GPS study of N-S trending Karaburun Belt (Turkey) and its E-W Trending Eastern Part

Muzaffer KAHVECİ, Oya PAMUKÇU, Ayça ÇIRMIK and Tolga GÖNENÇ, Turkey

Key words: GPS, Tectonic Elements, Karaburun Belt, Western Anatolia

SUMMARY

In the study area generally, there are N-S trending main faults and fault zones from Karaburun Peninsula through to the east. On the east of these faults, the characters of the tectonic elements rapidly turn to E-W trending basins after passing a certain border. Therefore, it can be thought that the kinematic of the area is affected by multiple influences. In order to investigate this kinematic structure in detail, episodic GPS campaigns were carried out in the area at 21 GPS stations in the years 2009, 2010 and 2011. GPS observations were processed by using GAMIT/GLOBK software. The computed displacements of the study area were analyzed with the relative Anatolian block fixed frame solutions and in these solutions it was pointed out that the velocity directions were generally towards S-SE and SW. Finally, these solutions were presented with tectonic structures of the study area, therefore, the borders of the N-S trending main faults and fault zones were determined and at the east, the initial border of the E-W trending basins was defined by noticing the changes of the GPS velocity directions. In particular, the non-uniformity of the fault zones were monitored in the Anatolian block fixed solutions. These results were examined with the earthquakes occurred in the study area since 1973. It was identified that the seismicity was higher on the Karaburun belt and its surrounding respectively to the east part wherein the E-W trending tectonic elements located. The border which separates the seismicity differences is coherent with the velocity direction changing border of GPS vectors. Additionally, the orientation of the seismic activity and the trending of the tectonic structures at eastern part of Karaburun are figured out coherent with the GPS velocity directions.

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1. INTRODUCTION

The study area which includes Karaburun (Belt) Peninsula and its surrounding locates in Izmir city and Western Anatolia (Figure 1). The Western Anatolia is one of the most active extensional regions in the world (McKenzie, 1978; Le Pichon and Angelier, 1979; Jackson and McKenzie, 1988; Goldsworthy et al., 2002; Nyst and Thatcher, 2004). The E-W trending graben system is the main tectonic structure of Western Anatolia, additionally; NE-SW trending basins which are located at NE side of E-W trending graben system are also effective at the complex tectonism of Western Anatolia (Bozkurt, 2001) (Figure 1). In Izmir and its surrounding, the dominant faults are the NE-SW directional dextral strike-slip faults and among them the most important faults are Seferihisar fault, Orhanlı fault zone and Gülbahçe fault zone (Inci et al., 2003; Emre et al., 2005; Sözbilir et al., 2009, 2011) (Figure 2). Gülbahçe fault zone borders the N-S directional Karaburun Peninsula at the east (Emre et al., 2005) (Figure 2). Karaburun fault zone which locates northern of Karaburun Peninsula is effective at the south-western of Izmir Bay. Besides, the E-W directional normal faults which locate throughout northern and southern of the Izmir Bay are the other significant faults for Izmir and its surroundings (Uzel et al., 2013) (Figure 2).

