Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

The Seismic Velocity Structures of Western Turkey, New Magma Chamber Found as the Heat Source of Geothermal Fields

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Keywords: Western Turkey, Geothermal, heat source, seismic velocity structures, magma chamber

ABSTRACT

In order to find the heat source of the high-temperature geothermal fields in western Turkey, 2,929 P-waves and 2,793 S-waves data gained from 41 seismic stations in Turkey were selected to perform the 0.5°× 0.5°× 5 km seismic velocity structures. 17360 P-waves and 15367 P-waves first arrived for the time data available that have been extracted. A Fast Marching Method is used in the ray-tracing method inversion and forward algorithm based on subspace. A new magma chamber has been found among the area 36.2°- 38.8°N, 26.8°- 29.6°E, at the depth of 10-50 km. The shallowest area is between Denizli Basin and Simav graben, especially in the Kula volcano area for the obvious low seismic velocity anomaly. This resulted in accordance with the hydro-geochemistry isotope research and deep MT profile. The seismic velocity anomaly coincides with the active faults in the Gediz graben and Menderes graben. It also shows these faults have reached the depth of 15 km, and the temperature is below the Curie point, it provided the access for the material and thermal from the mantle when the crust becomes thin and the magma upwelling.

1. GEOLOGICAL SETTING AND GEOTHERMAL DISTRIBUTION

Western Turkey is located at the north margin of the Eurasian plate. Since the late Oligocene-early Miocene, the African Plate, and the Arabian plate subducted in the north of this region, it put them in the tectonic stress field of back-arc extension. At the same time, as the eastern Arabian plate subducted faster, the crust in the study area moved westward during the stretching process (FIG. 1). In this process, the right strike-slip fault (NAFZ) was formed in northern Turkey, and the left strike-slip fault (EAFZ) was formed in the east. Meanwhile, a series of east-west normal faults, graben and tensile basin landforms were developed (Van Hinsbergen, 2010).

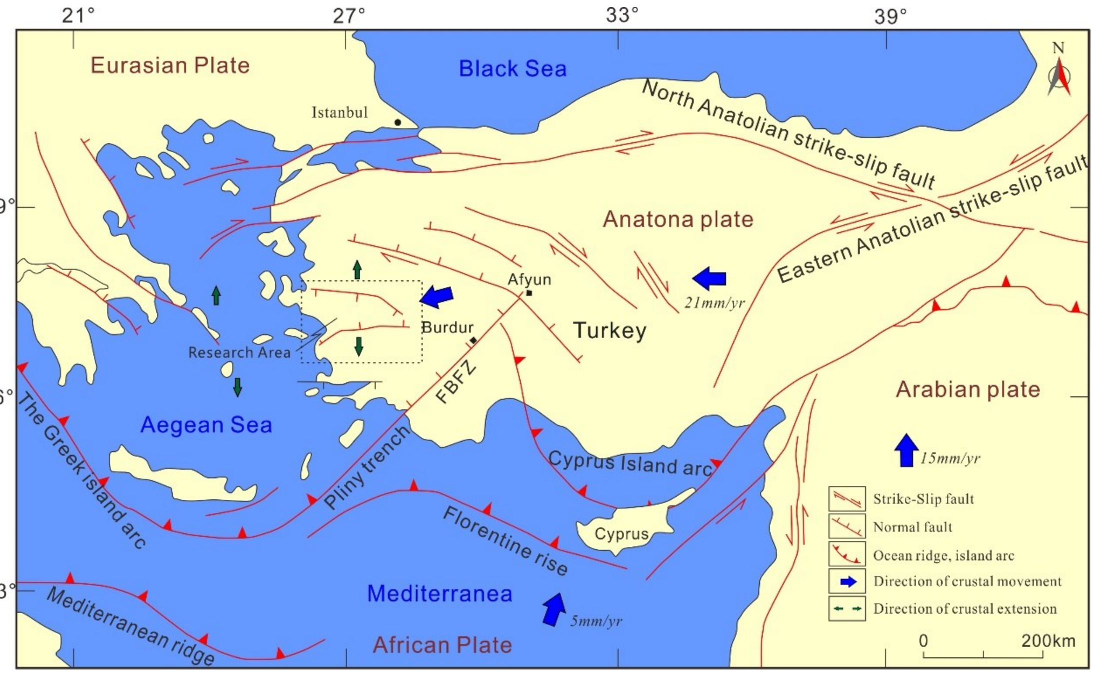

FIG 1. Tectonic location and active fault distribution map of western Turkey. Adapted from Yolsal-Çevikbilen, TaymazHelvacı (2014).

