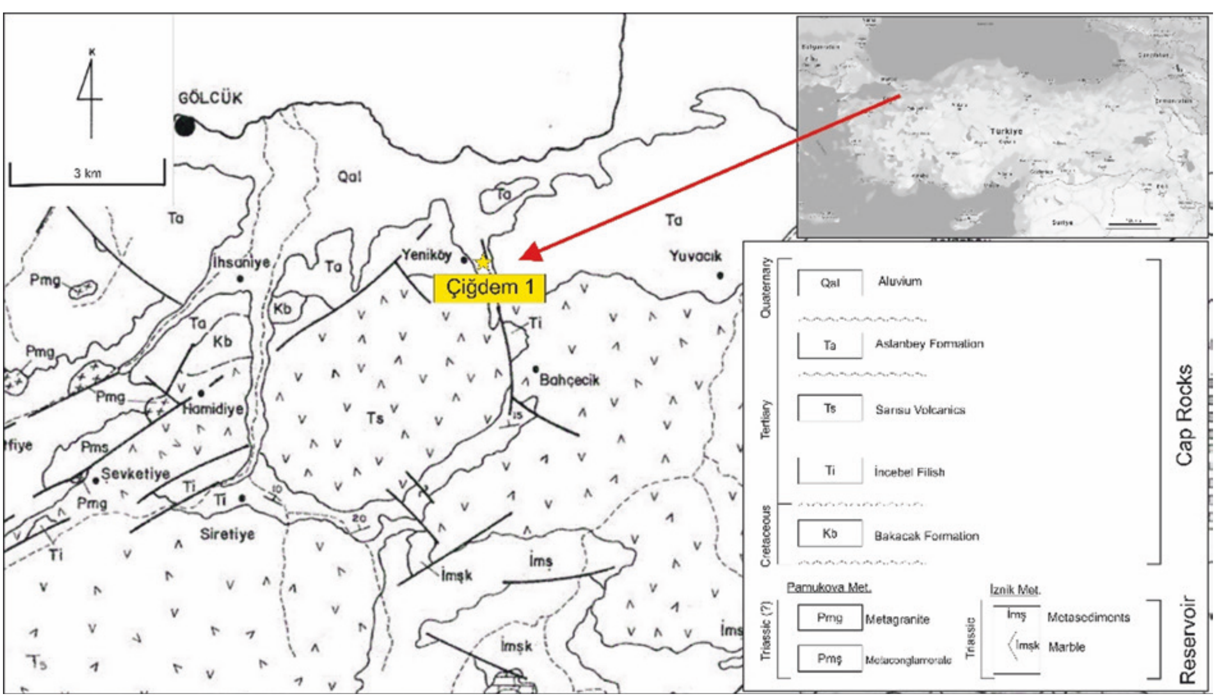

Fig. 1 Simplified geological map of the study area (modified from Erendil et al., 1991)