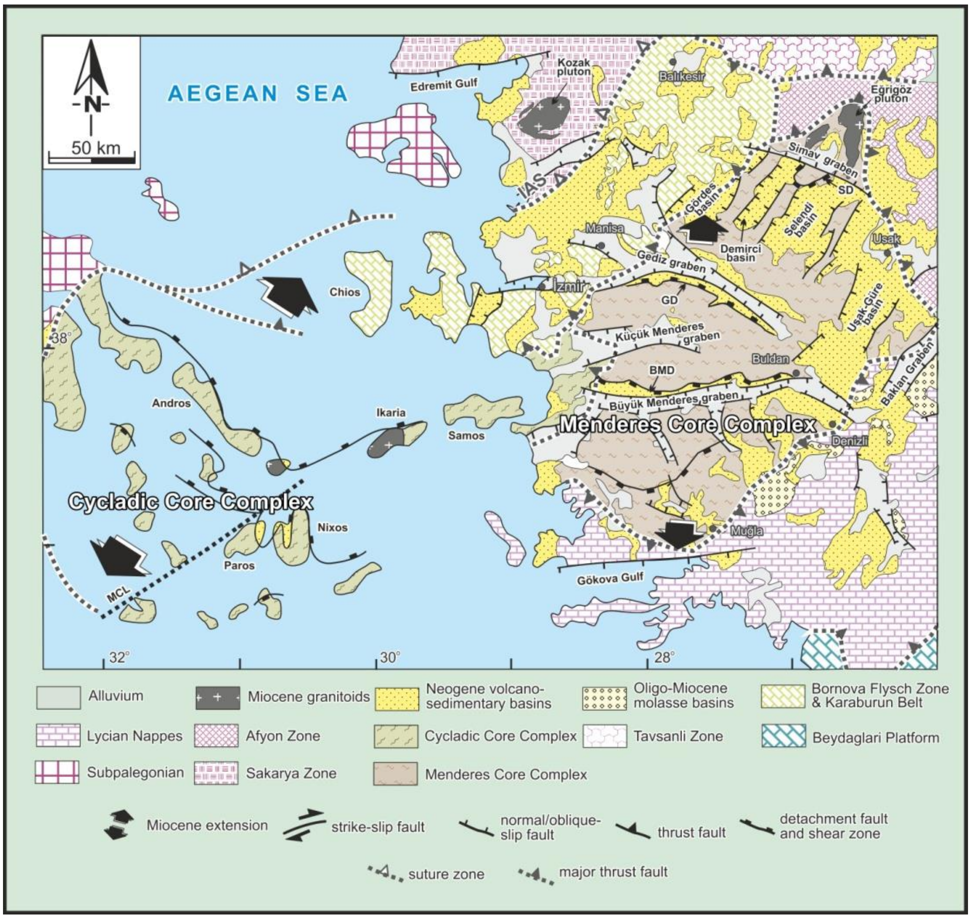

Figure 1. Main geological structure of Western Anatolia (Sözbilir et al., 2011; Uzel et al., 2013; Uzel, 2016).

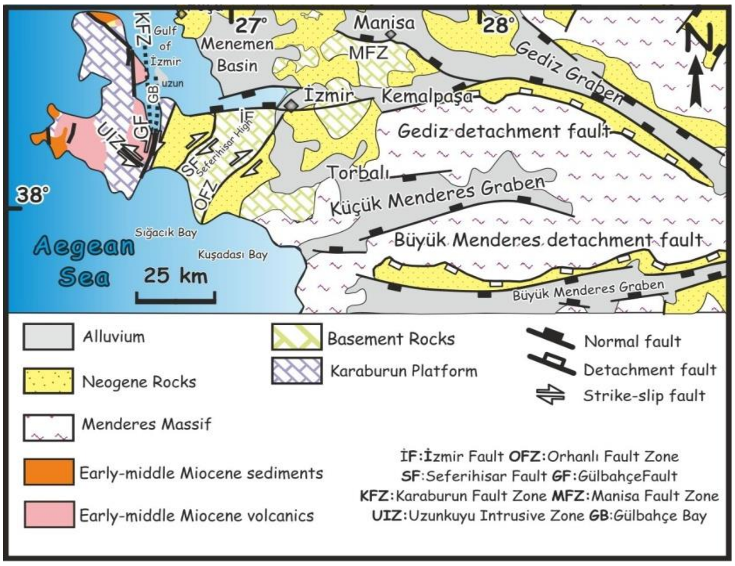

Figure 2. Main geological structure of Izmir and its surroundings (modified from Uzel et al., 2013).

In the study of Nyst and Thatcher (2004), according to the GPS observations, some dissimilarity in the GPS velocity vectors was found out between Western Anatolia and Izmir city. Additionally, Gessner et al. (2013) mentioned the existence of a N-S directional transfer zone, namely; Western Anatolia Transfer Zone (WATZ), approximately at 27.5-28º longitude by using the earthquake focal depths. Therefore, for analyzing the difference on the kinematic motions of Izmir and Western Anatolia, GPS observations which were realized in 2009, 2010 and 2011 around Izmir (Pamukçu et al. 2015a, 2015b; Çırmık et al., 2017a; supported by The Scientific and Technological Research Council of Turkey (TUBITAK) project No: 108Y285) and GPS data of two national GPS projects namely; the "Continuously Operating Reference Stations-Turkey" (CORS-TR) (obtained with the support of Dokuz Eylül University Scientific Research Foundation Grant BAP-Project No: 2012.KB.FEN.126) and "Multi-Disciplinary Earthquake Researches in High Risk Regions of Turkey Representing Different Tectonic Regimes (TURDEP)" were processed together with GAMIT/GLOBK software (Herring et al., 2015). In this study for investigating the interplate motions of the region, the Anatolian block fixed frame solutions which were realized by using the Euler vectors relative to Eurasia for Anatolian block (Reilinger et al., 2006) were calculated. Therefore, the study region is grouped into 3 zones due to the dissimilarities on the GPS velocity directions. Additionally, these findings were evaluated with the earthquakes occurred in the study area since 1973. It was found that the seismicity was higher on the Karaburun belt and its surrounding relative to the eastern side wherein the E-W trending tectonic elements located. Consequently, the border which separates the seismicity differences is coherent with the velocity direction changing border of GPS vectors. Additionally, the orientation of the seismic activity and the trending of the tectonic structures at eastern part of Karaburun are figured out coherent with the GPS velocity directions.

