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VERTICAL AND HORIZANTAL ANALYSIS OF CRUSTAL STRUCTURE IN EASTERN ANATOLIA REGION

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ABSTRACT

The tectonic regime of Eastern Anatolia is determined by Arabian-Eurasian continent-continent convergence and the mechanism occurred with the convergence. North Anatolian Fault Zone (NAFZ), Eastern Anatolian Fault Zone (EAFZ), North Eastern Anatolian Faults and Bitlis Zagros Suture Zone are formed by this convergence, represent the characteristic of lithospheric structure of the region. In the scope of this study, the gravity anomalies of Eastern Anatolia were used for investigating the lithospheric structure. Firstly, second order trend analyses were applied to gravity data for examining the characteristic of the anomaly. Later, the vertical and horizontal derivatives methods were applied to the same data. Generally, the purpose of the applying derivative methods is determining the vertical and horizontal borders of the structure. Therefore, this method gives the opinion about the characteristic of the lithospheric structure of the study region. According to the results of derivative methods, the structure transitions were increased rather especially with Bitlis Zagros Suture Zone. At the last step, the gravity studies were evaluated together with the seismic activity of the region. Consequently, the geodynamical structure of the region is examined with the previous studies done in the region.

1. Introduction

In Eastern Anatolia which has major tectonic structures, with the effect of Arabian Plate's northward motion, Anatolian block and Northeastern Anatolian Block escape to west and east, respectively (Ketin, 1948; McKenzie, 1972; Barka et al., 1987). Anatolian Block is bordered by right-lateral North Anatolian Fault Zone (NAFZ) at North and the left-lateral East Anatolian Fault Zone (EAFZ) at East (Figure 1). These two faults intersect in the Karlıova triple junction (Ketin, 1966; McKenzie, 1972; Dewey, 1976; Dewey et al., 1986; Barka et al., 1987). The eastern part of Anatolian block is divided into two blocks by the left-lateral Ovacık Fault. This fault intersects NAFZ at southerneast side of Erzincan Basin. The movement of Northeastern Anatolian Block to east is complicated because the block divided into lots of minor blocks with the effect of extensional interplate deformation (Barka et al., 1987). The region between the zones (Karlıova and Erzincan Basins), where NAFZ intersect EAFZ and Northeastern Anatolian Faults, is the conjunction border of the blocks (Anatolian and Northeastern Anatolian Blocks) move in the opposite directions relatively each other (Barka et al., 1987). The major part of NAFZ located in west of Erzincan was broken by a series of earthquakes which immigrated to west and occurred between the years 1939-1967. Until today, different comments were made about the geodynamic structure of the region by examining the

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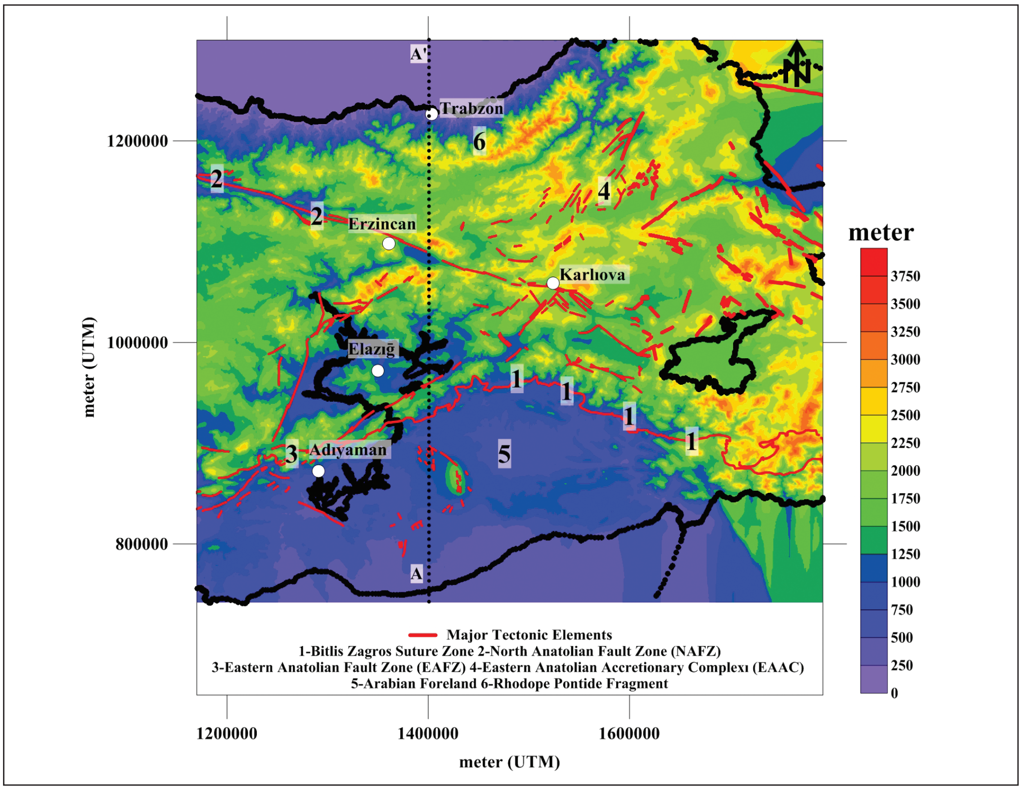

Figure 1- The topographic changes and major tectonic elements of Eastern Anatolian Region.

velocity differences on plate motions, topographic uplifts and volcanism activities and until 2003, four models were proposed (Rotstein and Kafka, 1982; McKenzie, 1972, 1976; Dewey et al., 1986; Pearce et al., 1990). In these studies generally, it was emphasized that the large-scale shortining and thickening in the crust was started by the tension of the Arabian-Anatolian Plates convergence. The new approaches were presented by the studies (Al-Lazki et al., 2003; Gök et al., 2003; Türkelli et al., 2003; Sandvol et al., 2003*a,b*; Zor et al., 2003; Şengör et al., 2003; Keskin, 2003, Pamukçu et al, 2007; Pamukçu and Akçığ, 2011; Pamukçu et al., 2014) realized after 2001 in Eastern Anatolia. In these new models, it was pointed out that the crustal thickening was not in the mentioned scale in previous studies (Rotstein and Kafka, 1982; McKenzie, 1972, 1976; Dewey et al., 1986; Pearce et al., 1990).