The formation in the study area is mainly a Paleozoic metamorphic basement (Menderes Massif), Neogene Oligocene-early Miocene conglomerate, and Quaternary (Yavuz Hakyemez, Erkal, & Göktas, 1999). The main lithology of the metamorphic basement is marble and gneiss. During the long-term crustal stretching process in the study area, the Neogene strata and quaternary strata of the overlying strata were deposited in graben and tensile basin with a thickness of 1-3 km (Özen, Bülbül, & Tarcan, 2012). Active faults are well developed in the study area, and the types of active faults are mainly deep-seated low-angle detachment faults, high-angle normal faults and strike-slip faults, which control the distribution of thermal fields in the area (Van Hinsbergen, 2010; Oner & Dilek, 2013).

2. DEEP STRUCTURAL CHARACTERISTICS OF THE STUDY AREA

In this paper, the tomography coordinate range is 36.5°-39°N and 27°-30°E. The selected natural seismic events and stations are all located in this research area, and their positions are shown in FIG. 2. With of seismic record of Turkey in 2010-2014, 41 seismic stations in the study area 2929 P wave and the 2793 S wave events were extracted and selected 17360 effective P wave initial motion to the data. Then, at the beginning of 15367 S waves effectively early were moved to the data. Then the use of a quick wavefront advance (Fast Marching Method) ray tracing Method of inversion and forward modeling based on subspace algorithm was used to obtain the crust and upper mantle in western Turkey resolution 0.5 ° * 0.5 ° * 5 km velocity structure. Then the deep structure of the research area is studied in depth. Tomographic imaging is an important tool to study crust and mantle structures. In order to find out crust and mantle velocity structures at different depths, we designed the vertical section arrangement shown in FIG. 3 According to the distribution of seismic events in the study area and previous research results.