2. PERFORMING AND PROCESSING GPS OBSERVATIONS

In this study, as difference from the previous studies (McClusky et al., 2000; Reilinger et al., 2006; Çırmık, 2014; Pamukçu et al., 2015 a; b, Çırmık et al., 2016; 2017a) GPS data of Izmir and surrounding which include Karaburun Peninsula was processed together with GPS data of Western Anatolia and besides, the Anatolian block fixed frame solutions were performed as the first time in this study for investigating the relationship between Izmir (and surrounding) and N-S directional graben system of Western Anatolia.

In the studies of Pamukçu et al. (2015 a; b) and Çırmık et al., (2017a), the GPS observations were obtained in 2009, 2010 and 2011at 21 stations of the GPS network which were built in the south of Izmir. In 2009, the GPS observations were performed for 3 session days in two groups (Day of Year/DOY: 183-185 and 186-190). In each group, 10 stations were observed per session for 10 hours. The station "UZUN" was observed for 4 days. In the 2010, the observations were performed in three groups (DOY: 184-186, 187-189 and 190-192) with 3 sessions for 10 hours. Besides, UZUN and DU12 stations were observed for nine days. In 2011, 21 stations were observed for 10 hours for 3 sessions in 3 groups (DOY: 183-185, 186-188 and 189-192). During this campaign DU05, DU12 and UZUN stations were observed continuously. For Western Anatolia in the two projects (CORS-TR and TURDEP), GPS observations were obtained continuously and in this study, the observations for the session days (DOY:183-192) for 2009, 2010 and 2011 were taken account for processing together with the GPS observations of Izmir and its surroundings. For connecting the local network with the ITRF (International Terrestrial reference Frame) global network International GPS Service (IGS) stations were also adding to the processing. These IGS stations let the necessary parameters estimation in the GPS data analyses (station coordinates, earth orientation parameters, atmospheric zenith delays etc.). 12 IGS stations; ISTA, TUBI, ANKR, ZECK, NSSP, NICO, MIKL, GLSV, BUCU, PENC, WTZR and MATE were used to define the Eurasia-fixed reference frame. ITRF2008 coordinates of these IGS stations were used as reference stations in the calculations. The GPS observations were processed by using GAMIT/GLOBK software. The strategy of GPS observations and processing with GAMIT/GLOBK is given at Table 1. The average repeatabilities were under 5 mm on horizontal (north and east) component and under 10 mm on the vertical component.

Table 1. The strategy of GPS observations and processing with GAMIT/GLOBK.

Data Interval	30 sec.
Cut Off Elevation	10 degree
Day Of Year	183-192
Orbit	IGS final orbit and ERP
Antenna Phase Center Variation	Elevation dependent weighting model (PCV-antmod.dat)
Troposphere Parameters	VMF (Vienna Mapping Function) model. Zenith parameters were estimated for every 2 hours.
Receiver Clock Syncronisation	Receiver clock unknowns were estimated for each epoch.
Phase Ambiguity Resolution method	WL (Wide Lane) and NL (Narrow Lane)
Correlation	Full correlation between observations and unknowns.
Final Coordinate Estimation	Daily solutions were combined using GLOBK

Reilinger et al. (2006) presented an elastic block model for African, Arabian and Eurasia plates. Besides, Anatolia was separated into 3 blocks (plates) as Anatolian block, Aegean block and Southwest Anatolian block for determining the block model and the Euler vectors were calculated relative to Eurasia. In the study of Reilinger et al., 2006, the Euler vectors were given as 30.8ºN, 32.1ºE and 1.231º/Myr for Anatolian block fixed solutions. In this study, for investigating the interplate motions of the study region, the Anatolian block fixed velocity vectors were calculated (Figure 3) by using Euler vectors given by Reilinger et al. (2006) which were obtained relative to Eurasia.