Pamukçu et al. (2007) determined the crustal thickness and the model of the region by using gravity data. Pamukçu and Akçığ (2011) calculated the effective elastic thickness for explaining the mechanism of the topography which compensates the crustal thickness. The Curie depths and heat flow values were obtained by using aeromagnetic data by Pamukçu et al. (2014). In the light of previous gravity and magnetic studies, in this study the estimation of the structure locations in Eastern Anatolia were done by applying the trend analysis, vertical and horizontal derivative methods (Butler, 1984; Gönenç, 2014) to the gravity data. In the last step, the results of this study were examining together with the results of the previous geophysical and geological studies.

2. Geodynamical Structure of The Study Region

As a result of the collision of Arabia with Eurasia, Neo-Tethy merged with Bitlis Ocean and closed in the late Middle Miocene in east, in the late Pliocene-Quaternary in west (Dewey et al., 1986; Robertson et al., 1991). The merging of Anatolia with Arabia along the Bitlis Zagros Suture Zone and north-south directional compression in the Late Middle Miocene obstructed the northward motion of Arabian plate (relative to African plate) up to early Pliocene (Hempton, 1987; Robertson et al., 1991; Yılmaz et al., 1993). In Eastern Anatolia the crustal thickening and high elevation (~ 2 km above the sea level) occurred between the Late Middle Miocene and the Early Pliocene (Şengör and Kidd, 1979). During these geologic time-scales, various structures were formed like as east-west directional thrust faults and extensional basins with the effect of the compression (Kelling et al., 1987; Gürsoy et al., 1992). After ending of inter-continental collision along Bitlis Zagros Suture Zone, in the early Pliocene a new compressional and extensional tectonic regime replaced the compressional tectonic regime in Eastern Anatolia (Bozkurt, 2001). NAFZ described as inter-continental transform fault belt was occurred as the result of that activity. Subsequently, EAFZ was formed in the late Pliocene (Westaway and Arger, 1996). The compressed Anatolian Plate began its westward motion on the oceanic lithosphere of African Plate. Therefore, NAFZ and EAFZ allowed Arabian Plate to move northward faster than African Plate (Reilinger et al, 1997; Oral et al., 1995; Barka and Reilinger, 1997).

In the studies of Reilenger et al. (1997); Oral et al. (1995) and Demets et al. (1994), it was explained that while Arabian Plate velocity was 25 mm/year to N-NW, the velocity of African Plate was only 10 mm/year to N. The other important fault which controls the motion between these plates is left-lateral Dead Sea Fault Zone (DSFZ) (Bozkurt, 2001). However, Kahle et al. (1998) pointed out that the velocity of this fault was approximately 7 mm/year. This result showed that the velocity of the fault was not effective on geologic time-scales. DSFZ links the northern border of the Arabian Plate with seafloor spreading in the Red Sea. This case influences the tectonic of Cyprian Arc (Bozkurt, 2001). Consequently, DSFZ has an important role on the active tectonics of Turkey. As the results of the tectonic movements, Şengör et al., (1985) defined four different Neotectonic provinces for Turkey. These are, East Anatolian Contractional Province, North Anatolian Province, Central Anatolian 'Ova' Province and West Anatolian Extensional Province.

Until 2001 four models were presented for characterizing the collision zone in Eastern Anatolia and describing its geodynamic. The issues discussed in the light of these models are also grouped into four main categories. The opinions are like as:

– The continental subduction or delamination continue or not (Rotstein and Kafka, 1982),

– While the approximate offset along NAFZ is 2 cm/year, along EAFZ is 1cm/year. This case shows that Anatolian Block, which escapes to westward, rotates anticlockwise. It can be said that the strain, which appeared with the effect of the collision of Arabian with the Eurasia, can not be the only reason of this westward offset. Therefore, there is any lithospheric thickening on Eurasia or not (Dewey et al., 1986),

– The convergence of Arabian plate moves with the Anatolian Block which escapes as the result of right-lateral movement along NAFZ and left-lateral movement along EAFZ or not (McKenzie, 1972),

– The combinations of all process explained above occurred or not (Pearce et al., 1995).

By the help of seismological studies done in Eastern Anatolia after 2001 (Al-Lazki et al., 2003; Gök et al., 2003; Türkelli et al., 2003; Sandvol et al., 2003*a,b*; Zor et al., 2003), new opinions were presented about the model of the region (Keskin, 2003; Şengör et al., 2003)..

According to Keskin (2003), almost two-thirds of Eastern Anatolia is covered by young volcanic units ranging in age from 11 Ma to recent with the thickness approximately 1 km. This formation represents only the small part of the melt, the greater part probably locate deeper in the crust as plutonic intrusions. The Eastern Anatolian topographic uplift resembles the Tibetan plateau and was viewed as a younger version of it in many studies (Şengör and Kidd, 1979; Dewey et al., 1986). In some of these early studies pointed out that lithospheric mantle beneath Eastern Anatolia was doubled in thickness up to 300 km due to continental collision and thickening. The study of Pearce et al. (1990) about the collision-related volcanic units across the region provided a new view into the tectono-magmatic evolution of Eastern Anatolia. They recommended the delamination model which involved the detachment of the thermal boundary layer by delamination. In the study of Keskin et al. (1998) about the collision-related volcanic units on the Erzurum-Kars Plateau in the north was pointed out that the initiation of volcanism was much earlier in the north than previously thought, almost coincident with rapid uplift of the region.

The seismological studies in the region defined that an almost normal-thickness crust resides on an extremely thin mantle lithosphere or perhaps almost directly on the asthenosphere. The most remarkable point is that the areas of inferred complete lithospheric detachment almost exactly coincide with the extent of the Eastern Anatolian Accretionary Complex (Şengör et al., 2003).

Keskin (2003) explained the reasons of his model in details. According to auther the collision-related volcanic units across the author region extend from basalts to rhyolites. In lava chemistry, there is an important difference between the Erzurum-Kars Plateau in north and Muş-Nemrut-Tendürek volcanoes in the south. Lavas of Bingol and Suphan volcanoes present transitional chemical characteristics (Pearce et al., 1990). The characteristic of volcanic products in the north around Erzurum-Kars Plateau and Mount Ararat are calc-alkaline and seem to have been occurred from an enriched mantle source including different subduction. This different subduction decreases to the south and disappears around Muş-Nemrut-Tendürek volcanoes. These lavas are alkaline and present with-in plate character. Additionally, the magma-crust interaction degree is more important in the south than in the north.