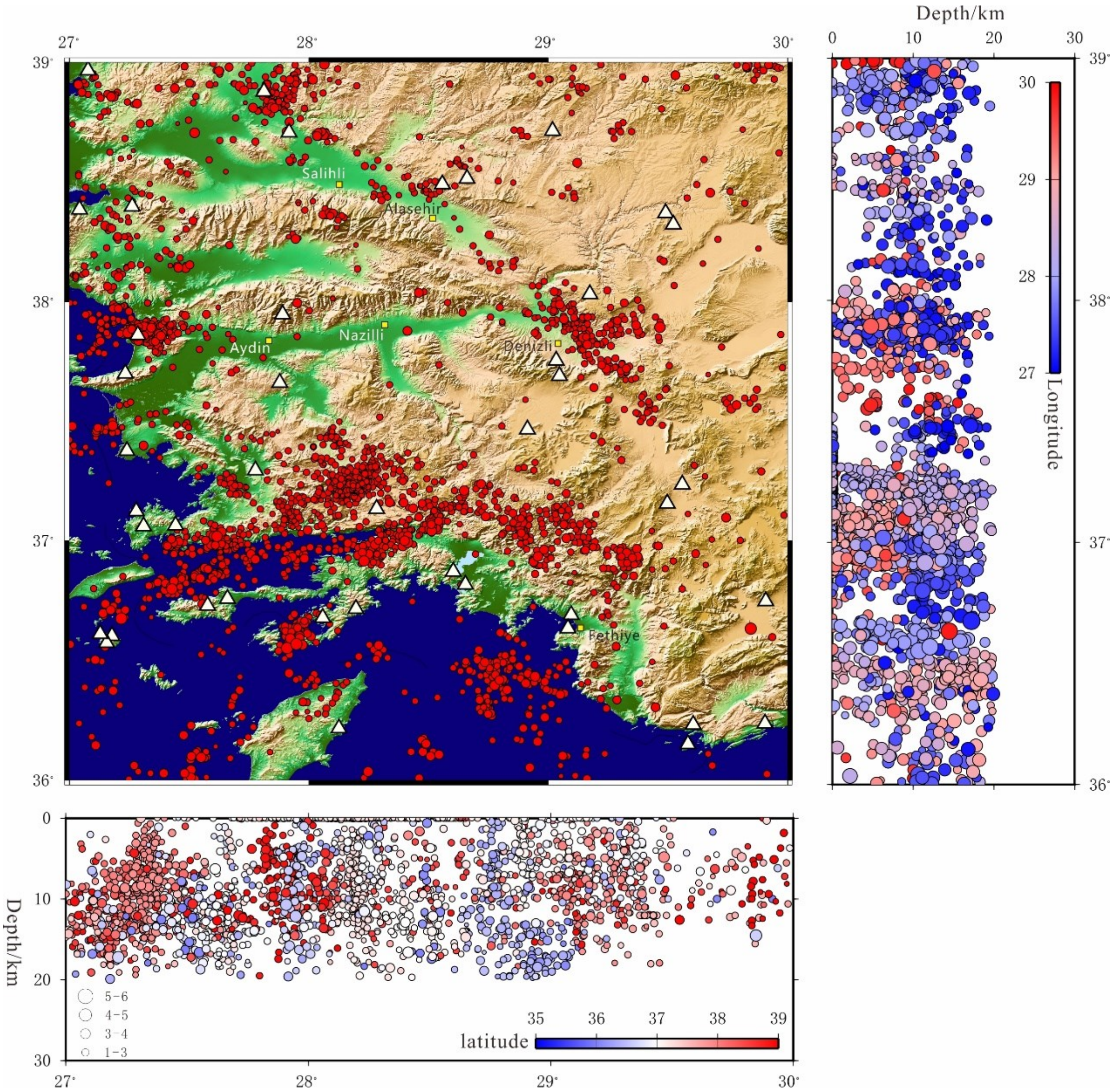

FIG 2 The distribution map of seismic events and seismic networks, with white triangles representing seismic stations and red dots representing seismic events