Additionally, for interpreting the dissimilarities on the GPS velocities of the micro-plates, the earthquakes occurred between the years 1973 and 2016, with an amplitude range between 2.5 and

9.0 were taken from United States Geological Service (USGS) and the focal depth distribution map was obtained (Figure 4).

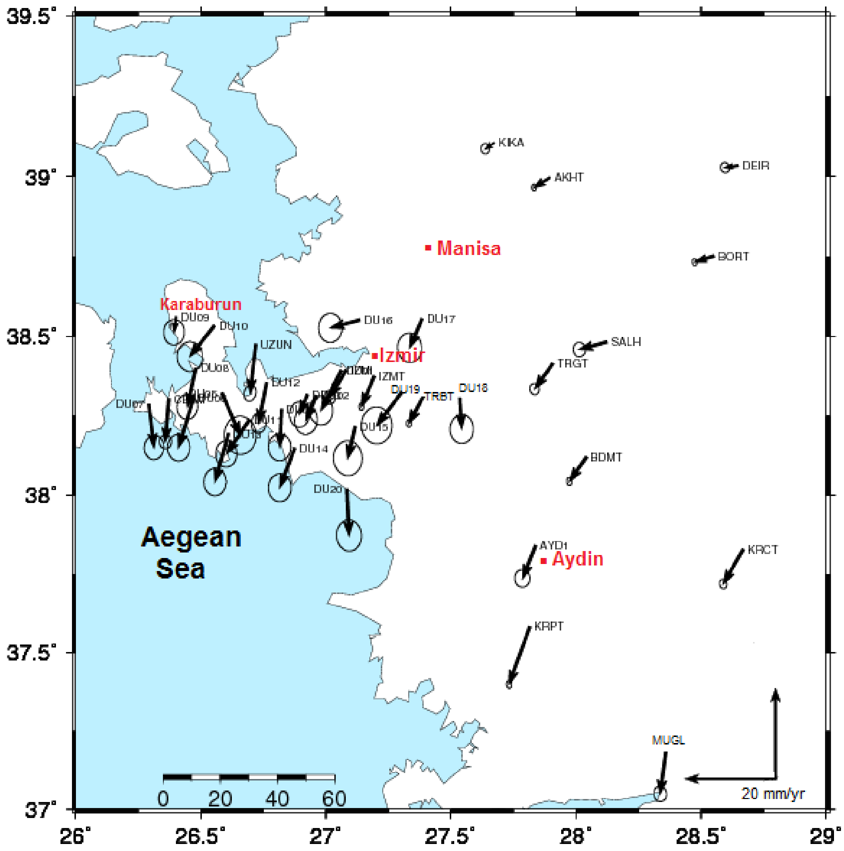

Figure 3. The velocity field with 95% confidence ellipses of the stations computed in Anatolian block fixed frame from 3-years (2009, 2010 and 2011) GPS observations by using Euler vectors; 30.8ºN, 32.1ºE and 1.231º/Myr (Reilinger et al., 2006) obtained relative to Eurasia.