The radiometric studies defined that the volcanic activity began earlier in north than in the south and migrated to the south during the time (Keskin, 2003). Keskin (2003) criticized the previously proposed geodynamic models for Eastern Anatolian collision zone and defended that except for the slab steepening and breakoff model, there were inconsistencies in all the other models and commented as:

– The tectonic escape of micro-plates to the east and west (McKenzie, 1972) did not compensate completely for the strain triggered by the 2.5 cm/year convergence of the Arabian plate relative to Eurasia (Dewey et al., 1986);

– The subduction of Arabian plate beneath Eastern Anatolia (Rotstein and Kafka, 1982) was not supported by seismic evidence;

– The melting of normal asthenosphere by the effect of adiabatic decompression of upwelling mantle (McKenzie and Bickle, 1988) was not consistent with the seismic data;

– The continental collision and thickening of the Anatolian lithosphere (Dewey et al., 1986) were not supported by recent tomographic data;

– The hot spot activity created by a mantle plume was not consistent with the topography and fault plane solutions;

– The delamination of mantle lithosphere beneath the region (Pearce et al., 1990; Keskin et al., 1998) clarified thoroughly magma formation. Whereas, new seismic data display that there is no lithospheric mantle over a large area beneath the region. This case raises a question about whether a shallow delamination in the whole lithospheric mantle and the lower crust. Nevertheless, the shallow delamination could not be acceptable, because the existence of a mantle attached to the crust basement is needed for delamination. This case is not valid for the area underlain by the Eastern Anatolian Accretionary Complex, since these large subduction-accretion complexes do not have their own lithospheric roots as distinct from continents.

– The slab steepening and subsequently the breaking beneath a subduction-accretion complex may be the most acceptable model, consistent with the geology of the region as well as variations in magma age and chemistry across the region.

Şengör et al. (2003) discussed that oceanic area was closed in a geologic time-scale between the Late Eocene and Oligocene at the first contact of the Eastern Anatolian Accretionary Complex with Bitlis-Pötürge Massif. This complex was shortened and thickened over the oceanic lithospheric slap during the time-scale between the Late Oligecene and 13-15 Ma. This duration continued until the slap was steepened and separated from the complex approximately in 10-11 Ma. The separated slap should be vanished by sinking into the asthenosphere in the 10 Myr time-scales. The authors pointed out that the lack of deep earthquakes in region supported this opinion.

Keskin (2003) presented in the light of new geophysical data that the breakoff may be formed as shallow as 45–50 km. The disappearing of this great load and the supersession of less denser asthenosphere beneath the Eastern Anatolian Accretionary Complex was the reason of the rapid block uplift and volcanism in the region.

Örgülü et al. (2003) and Koçyiğit et al. (2001) indicated that the crustal stress field varied in the past 5 to 10 Myr. This variation corresponded with the initial of widespread volcanism in Eastern Anatolian plateau. It was pointed out that these observations were correlated with the Neo-Tethys slab breakoff beneath the region.

The slab steepening and breakoff model clarified the geochemical variations in volcanic products in the region better than the other proposed models. McKenzie and Bickle (1988) pointed out that upwelling of asthenosphere with the temperature of 1280 ºC create widespread adiabatic decompression melting at approximately 50 km. According to this model, the presence of a subduction component in the mantle increases the melting by reducing the melting temperature. This case can represent the reason of existence of the erupted volcanic units in greater volumes in the north around the Erzurum-Kars plateau than in the south. The melting temperature are attracted to the more shallow depths by interplaying of the hot asthenosphere with the Eastern Anatolian Accretionary Complex, therefore, widespread melting are created in the crust. This view may explain the instabilities in lava chemistry and degree of magma-crust interplaying in the region (Keskin, 2003).

Keskin (2003) demonstrated that the collision type in Eastern Anatolia was not like as in Tibet and was specific character according to its crustal/lithospheric structure and plate tectonic history. Additionally, it was indicated that the slab steepening and breakoff beneath the Eastern Anatolian Accretionary Complex seemed as the great controlling mechanism for the magma genesis related with the collision in the region.

According to Şengör et al. (2003), the absence of mantle lithosphere in the Eastern Anatolian Accretionary Complex was the main question in the region. The geological evolution explained the reasons of it. The authors reported that in the early Eocene, Rhodope-Pontide arc was still active and there was no a widespread subduction-accretion complex. It was defined that the end side of the accretionary complex may contact the northern side of Bitlis-Pötürge Massif in the late Eocene and this complex was shortened and thickened over the oceanic lithospheric sliding beneath it throughout the Oligocene and additionally, the Oligocene intrusions in the Rhodope-Pontide arc may be generated by this subduction in 38.5 Ma. It was pointed out that after the East Anatolian Accretionary Complex reached to normal continental crustal thickness, the subduction was interrupted and Arabian-Eurasian convergence started to be provided by intercontinental convergence and crustal shortening from Caucasus to Northern Arabia approximately 24 Ma ago in the early Miocene and if the dip angle of slap was 45° and the velocity of convergence was 25 mm/yr, the slab would begin to break approximately at 200 km in the period between 24 Ma and 11 Ma. According to them, the breakoff would occur approximately at a depth of 50 km and 300 km north of the suture if the subducting lithosphere interrelated with the bottom of the East Anatolian Accretionary Complex. At the same time, location of initial collision-related volcanism was approximately at 75 km south of the Eastern Pontide by assuming that the plateau was shortened homogeneously along north-south and the collision-related magmatism began approximately at 200 km north of the today suture line 11 Ma ago. It was indicated that 8 Ma ago when the post-collision volcanism expanded by southward spreading, the breaking of the slap was finished.

According to them, since the slap was approximately older than 100 Ma and the thickness of the accretionary complex was approximately thinner than 45 km, the top of the complex located below the ocean level. It was represented that exposing the asthenospheric temperatures was the reason of partial melting on the bottom surface the East Anatolian Accretionary Complex. Additionally, the volcanicity of Eastern Turkey display a complex composition geochemistry ranging from andesitic-rhyolitic crustal melts to alkali olivine basalts from late Miocene to present. The volcanism most likely represents the asthenospheric rising, the adiabatic melting and the crust heating.

After the continental crust reached some thickness, the magmatism of continent-continent convergence region arised by melting of bottom part of the crust and the magmatism represented by the granites contained high potassium and the rhyolites which were the derivatives of granites on surface. On the light of plate tectonics, Alps, Appalachian Mountains, Greenville, Taurus Mountains and Himalayas are displayed as the tectonic structures occurred by lithospheric subduction or continent-continent convergence. The most prominent belts are the Bitlis Zagros Suture and Himalayas and both of them are located in Alpine-Himalayan Belt. The Bitlis Zagros Belt and Himalayas Belt occurred by the effect of Eurasian-Arabian Convergence and Eurasian-Indian Convergence, respectively.

