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Research paper

Crustal thickness variations in the Eastern Mediterranean and southern Aegean region

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A B S T R A C T

In this paper, regional analog gravity anomaly map obtained from the General Directorate of Mineral Research and Exploration (MTA) was digitized and used for the calculation of the crustal thickness (Moho depth) variations in the Eastern Mediterranean and the southern part of the Aegean Region. In the gravity anomaly map, there are mainly E–W trending apparent gravity anomalies represented by the contours up to 150 mGal. They are generally parallel to the shorelines of Africa, Turkey and Crete. Crustal thickness variations were calculated from the gravity anomalies, using an empirical equation in this study. Obtained thicknesses (Moho depths) were mapped and correlated with the previous investigations and seismological findings. According to the estimations, crustal thicknesses are about 25–30 km along the coastal regions and more than 30 km on the onshore part of Turkey increasing up to 42 km through the eastern Anatolia. However, there are thin crustal zones around 17 km in the offshore Egypt, to the NW part of Cyprus and about 19 km to the north of Crete. They may be related with the main tectonic trends in this region except the circular thinning to the south of Kas (southwestern part of Turkey). In order to determine the locations and boundaries of prominent tectonic elements, Analytic Signal (AS) and maxspots maps of the gravity anomalies were also prepared in this study. All produced maps are generally consistent to each other and the boundaries of main tectonic units were apparently illustrated in the maxspots map from the horizontal gradient of Bouguer anomalies.

1. Introduction

Tectonic framework of the Eastern Mediterranean is dominated by the subduction of the African Plate beneath the Eurasian Plate (Fig. 1). In addition, the Anatolian Plate has been converging through the Aegean Sea and Greece with the counter-clockwise rotational tectonic escapement (30–40 mm/y; Le Pichon et al., 1995). This movement is controlled by two strike-slip fault systems (Fig. 1); the North Anatolian Fault-NAF and the East Anatolian Fault-EAF (Ketin, 1948; McKenzie, 1972; Le Pichon and Angelier, 1979; Sengor and Yilmaz, 1981). The African Plate subduction beneath the Anatolian Block triggered N-S directional extension in the western Anatolia (Sengor and Yilmaz, 1981) and crustal thickness was found about 34 km to the east and 25 km to the further west of the onshore Aegean region (Ates et al., 2012) under the influence of extension. Tectonics of the Aegean zone can be summarized by its rapid extension characteristics that allows to consider this region as one of the world's most rapidly extending crustal thinning zone (the extension rate was given as 14 ± 5 mm/yr by Reilinger et al., 1997; McClusky et al., 2000).

Tectonic model of the Eastern Mediterranean can be explained by the subduction of the African Plate dipping north beneath the Aegean Sea (Eurasian Plate) through the Hellenic and Cyprian arcs from west and to the east, respectively (McKenzie, 1978; Le Pichon and Angelier, 1979; Le Pichon, 1982). The most active part of the subduction is observed around the southern Aegean or Hellenic trench. Tomographic results indicated a high-velocity anomaly dipping north, down to 600 km beneath the Hellenic arc and it was interpreted as the subducting lithosphere of the African Plate (Wortel et al., 1990).

Crustal thicknesses in the study area were calculated previously for very limited zones, mainly based on the seismological studies. However, there is no investigation to cover entire region for the Eastern Mediterranean, whether based on seismological

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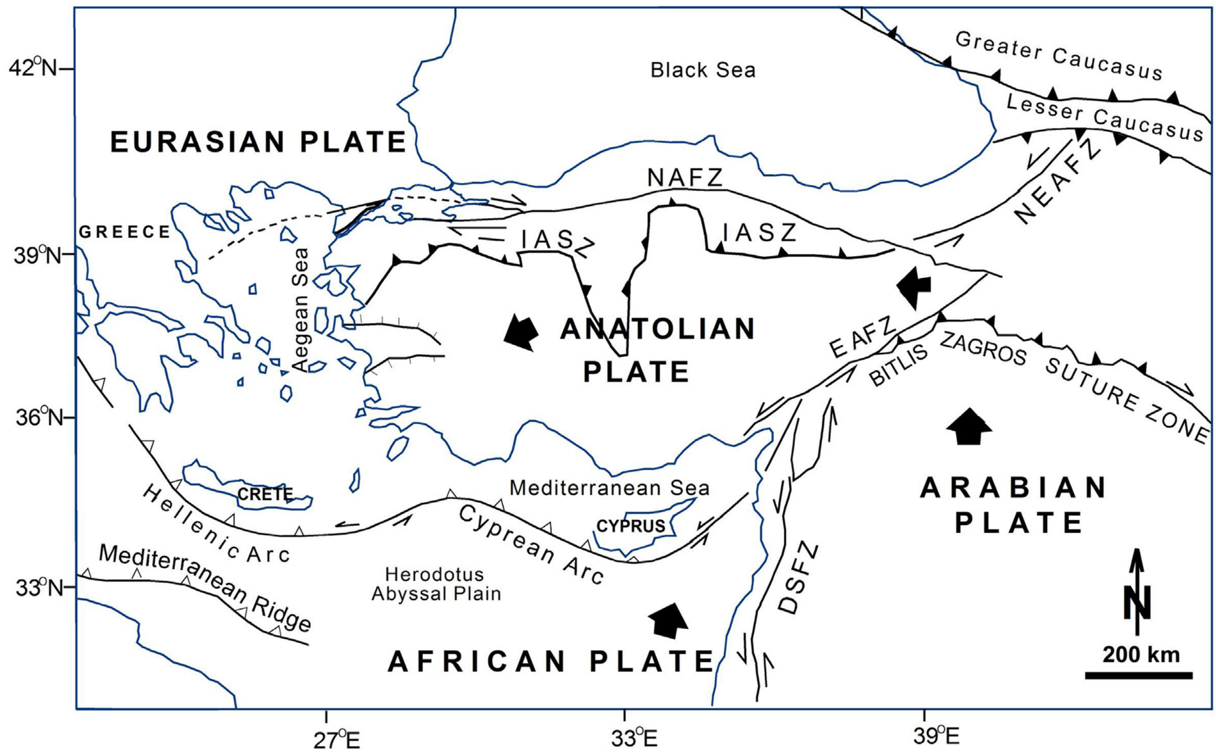