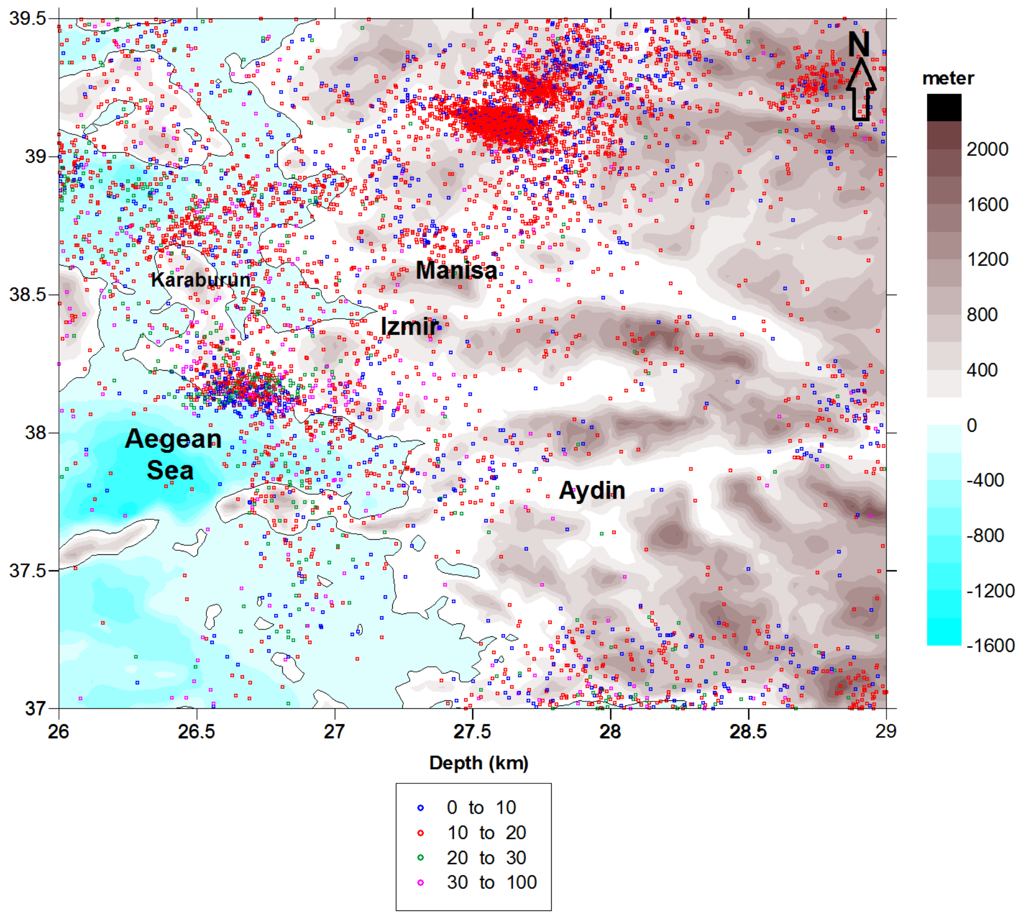

Figure 4. Topographic map of study area and the earthquake focal depth distributions between the years 1973-2016 (from USGS) (The topographic data was obtained from TOPEX; Smith and Sandwell, 1997).

3. DISCUSSION AND CONCLUSION

In this study, GPS observations for Izmir and surrounding (Pamukçu et al., 2015a, b; Çırmık et al., 2017a) and Western Anatolia were processed together for investigating the interplate motions relative to the Anatolian block fixed frame. As a result, the dissimilarities on the GPS velocity directions were noticed in the Anatolian block fixed frame solution (Figure 3), therefore, the study area was separated to 3 zones (as A, B and C zones, Figure 5) by taking account these directional dissimilarities.

In A zone the directions of GPS velocities are approximately towards W and the velocity amplitudes are lower than the other GPS velocities seen at B and C zones (Figure 5) and it is thought that these GPS stations which locate at A zone are under the effect of NE-SW trending basins (Figure 1).

In Figure 3, it is seen that the directions of GPS velocities which locate at the western side of 27.5º longitude (at B zone) are generally towards S. On the other hand, the directions of GPS velocities which locate at the eastern side of 27.5º longitude (at C zone) are generally towards SW (Figure 3 and Figure 5). It is thought that the orientations for the GPS velocities locate at B zone (at Karaburun and its surroundings) are occurred with the effect of the roll-back process at Eastern Mediterranean Sea through Hellenic Subduction zone (Gönenç and Akgün, 2012) (Figure 1) and additionally, a stabile block which locates at western of Karaburun Peninsula stops these movements and is changed the directions of the GPS velocities. Besides, the existence of this stabile block may be the reason of occurrence of the N-S directional fault systems and Gülbahçe fault (Figure 2). Furthermore, the N-S extensional features are not affected at B zone (Figure 5).

The GPS stations which locate at the region called as C zone (Fig 5) exist in the N-S directional extensional graben system (Figure 2). Figure 5, it is seen that the GPS velocities which locate at C zone are higher than the GPS velocities which locate at B zone. The reason of the differences on the velocity magnitudes for these zones may be the effect of existence of greater dipping angle at eastern wing of Hellenic Subduction zone relative to western wing (Papazachos et al. 1995, Papazachos and Nolet, 1997).