Apart from the difficulty on evaluating the effects of lower lithosphere, the geology of continental crust is emerged by the result of the lithospheric flexure, extension and shortening. The lithospheric extension and shortening, rapidly are occurred the isothermal thinning and thickening which create the basins and mountains, respectively. Thermal discharging creates subsidence or uplift developed by sedimentation or denudation. Therefore, the most of the vertical movement caused the complexity on stratigraphic development are the result of the lithospheric deformation. Continental convergence contains the development of the floating or high field parts including subduction zones (Dewey, 1977). One of the continental boundary or both of the boundaries may have had a long and complex terrain combination before formation of continental convergence (Coney et al., 1980). The continental convergence plate boundaries such as Alpine-Himalayan system are wide and complex zones where the relative plate displacements turned to complex and inconsistent stress. Suture belts occurred in this context developed by the thickening of the rifted boundary in the thinned continental crust accumulated again along the fore-plate. The suture zones include the crustal low velocity zones (Rybach et al., 1980). Besides, the structures in convergence systems are involved in one of the tectonic component such as plateaus, suture zones, lithospheric flexures on the fore-plate, the deformation zones on the fore-plate/ back-plate, orogenic collapse/tension zones and the structures are formed with the uplifting of topography. The tectonic components for Eastern Anatolian region were examined in details in the studies of Al-Lazki et al., 2003; Gök et al., 2003; Türkelli et al., 2003; Sandvol et al, 2003*a,b*; Zor et al., 2003, Şengör et al., 2003; Keskin, 2003; Pamukçu et al., 2007; Pamukçu and Akçığ, 2011; Pamukçu et al., 2014.

3. The Trend Analysis and Derivative Applications on Bouguer Anomalies

Butler (1984) applied 1st and 2nd order derivative methods to gravity data in his study. He mentioned that 1st order derivative was more sensitive and the results according to 2nd order derivative could be used in estimation of structure locations. Therefore, the horizontal derivative application was obtained by the methods of Blakely and Simpson (1986).

In the first step of this study, the trend analysis (Figure 3), horizontal derivative (Figure 4) and vertical derivative (Figure 5) applications were realized by using the data in the map of 500x500 m gridded Bouguer gravity anomalies (Figure 2) for the region between 37°-44° E longitudes and 37°-42° N latitudes. The values in the map of Bouguer gravity anomalies changed from 50 mGal to -210 mGal and the negative anomalies showed north-south directional extension from west to east like a fan (Figure 2).

In the obtained residual map by the results of the 2nd order trend applications, the anomaly extensions were west-east directional and the maximum and

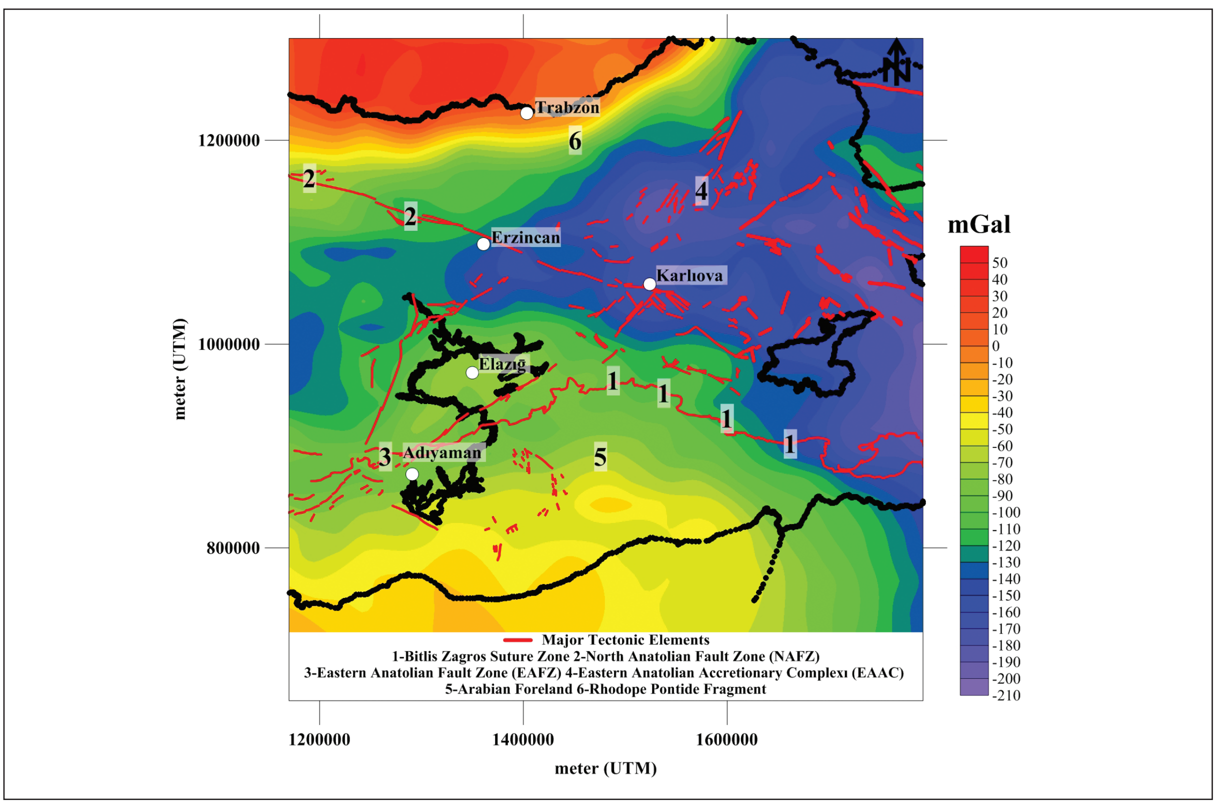

Figure 2- The Bouguer gravity anomaly map of Eastern Anatolian Region (MTA). Red lines represent the major tectonic elements of the region (Bozkurt, 2001).