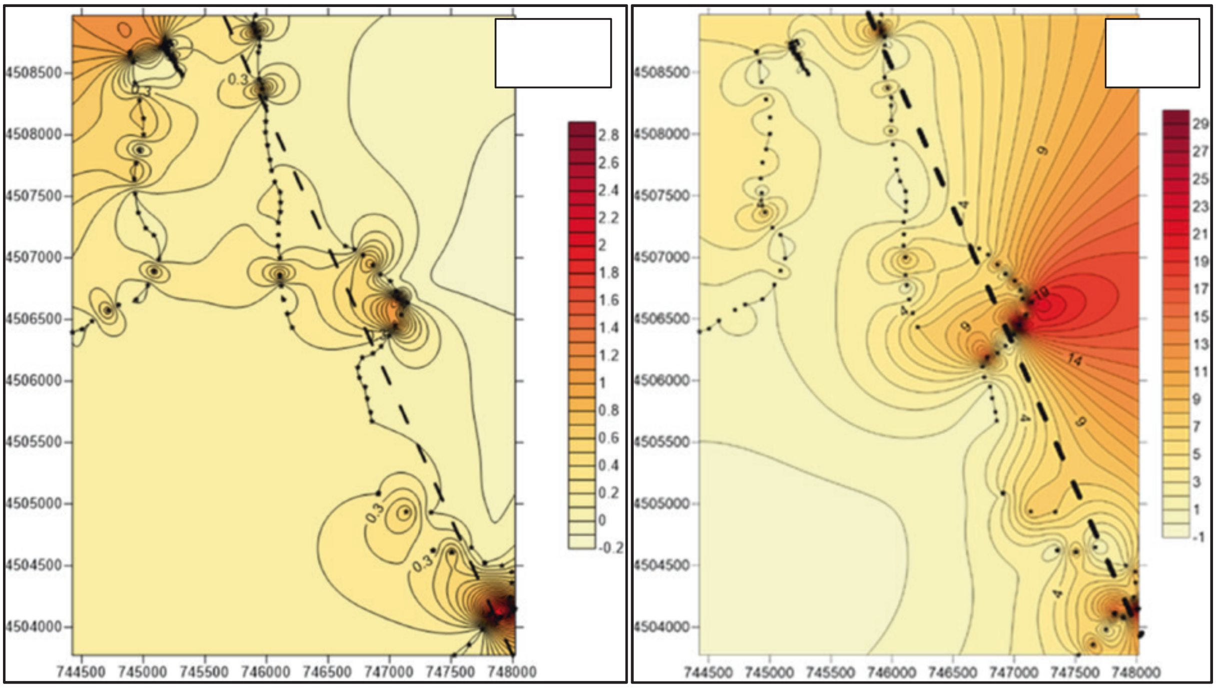

Fig. 2 Distribution map of CO_2 (ppm) gas and radon gas in the study area and possible fault zones (KbBq/m^3)

soda waters), $= Cl + SO_4 > HCO_3 + CO_3$, and non-carbonate alkalinity > carbonate alkalinity (waters with NaCl, Na_2SO_4, and KCl). Furthermore, it is seen that the water sample is in the Na–Cl class (Fig. 3).

According to the Schoeller diagram, the dominant cation of the Çiğdem 1 well sample is Na, and the dominant anion is Cl. Therefore, according to the diagram, this water is in the class of waters with NaCl (Fig. 3).

Chemical analysis results were evaluated in the Giggenbach Na–K–Mg diagram (Giggenbach, 1988) to use cation geothermometers to determine the reservoir rock temperatures. According to the Giggenbach diagram, the sample of Çiğdem 1 well is fully balanced (mature) waters (Fig. 4).

The maturity index (MI) was determined as 3.08 for Çiğdem 1 well sample. As a result, according to the