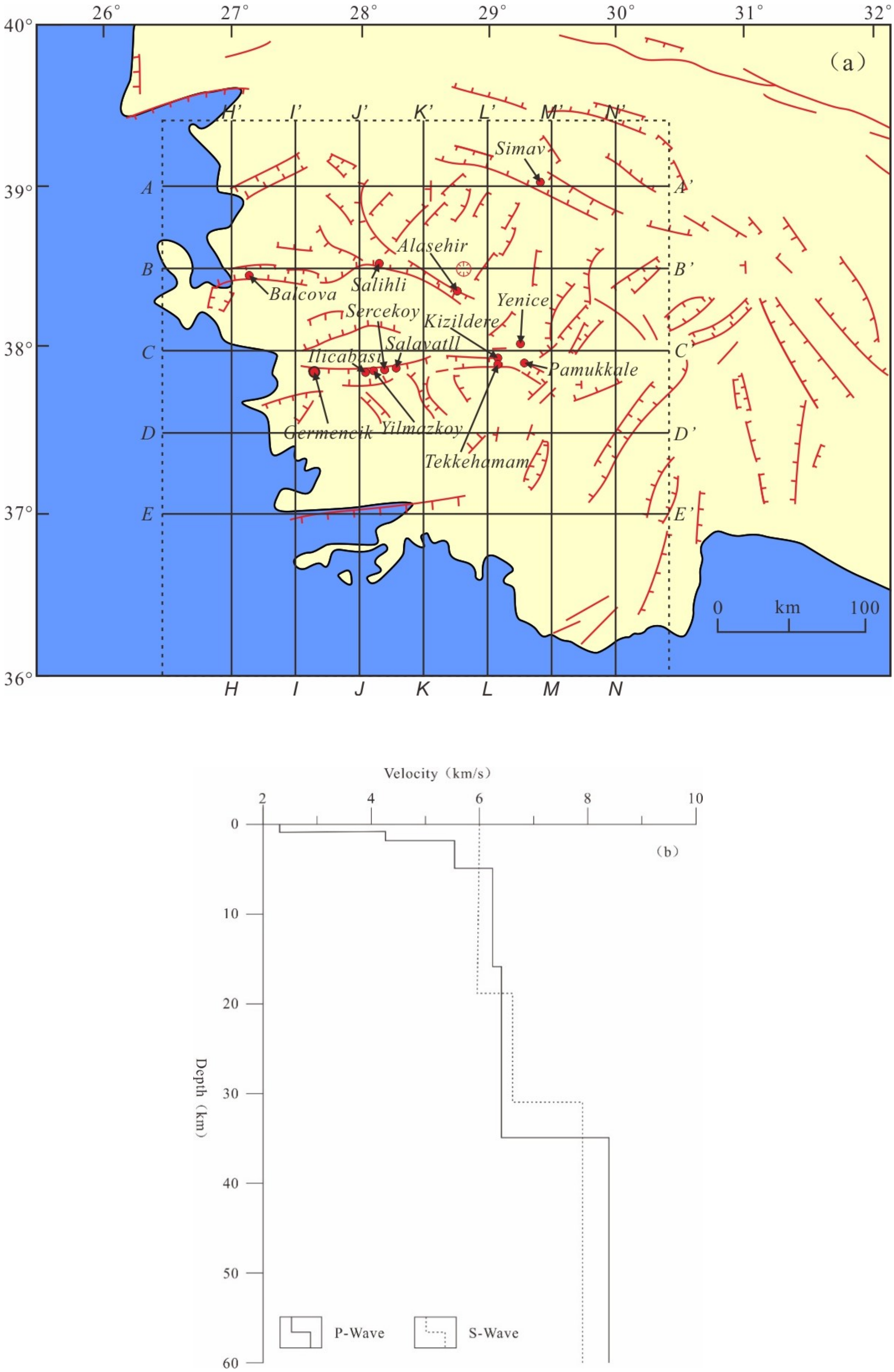

FIG 3. Design of vertical section of tomography in western Turkey (a) and crustal velocity structure (b)

The Poisson ratio is closely related to the composition of deep matter. Previous studies have shown that when the Poisson ratio of the deep matter is between 0.26 and 0.28, the composition of deep matter is moderate (Salah, Sahin, & Destici, 2007; Salah, Şahin, & Aydin, 2011). When it's less than 0.26, it is considered as a quartz-feldspathic rock. Above 0.28, it is a Mafic rock. Because the mantle is rich in iron and magnesium, the upwelling of mantle material is often accompanied by the positive anomaly of Poisson ratio. It can be seen from FIG.4 that, at a depth of 10 km, the Denizli basin and its southern margin have a low Poisson ratio anomaly area with a Poisson ratio of about 0.16, while in the south, there is a high Poisson ratio anomaly area with a wide range and a value greater than 0.4. At a depth of 20 km, low Poisson ratio anomalies appeared in places such as the Denizli basin and Aydin, while high Poisson ratio anomalies appeared in places such as the Nazilli region and south Mugla region. At the depth of 30 km, the Poisson ratio of Aydin and its southern region is higher. At a depth of 40 km, the Poisson ratio of the southern margin of the Denizli basin and the southern side of the Bergama basin is low, while the Poisson ratio of the southern side of the Nazilli-Salihli and Mugla basin is much higher.