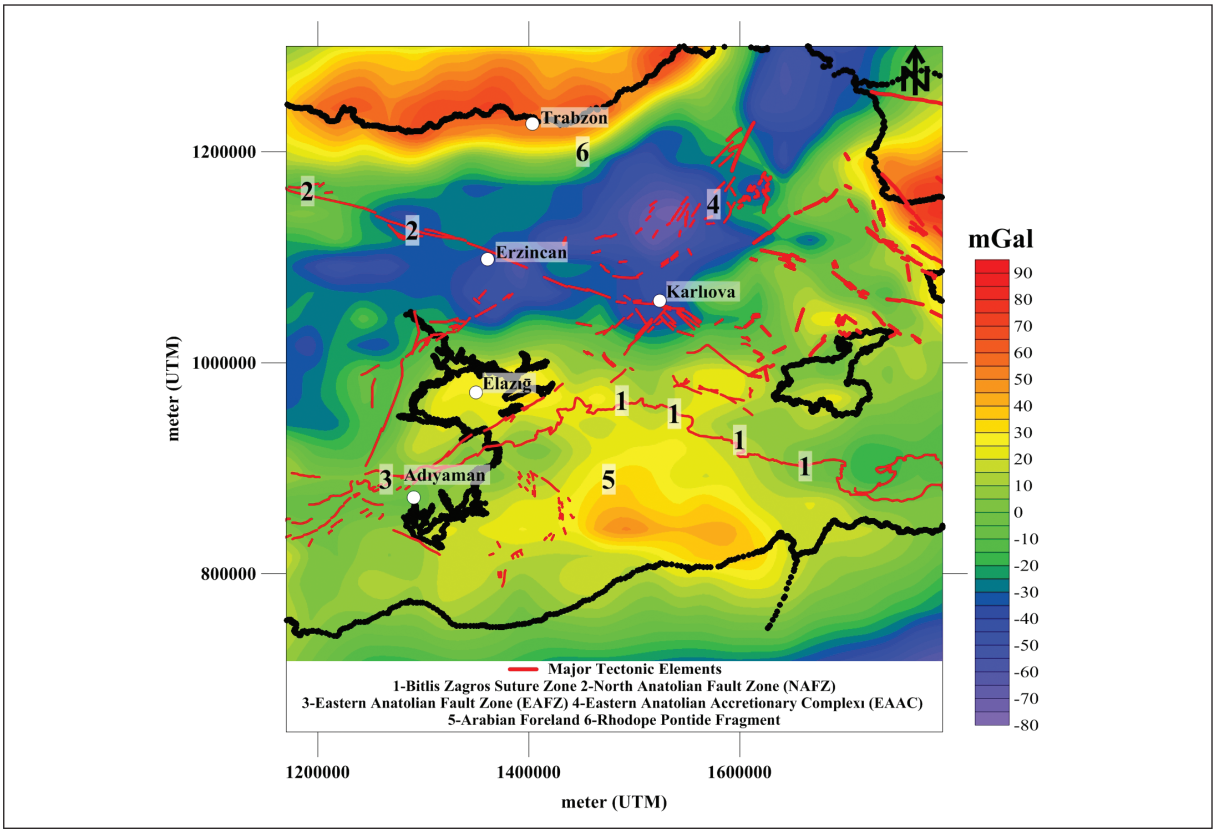

Figure 3- The gravity anomaly map obtained by eliminating 2nd order trend effect from Bouguer gravity anomaly map.

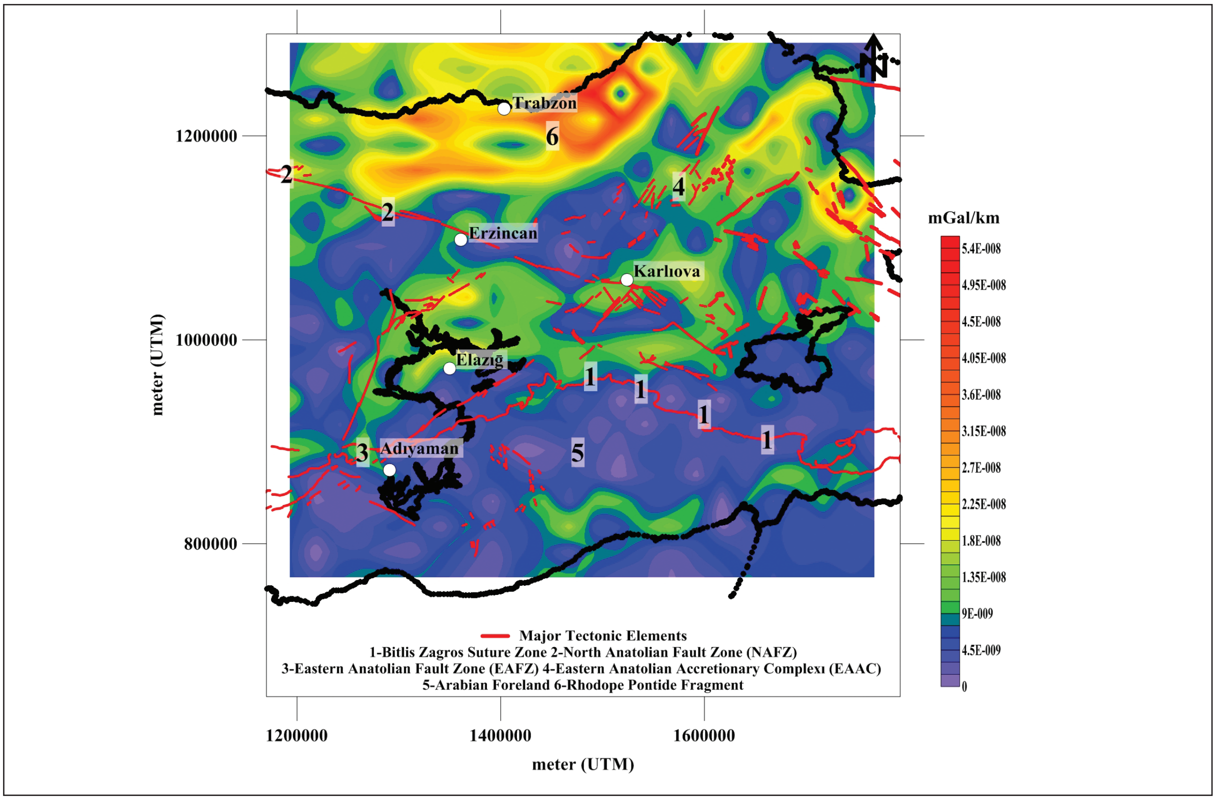

Figure 4- The map obtained by applying horizontal derivative applications on residual Bouguer anomalies shown in figure 3.

