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Full Length Article

Conceptual model of the Gülbahçe geothermal system, Western Anatolia, Turkey: Based on structural and hydrogeochemical data

Taygun Uzelli[a], Alper Baba[b,*], Gamze Gül Mungan[b], R. Kadir Dirik[a], Hasan Sözbilir[c]

[a] Hacettepe University, Department of Geological Engineering, 06800, Ankara, Turkey
[b] İzmir Institute of Technology, Geothermal Energy Research and Application Center, 35430, İzmir, Turkey
[c] Dokuz Eylül University, Earthquake Research and Application Center, 35100, İzmir, Turkey

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ABSTRACT

The Gülbahçe Geothermal Field is located on the eastern margin of the Karaburun Peninsula, about 45 km from the city of İzmir, western Anatolia, Turkey. The stratigraphy of the study area is represented by a Miocene volcano-sedimentary succession, including several sedimentary and volcanic units. These units overlie the basement rocks of the Karaburun Platform and Bornova Flysch Zone which consist of sandstones, shales and carbonate blocks. These rock units are cut and deformed by a series of NW-SE- to NE-SW-trending faults, extending from Sığacık Bay to Gülbahçe Bay. Structural studies suggest that while most of the geothermal systems in western Anatolia are controlled by normal faults, the geothermal system at Gülbahçe is controlled by a strike-slip dominated shear zone, previously named the İzmir-Balıkesir Transfer Zone. Along the fault zone, associations of active fault segments accommodate deep circulation of hydrothermally modified sea water, and thus the resulting negative flower structure is the primary control mechanism for the geothermal system.

Hydrogeochemical properties of the field show that surface temperature of fluid ranges from 30 to 34 °C. Geothermal fluids in Gülbahçe have high salinity (EC > 34 mS/cm) and low enthalpy. Piper and Schoeller diagrams indicate that geothermal fluid is in the NaCl facies. Chemical geothermometers suggest that the reservoir temperature is around 53–136 °C. The isotopic data (oxygen-18, deuterium and tritium) suggest that geothermal fluids are formed by local recharge and deep circulation of sea water.

1. Introduction

Geological framework has been an important focus for interpreting and finding suitable locations for geothermal systems without any surface manifestation. Stratigraphic sequence, cap rock, reservoir rock, permeability and porosity, fluid dynamics, fault-fracture relations to regional and/or local stress regime, and heat flow in lithosphere are requisite parameters to develop a favorable geothermal system.

From the global view point, plate tectonics control the thermal conditions in the crust and geothermal systems are shaped by large-scale movements of plates. Likewise, geothermal systems in Turkey fall within the active Alpine-Himalayan Fold and Thrust Belt where the collision of African and Eurasian plates and also the closure of the Tethys Ocean occurs today (Bozkurt, 2001). As part of the Alpine-Himalayan Fold and Thrust Belt, the Aegean Sea, Greece, FYR of Macedonia, Bulgaria, Albania and West Anatolia are located in the Aegean Extensional Province (AEP), which is one of the most rapidly extending and deforming areas on the continent today (Roberts and Jackson, 1991; Bozkurt, 2001; Bozkurt and Mitwede, 2001).

Deformation due to tectonism causes N–S extension and forms normal faulting with the development of many E–W oriented continental basins in the AEP (Şengör et al., 1985; Yilmaz et al., 2000). The graben systems and major faults accompanied by young volcanism form abundant geothermal areas in tectonically-active western Anatolia (Bozkurt, 2001). Geothermal springs in western AEP roughly parallel the trends of the graben-bounding faults of the Menderes Metamorphic Core Complex (MMCC), young volcanism and generally hydrothermally altered areas (Şimsek, 1997; Mutlu and Güleç, 1998; Şimsek et al., 2002; Baba and Ármannsson, 2006; Baba and Sözbilir, 2012) (Fig. 1(**a**)).

Fig. 1 shows the geological map of western Anatolia with the main graben-horst structures which are limited by a major strike-slip shear zone at the western boundary of the region where the study area is located. The strike-slip shear zone, namely the İzmir-Balıkesir Transfer Zone (İBTZ), previously acted as a deep crustal

* Corresponding author.
E-mail addresses: alperbaba@iyte.edu.tr, alperbaba33@yahoo.com (A. Baba).