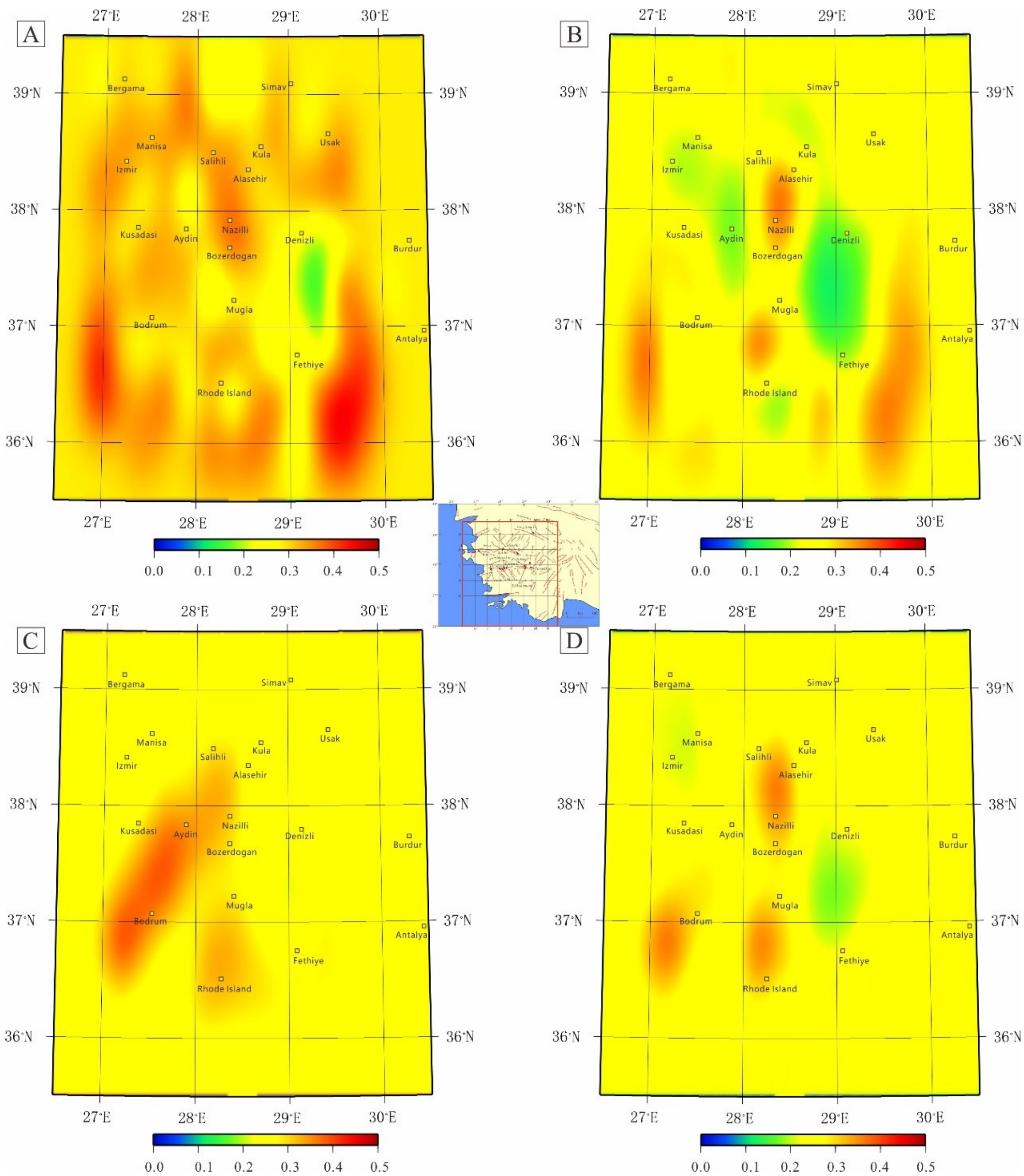

FIG 4. Poisson ratio section in different depth. At a depth of 10 km, B depth of 20 km, C depth of 30 km, D depth of 40 km

In the P-wave section of the KK section (FIG. 5a), from south to north, within a depth of 20 km and a range of 36-38 °N, local high-speed anomalies are shown in a small range, which may show the characteristics of salivary granite. At depths of 36-39°N and 20-55 km, large areas of low-velocity anomalies were also shown, indicating the presence of partially consolidated magma. The S-wave section of the KK section (FIG. 5b) shows a wide range of high-speed anomalies within a depth of 10 km and a range of 36-39 °N from south to north, probably showing the physical characteristics of Neogene sediments in the Menderes graben. At depths of 36.2-37 °N and 38.2-39 °N depths of 12-25 km, large areas of low-velocity anomalies are also shown, indicating that there may be partially consolidated magma. In the Poisson ratio section of the KK section (FIG. 5c), it can be seen that within 38°N and 30 km in-depth, the Poisson ratio is relatively high and mushroom-like, indicating the upwelling phenomenon of magma. Within the range of 10 km-20 km depth, the Poisson ratio is also high, indicating that there is deep mantle material.