Fig. 1. The major tectonic elements in and around Turkey, and Eastern Mediterranean region (modified from Bozkurt and Mittwede, 2005). The large arrows show relative motions of the Anatolian Block and convergent motions of the African Plate and Arabian Platform. NAFZ: North Anatolian Fault Zone, DSFZ: Dead Sea Fault Zone, NEAFZ: North-East Anatolian Fault Zone, EAFZ: East Anatolian Fault Zone, IASZ: Izmir-Ankara-Erzincan Suture Zone.

observations or estimations from the gravity data. Zelt et al. (2005) performed a 2D inversion of refraction and reflection traveltimes along an axial seismic profile through Gulf of Corinth, Greece and found the Moho depth at 29 km to the east and 39 km to the west of the Corinth strait. Crustal thickness to the east of the Corinth is consistent with the results of Sodoudi et al. (2006) where they calculated the Moho depths using the P and S receiver functions. In their research, they found shallow Moho depths in the Aegean Sea to the north of Crete, varying between 19 and 26 km. Van der Meijde et al. (2003) also analysed receiver functions below 17 seismological stations in the Mediterranean region and North Africa. Three stations in their investigations are located in the area of our study and they found Moho depth 25 ± 1.4 km below the station KOUM to the south of Izmir, 29 ± 2.3 km below APER station to the east of Crete and 32 ± 1.1 km below the station named KEG to the south of Port Said. Di Luccio and Pasyanos (2007) used surface wave dispersion curves in the analysis and found shallower crust in the Ionian Sea, southern Italy (8–16 km) and the central part of the Eastern Mediterranean (16–24 km). Their calculations in the southern, central-western Aegean are in the range of 20–25 km and consistent with this study. Recently, ElGabry et al. (2013) investigated the crustal thickness and mantle structure of the Eastern Mediterranean using the non-linear inversion of Rayleigh wave dispersion curves extracted from the broad-band records on the profiles along the Hellenic and Cyprian arcs. In the first profile (Hellenic arc profile), they found the average thickness around 31 km and they stated that the Moho depth decreases gradually down to 21 km under the Aegean Sea, to the north of Crete. In the Cyprian arc profile, the Moho was found at a depth of 37 km in the Sinai Peninsula to the south, rapidly rising to 21 km below the Levantine Basin (to the south of Cyprus) that is known as the Herodotus Abyssal Plain as well. Similar to the seismological investigations, crustal thickness calculations based on the gravity data or gravity modeling were performed for the limited zones or regions in the Aegean region, Turkey, Middle East and North Africa. A study covering large area was accomplished by Seber et al. (2001), attempting to develop a crustal model for the Middle East and North Africa region. In their study, they presented a 3D crustal model after they integrated and interpolated rock thicknesses and Moho depth measurements in this part of the world. The Eastern Mediterranean region was represented by 20–25 km Moho depths in general. The shallowest zone was given with the 10–15 km interval to the south of Crete and the Herodotus Abyssal Plain. Makris and Stobbe (1984) also created a crustal thickness map of the area interested, deduced from the geophysical data. They found two different shallowest zones; one of them is located to the NW of Alexandria and the second one to the NW of Cyprus about 22 km. The other shallow zone to the north of Crete is about 24 km in their map. Casten and Snopek (2006) compiled the gravity data from the land, marine and satellite sources in the area including the Hellenic subduction zone and they obtained a Bouguer anomaly map range from +170 mGal to −10 mGal. After the 3D gravity modeling study, they found the Moho depths less than 20 km under the Cretan Sea (to the north of Crete) and it gets deeper to the south of the island (around 30 km). They proposed extremely thick sedimentary cover (up to 18 km) around the Mediterranean Ridge and the Herodotus Abyssal Plain. Tirel et al. (2004) calculated maximum thinning of the crust to the north of Crete (around 22 km) and they estimated an average thickness of 25 km to the north of Cretan Sea (the area of Cyclades islands) where the rigid block-type behaviour was suggested during the post-Miocene times. Staackmann et al. (2008) found similar results (20 km of Moho depth beneath the Cretan Sea) with Tirel