According to the GPS and Coulomb analysing study of Çırmık et al. (2017b) realized at Gülbahçe fault and its surroundings, the region, which is called as B zone in this study, has the complicated stress and strain features up to 8 km depths. In the seismic velocity study of Özer and Polat (2017) which were performed at Izmir and its surroundings (called as B zone at this study), V_p seismic velocities for upper 10 km were found slower than V_p seismic velocities which were calculated by Kaypak and Gökkaya (2012) beneath Denizli basin, Western Anatolia (called as C zone in this study). These results show that the weakness zone is in upper 10 km of the crust at B zone where Karaburun and its surrounding locate in. In Figure 4, the region where represents complicated GPS velocities directions and includes Karaburun, Gülbahçe and Orhanlı fault zones is coherent with this condition.

Additionally, the N-S directional border between B and C zones (Figure 5) is seemed as coherent with WATZ which represented by Gessner et al. (2013) at 27.5-28º longitude by using the earthquake focal depths.

Consequently, if these results are compared with the earthquakes occurred at the study area between the years 1973-2016 (Figure 4), it is noticed that the distributions of earthquakes (Figure 6) represent coherency with the groups at Figure 4 created by directional dissimilarities of GPS velocities.

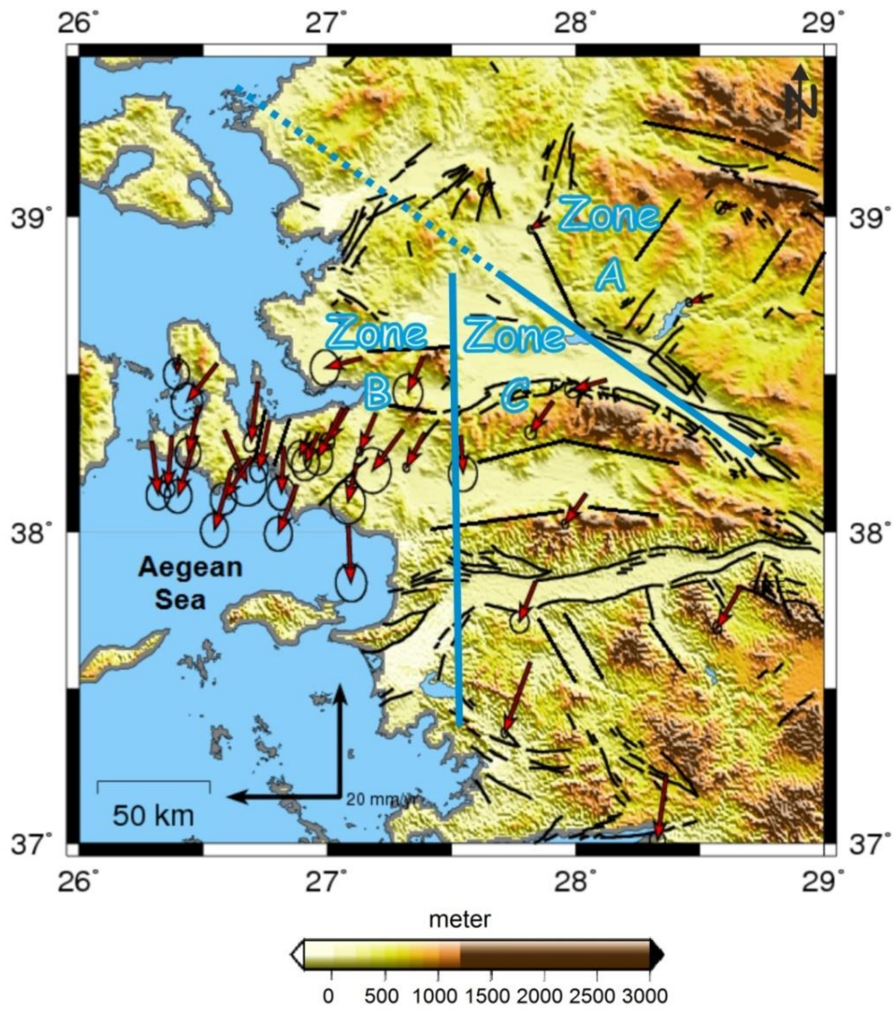

Figure 5. The station velocities of Anatolian block solution (Figure 3) are separated to 3 regions as A, B and C zones shown by blue lines.