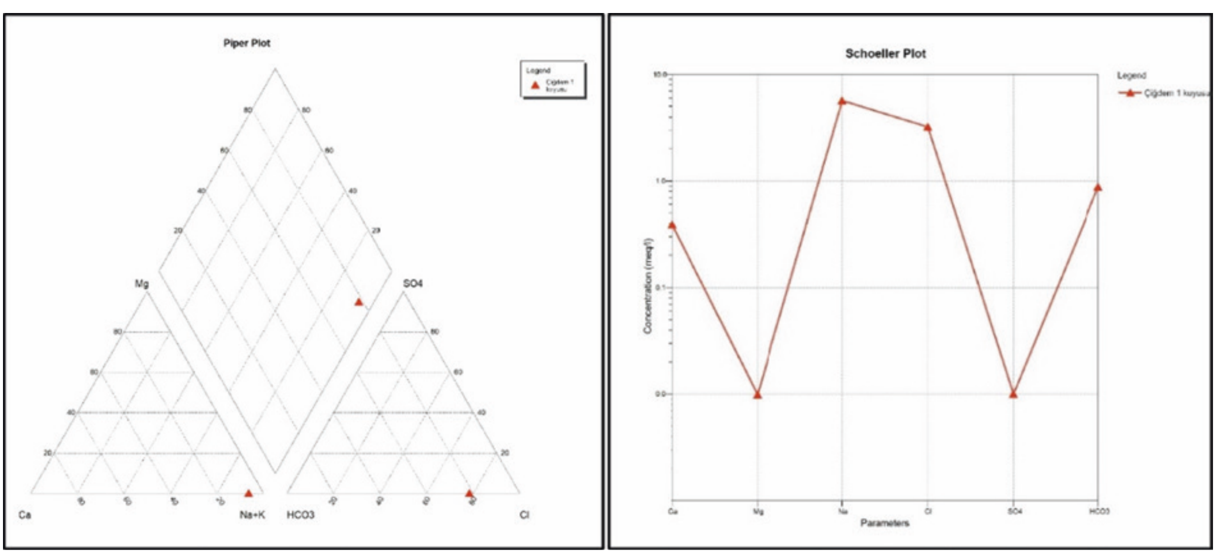

Fig. 3 Representation of the sample of the Çigdem 1 well in the Piper and Schoeller diagrams

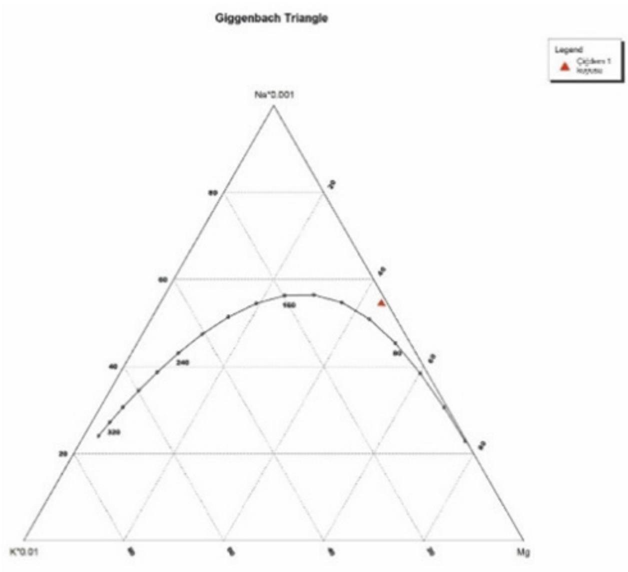

Fig. 4 Position of the Çiğdem-1 well sample in the Giggenbach diagram

Table 1 Na–K geothermometer calculations of Çigdem 1 sample according to various research

Sample	Na mg/L	K mg/L	Ca mg/L	Na–K–Ca ºC	Na–K–Ca ºC	Na–K Arnorsson (1983)	Na–K Fournier (1979)	Na–K Nivea and Nivea (1987)
Çiğdem-1	130.3	0.9	7.8	47	$T_{Na–K–Ca}$ < 70 °C not applicable	68.64	65.02	73.42

Giggenbach diagram, this water sample is in the class of waters in full equilibrium, and Na–K geothermometry can be applied.

Since geothermal aquifers are generally fed by aged groundwater, the use of Na–K geothermometers (cation geothermometers) in these aquifers is preferred. Therefore, many researchers have developed Na–K geothermometer calculations, and some have been calculated for the Çiğdem 1 well sample (Table 1). With the calculations made, the reservoir temperatures of the source were determined.

4 Concluding Remarks

The marbles, calcschists, and quartzites belonging to the metamorphics starting after a depth of 830 m, gained secondary permeability with fractures. Thus, these units formed the reservoir rocks of the system. According to the Piper and Schöller diagrams, the system's water is in the Na-Cl water class. Chemical analysis results of the water sample were evaluated in the Giggenbach Na–K–Mg diagram to use cation geothermometers to determine the reservoir temperatures. Giggenbach diagram shows that Çiğdem 1 well sample is in the class of waters that are in full equilibrium (mature). The reservoir temperature was calculated with the Na–K thermometer, and it was determined that the computed temperatures vary between 68.64 and 73.42 °C. The water sample taken at 57 °C from the well has a pH of 9.1. Based on the hydrochemical features and amount of the prominent elements of the water, it has been recommended that this resource be used in balneological and hydrothermal therapy.

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