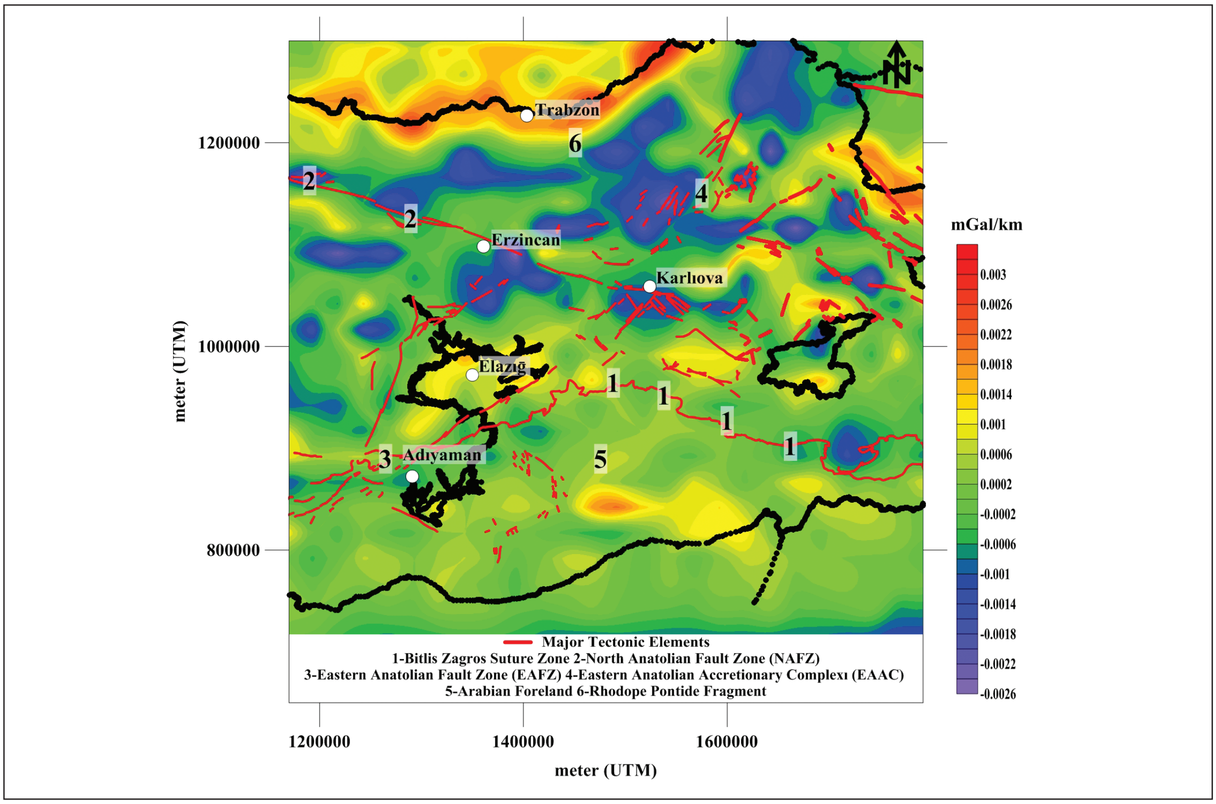

Figure 5- The map obtained by applying 1st vertical derivative application on residual Bouguer anomalies shown in figure 3.

minimum closures alternated from south to north (Figure 3). In horizontal derivative anomaly map (Figure 4), it was obtained that the borders of structures were coherence with the fracture system defined in the study and finally, the possible dominant structure locations were specified with positive anomaly closures in the vertical derivative anomaly map (Figure 5).

4. Results and Discussions

Eastern Anatolia and similar regions located in the borders of the compressional plates are large and complicated zones where the relative displacements turn to the complex and inconsistent stresses. By this scope, the research field Eastern Anatolia has too complex tectonic structures in geologic time scale. In the evaluation of the region, the marine and continental basins have significant roles. The seismological studies (Al-Lazki et al., 2003; Gök et al., 2003; Türkelli et al., 2003; Sandvol et al., 2003*a*, 2003*b*; Zor et al., 2003) realized for characterizing the compressional zone of the region and defining the geodynamics of the compression since 2003, the evolution was explained in the light of the studies and the presence of asthenospheric upwelling was determined (Şengör et al., 2003; Keskin 2003, 2007). It is expected that this upwelling causes to reduce the density of the subsurface formation with the effect of the high temperature and accordingly, brings along the reduction on values of the gravity anomalies. Therefore, the gravity anomalies of the region are examined.

In the first step of the study, the Bouguer gravity anomaly of Eastern Anatolia given in figure 3 was evaluated and 2nd order trend effect was eliminated from the anomaly. When this residual map was examined, it was seen that high amplitude gravity anomalies reached approximately 40 mGal in South of Bitlis Zagros Suture Zone, additionally in North up to Black Sea coasts the gravity anomalies presented negative values. In particular, SW-NE axial high negative amplitude anomalies which contained the Northeastern Anatolian faults were remarkable.

According to horizontal derivative results in figure 4, the possible structure boundaries were obtained as relatively high and low amplitude anomaly transitions structure and these anomaly transitions were consistent with the extensions of NAFZ and EAFZ. Besides, it was obtained that the trends of the anomalies in horizontal derivative were SW-NE directional.

In figure 5, the negative amplitude structure borders/transition zones and positive amplitude structure locations which shown in the vertical derivative map were determined. In Figure 5, obtaining of transition zone featured structures in a wide area from North of Bitlis Zagros Suture Zone to Black Sea is a trace about the grandness of effected area of the deformation. The positive amplitude anomalies in vertical derivative method indicate the location of the structure (Gönenç, 2014). Relatively, the reduction on derivative values corresponds to the transition zone between two structures. In figure 5, the negative amplitude on vertical derivative particularly in the intersection of NAFZ and EAFZ, Karlıova and surrounding, point out the presence of a significant border there, most likely.

The subduction processes in the thermal and mechanical models (Bird et al., 1975) related with convergence zones in continental-continental compressional regions were explained by heat flows, reduction on gravity and low density zones. The high temperature degree accurring with the effect of friction on suture zones and shear stress related to the depth have importancy on thermal regimes of the shallow parts of the subduction zone. These geodynamic processes can be evaluated for Eastern Anatolia. The presence of shallow seismisity in the region (Zor et al., 2003), obtaining the effective elastic thickness thinner than crustal thickness (Pamukçu and Akçığ, 2011) and determining structure transitions throughout the Bitlis Zagros Suture Zone, NAFZ and EAFZ locations in normalized full gradient studies (Pamukçu and Akçığ, 2011) may indicate that the deformation begins just north of the suture zone. The regions with low velocities and low gravity (Figure 5), have most probably low density structure. These cases can be the results of the mechanisms of convergence duration.