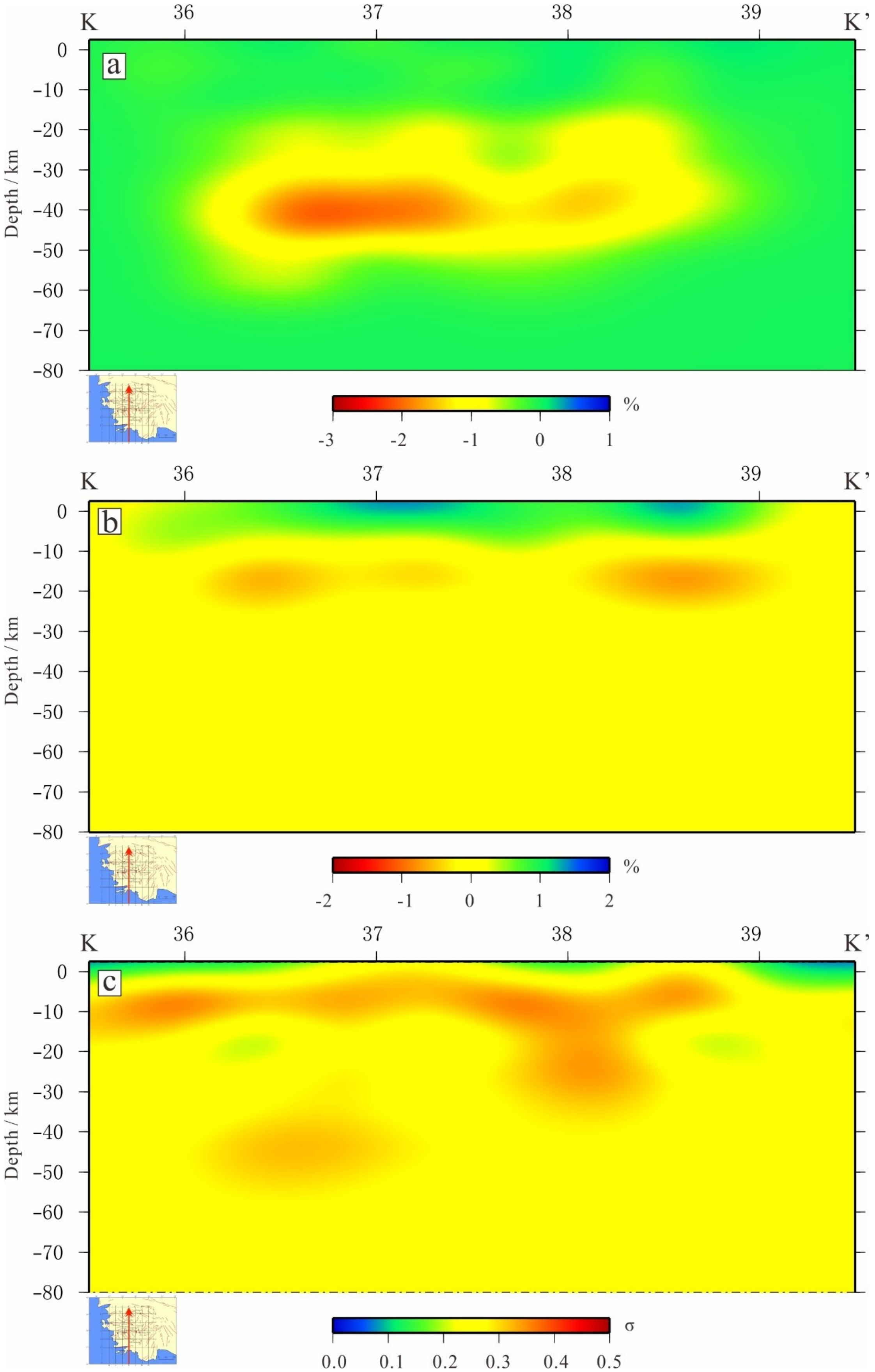

FIG 5 P wave velocity (a), S wave velocity (b), and Poisson ratio (c) of KK 'vertical slice.

3. CONCLUSION

Van Hinsbergen et al. (2010) show how the tomography reflect the study area at 300 km depth mantle upwelling of the material and heat flow along the delamination block. Gurer and Bayrak (2007) believe that deep Magnetotelluric sounding shows the mantle heat flow along the north of the study area of the North Anatolian strike-slip faults and the southeast of Anatolia strike-slip faults upwelling (Gürer & Bayrak, 2007). In this study, the tomography for the first time carefully controlled the spatial distribution of the magma sac in the study area and the velocity anomaly of the deep active fault in the study area (FIG. 6).