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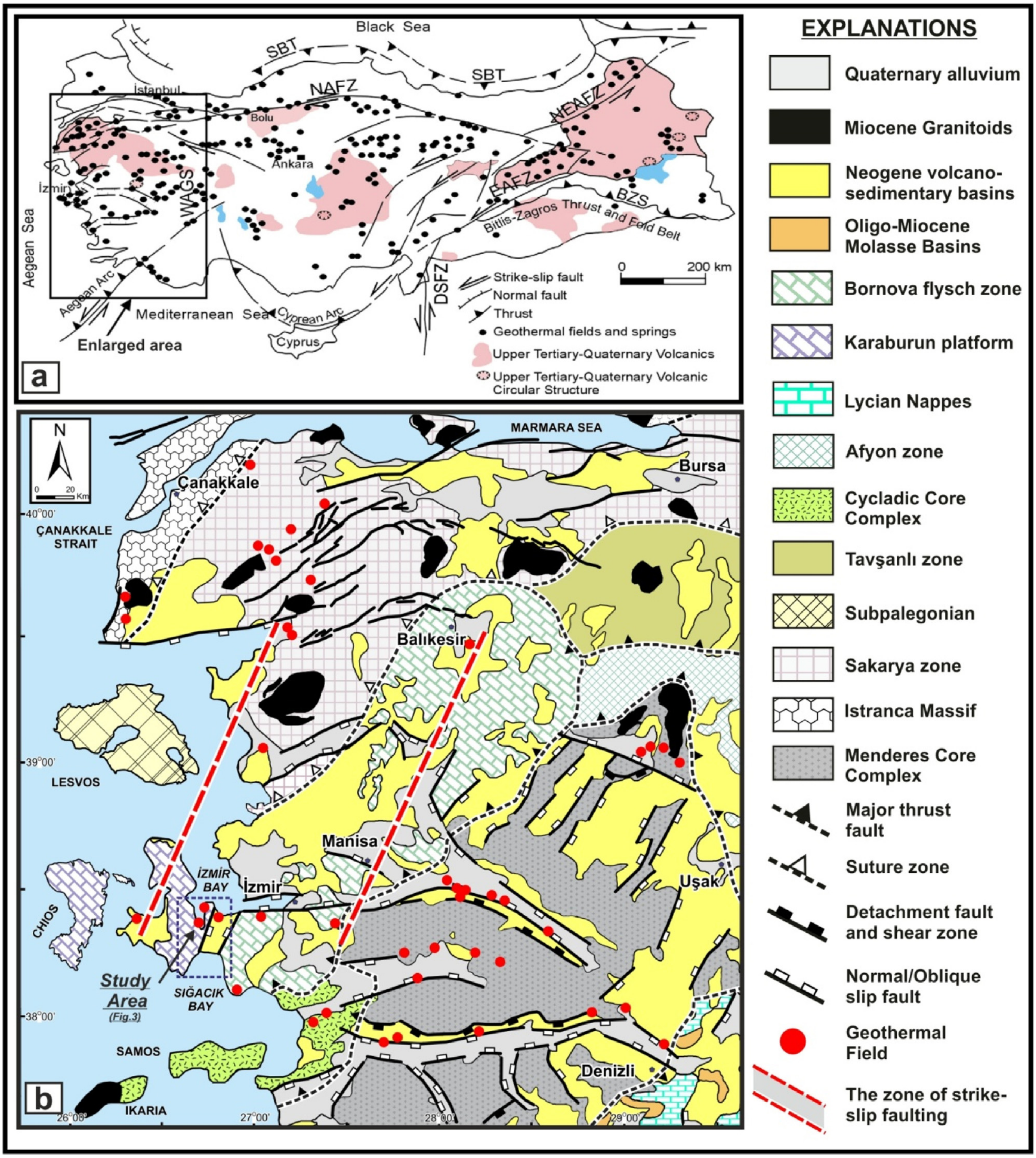

Fig. 1. (a) Tectonic map of the eastern Mediterranean region showing main neotectonic structures and distribution of geothermal areas of Turkey (compiled from; Şimsek et al., 2002; Yiğitbaş et al., 2004; Baba and Armannsson, 2006; Baba and Sözbilir, 2012) (SBT, Southern Black Sea Thrust; NAFZ, North Anatolian Fault Zone; NEAFZ, Northeast Anatolian Fault Zone; EAFZ, Eastern Anatolian Fault Zone; WAGS, Western Anatolian Graben System; DSF, Dead Sea Fault Zone; BZS, Bitlis-Zagros Suture) (b) Simplified tectonic map of western Anatolia with known geothermal fields (after Sözbilir et al., 2011) with the zone of strike-slip faulting.

transform fault zone during the Late Cretaceous, while during the Neogene stress regimes in the region changed and it was controlled by transtensional stresses (Okay and Siyako, 1993; Okay et al., 1996; Ring et al., 1999; Sözbilir et al., 2008; Sözbilir et al., 2011; Özkaymak and Sözbilir, 2008; Uzel and Sözbilir, 2008; Uzel et al., 2012, 2013, 2015; Özkaymak et al., 2011). The transtensional tectonic regime also controls the deformation of pre-Neogene basement rock units, Miocene volcano-sedimentary units and Quaternary units (Fig. 1**(b)).**

The NE-SW-trending İBTZ includes strike-slip faults that generally have N-S, NE-SW and NW-SE orientations. Some of the strike-slip faults form geothermal systems in the region between Balıkesir and İzmir cities. The southern part of the İBTZ, İzmir and its surroundings, contains important geothermal fields such as Balçova, Seferihisar, Dikili, Bergama, Özbek-Ilıksu and Çeşme, and also there are many hot water springs on Karaburun Peninsula. The study area is located on the eastern margin of Karaburun Peninsula