For examining the seismic activity of the study area, the earthquakes (2<M<7) occurred between the years 1973-2015, obtained from Boğaziçi University, Kandilli Observatory and Earthquake Research Institute (KOERI), National Earthquake Monitoring Center were given in figure 6. These earthquakes

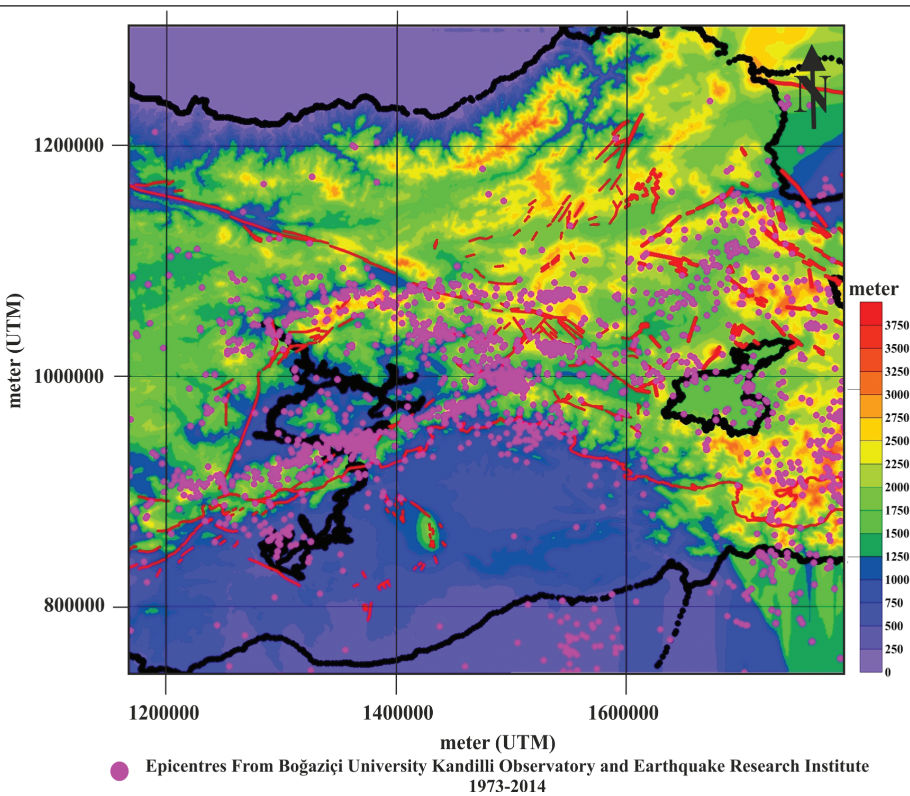

Figure 6- The earthquake epicenter distributions map of study region.

distributed as 8819 of them on NAFZ and 16548 of them on EAFZ. Therefore, it can be said that the negative amplitude structure, which was dominant in NAFZ and its surrounding shown in figure 5, may be related with less brittle and more deformed structure relative to EAFZ.

Additionally, the reasons of the negative amplitude parts obtained in figure 5 may be originated from the crustal problematic area (between the depth 20 km and 40 km) which was represented by Türkelli et al. (2003), Zor et al. (2003), Pamukçu et al. (2007), Keskin et al. (2003, 2007), Şengör et al. (2003), Pamukçu and Akçığ (2011) in figure 7.

In the area between NAFZ and EAFZ near 100000 meter latitude, the structure transition in figure 4, the negative amplitude closures in figure 5 and the regions show high seismic activity in figure 6 were determined as the area which showed decreasing crustal thickness (Pamukçu et al., 2007), decreasing S-wave velocity (Zor et al., 2003), decreasing Curie depths and increasing heat flow (Pamukçu et al., 2014). Additionally, Pamukçu et al. (2007) pointed out that in their Euler deconvolution study results, the 1400000 meter longitude was a border and the lithospheric structures may be different in west and east sides of this border.

As the last step, in figure 8, the topography (Figure 1), Bouguer gravity (Figure 2), 2nd order trend gravity (Figure 3), horizontal derivative (Figure 4), vertical derivative (Figure 5) and heat flow (Pamukçu et al., 2014) sections through 1400000 meter longitude (Figure 1, A-A¢ profile) were compared together. In the region, the latitudes between 100000 and 1200000 meter, where the topography reaches approximately 3 km (Figure 8a), Bouguer and 2nd order trend gravity anomalies present negative values (Figure 8b and Figure 8e), the region which show border features in horizontal and vertical derivatives (Figure 8d and Figure 8e) are coherent with the region which has relatively high amplitude heat flow values (Figure 8f) and indicate the borders of the flexible region which begins at 10 km depths given in figure 7. Particularly Bitlis Zagros Suture Zone, NAFZ and EAFZ present relative changes in gravity anomalies shown in figure 8b. In 2nd derivative anomalies (Figure 8d), the presence of a structure between EAFZ and NAFZ are viewed dominantly. According to the vertical derivative results (in Figure 8e), while this structure shows more