Through the study of the distribution characteristics and rules of geothermal anomalies in the study area, as well as the exploration of its geological origin, deep structural origin and dynamic mechanism, combined with the above research results, allowed us to obtain a comprehensive model of the geothermal anomaly mechanism in the study area. The genetic mechanism of regional geothermal anomalies is as follows: (1) the subduction of the African plate has led to the establishment of such a process in the post-arc tensile tectonic stress field, deep tomography, GPS crustal deformation monitoring and other geological models in the study area since the Neogene. (2) in the process of stretching, a series of east-west detachment normal faults are produced, mainly including the Alasehir detachment fault which inclines to the north of the fault plane and the Menderes detachment fault which inclines to the south of the fault plane. These faults have been active for a long time, and the cutting depth has reached the lower crust, forming a good channel. (3) The volcano and magma upwelling along the channel formed the deep magma sac, the Kula volcano group, and the Bozdag granite area. (4) Mantle heat flow upwelling along the channel provides energy and material basis for geothermal anomalies and frequent earthquakes. (5) In this context, today's geothermal anomaly distribution pattern is formed in the study area, and there is a significant correlation between the frequency of earthquakes and geothermal anomaly distribution.

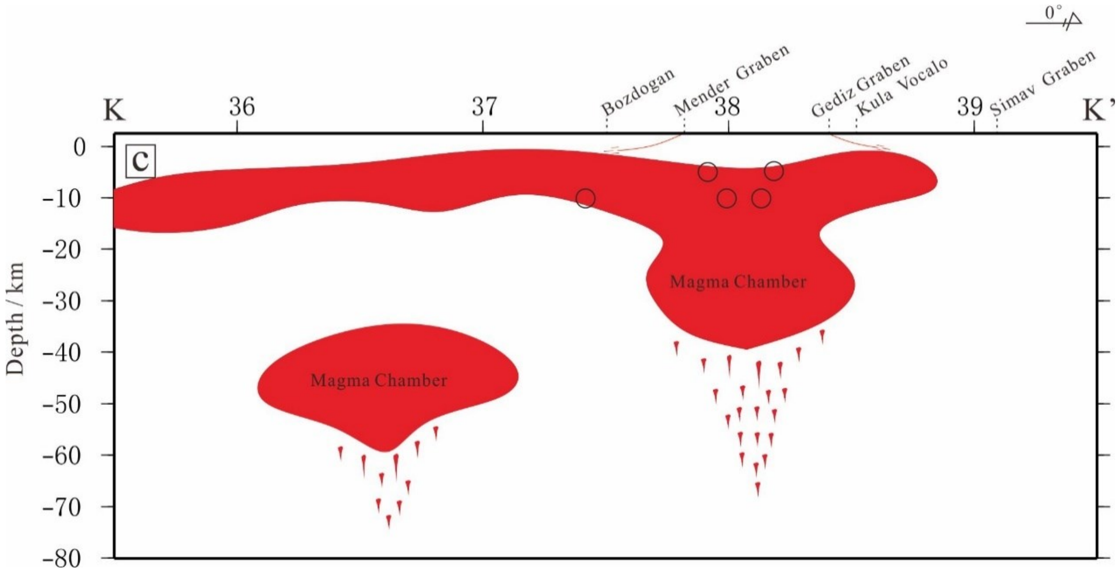

FIG 6 Geothermal genetic model of the study area According to the KK section, this section is very consistent with previous research achievements in regional geophysics, hydro-geochemistry, and other aspects. The lower Poisson ratio material at the top may represent the Neogene and quaternary sediments in the graben, consistent with regional gravity data and interpretation of drilling data.

The crustal thickness of eastern Turkey is 40-45 km, and that of the western part of Turkey is 20-25 km, which shows the process of crustal stretching and thinning under the back-arc extensional tectonic background, providing favorable conditions for mantle uplift. The influence of this process on active faults is that the fault keeps moving and cutting deeper, providing a tectonic channel for the upwelling of deep mantle energy and materials. The influence on volcanic magmatism is that deep magma can upwelling, providing material for magma emplacement and even volcanic eruption. The influence on geothermal energy is that the activity of faults and the upwelling of magma provide the thermal, recharge fluid and heat sources for the formation of geothermal anomalies. Earthquakes are often accompanied by geothermal because this tectonic background can also provide energy and material for Earthquakes. The occurrence of the earthquake can make the channel more open, more abundant geothermal, geothermal circulation, also can produce more energy accumulation and the gestation of the earthquake.

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