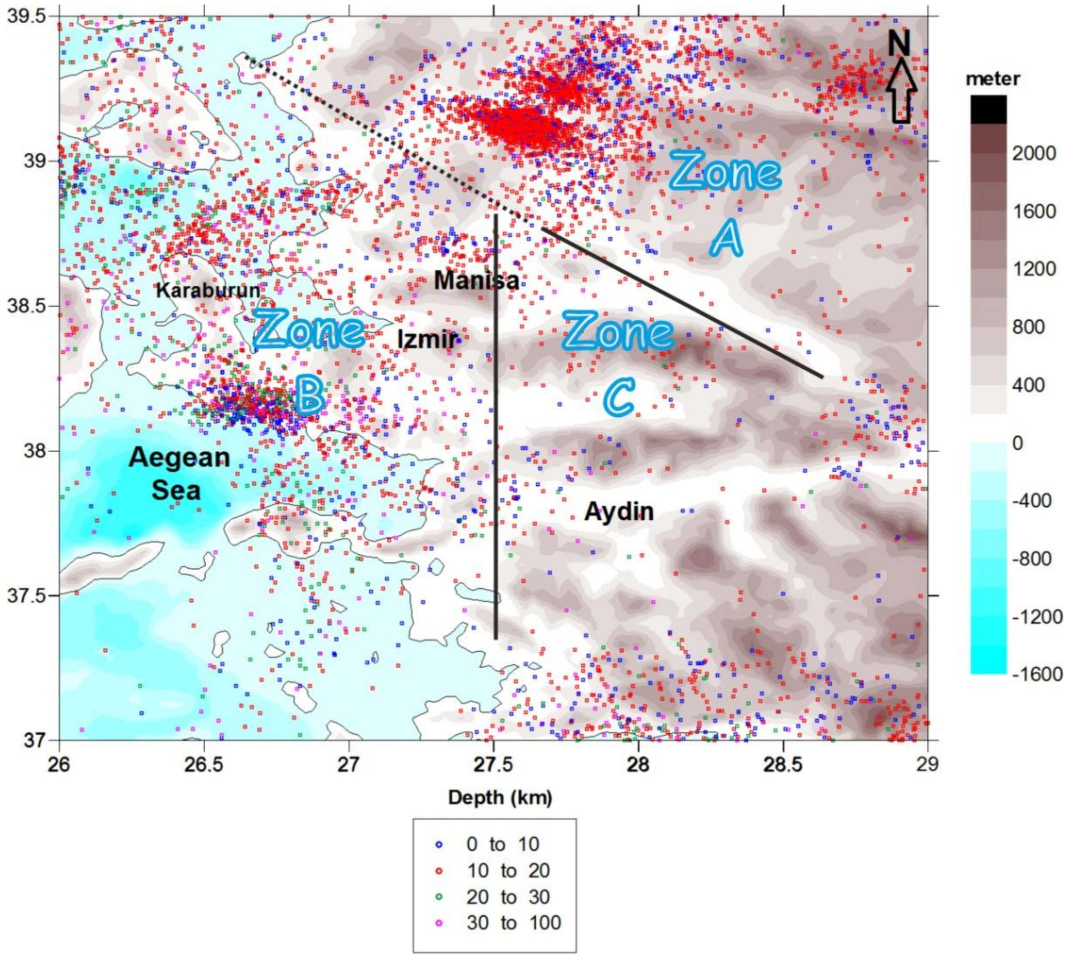

Figure 6. The study region is separated to 3 regions as A, B and C zones shown by black lines due to the earthquake focal depth distributions.

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CONTACTS

Assoc. Prof. Dr. Muzaffer KAHVECİ
Selcuk University
Engineering Faculty, Department of Surveying, Alaeddin Keykubat Campus, Selcuklu, Konya
TURKEY
Email: muzaffer.kahveci@hotmail.com

Assoc. Prof. Dr. Oya PAMUKÇU
Dokuz Eylul University
Engineering Faculty, Dep. of Geophysical Engineering, Tinaztepe Campus, Buca
Izmir
TURKEY
Tel.: +90232 3017269
Fax: +90232 4538366
Email: oya.pamukcu@deu.edu.tr

Dr. Ayça ÇIRMIK
Dokuz Eylul University
Engineering Faculty, Dep. of Geophysical Engineering, Tinaztepe Campus, Buca
Izmir
TURKEY
Tel.: +90232 3017282
Fax: +90232 4538366
Email: ayca.yurdakul@deu.edu.tr

Assoc. Prof. Dr. Tolga GÖNENÇ
Dokuz Eylul University
Engineering Faculty, Dep. of Geophysical Engineering, Tinaztepe Campus, Buca
Izmir
TURKEY
Tel.: +90232 3017288
Fax: +90232 4538366
Email: tolga.gonenc@deu.edu.tr