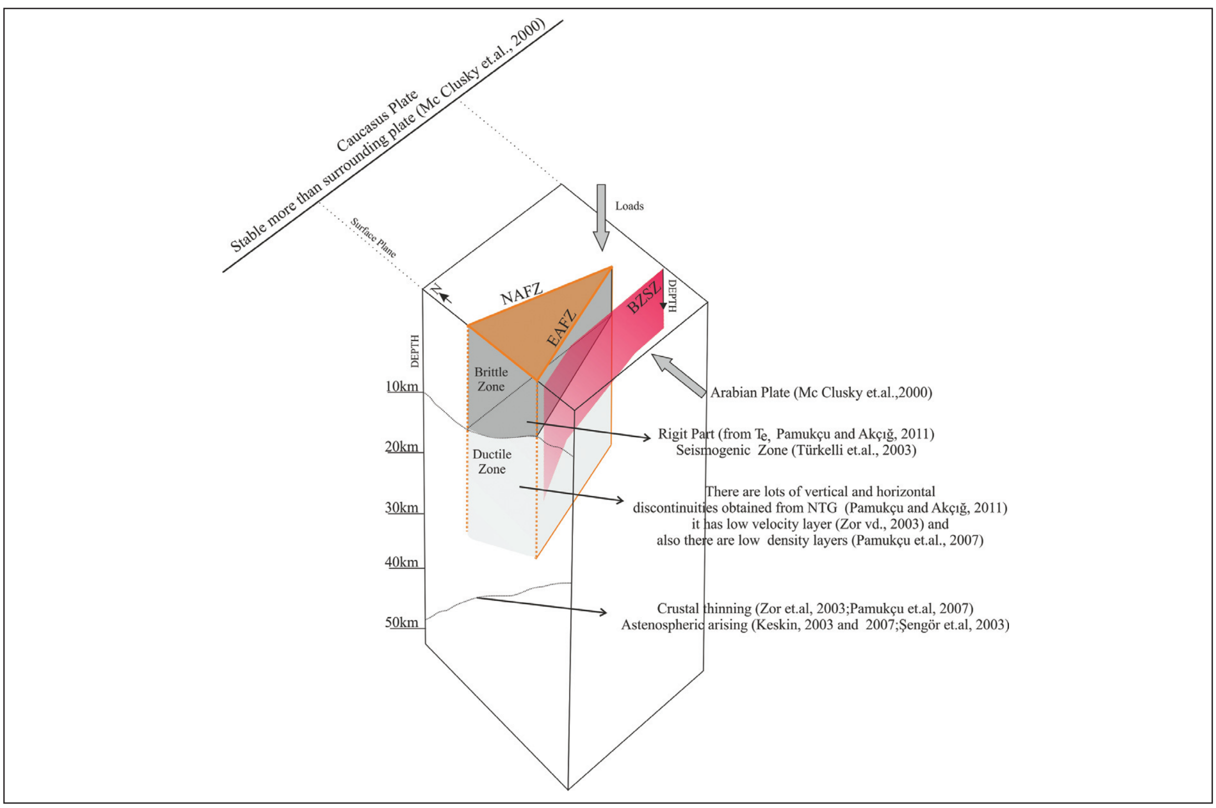

Figure 7- The schematic view of the results of the studies done for investigating the lithospheric structure of Eastern Anatolian Region (modified from Pamukçu and Akçığ 2011).

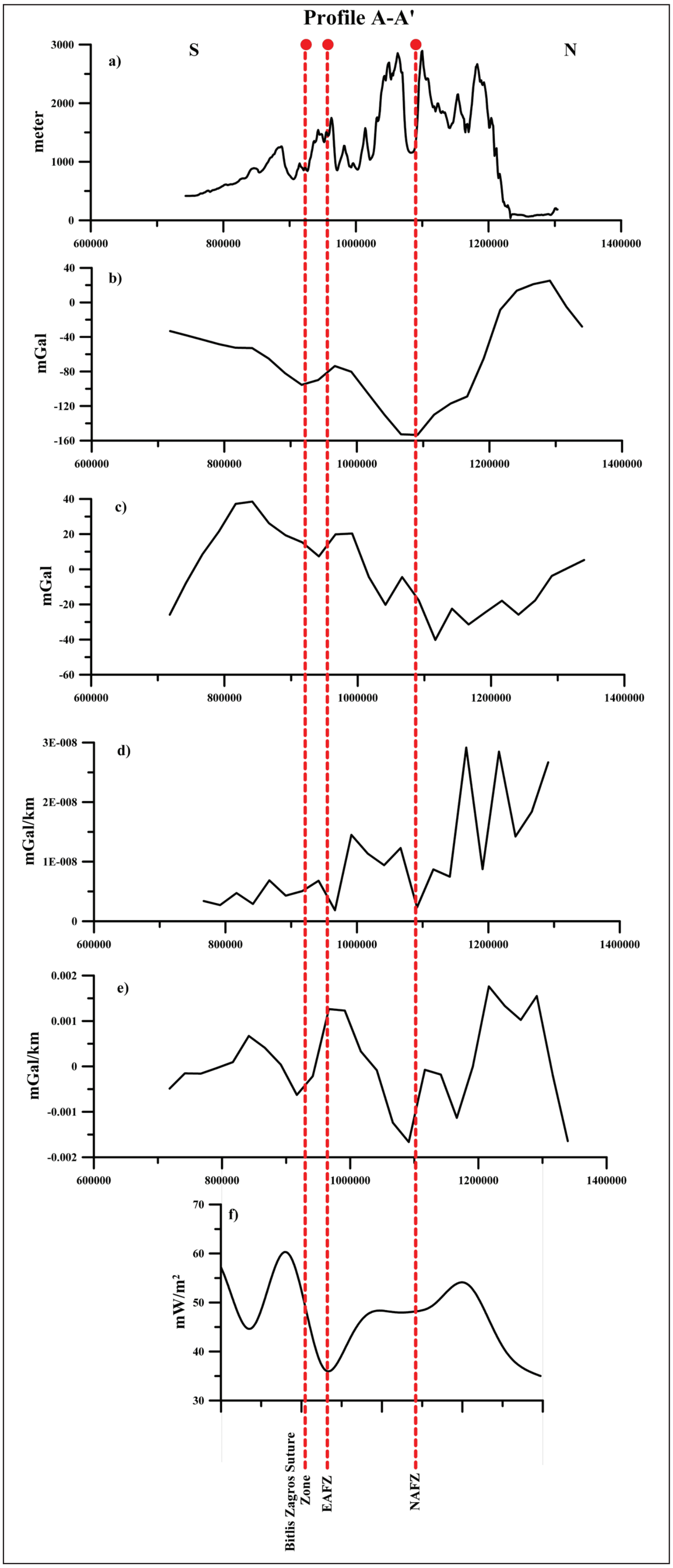

Figure 8- Between the latitudes 100000 and 1200000 meters (Figure 1, A-A' profile) a) Topographic anomaly b) Bouguer c) 2nd order trend Bouguer gravity anomaly d) horizontal and e) vertical derivative values f) heat flow values (Pamukçu et al., 2014).

compact (+mgal/km) behavior nearby EAFZ, behaves like a structure transition border (-mgal/km) toward NAFZ. Existence of amplitude of the gravity anomalies relatively low nearby NAFZ (in Figure 8b), and the heat flow values are high in the same region (in Figure 8f) indicate that the deformation is high in the region where have structure transition behavior in vertical derivative (Figure 8e). Additionally, these cases support the result which shows the earthquake focal depth distributions are less nearby NAFZ given in figure 6.

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