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Geophysical Data (Gravity and Magnetic) from the Area Between Adana, Kahramanmaras and Hatay in the Eastern Mediterranean Region: Tectonic Implications

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Abstract—The gravity and magnetic maps of the area between Adana–Kahramanmaras–Hatay provinces were produced from a compilation of data gathered during the period between 1973 and 1989. Reduced to the pole (RTP) and pseudo-gravity transformation (PGT) methods were applied to the magnetic data, while derivative ratio (DR) processing was applied to both gravity and magnetic data, respectively. Bouguer, RTP and PGT maps show the image of a buried structure corresponding to ophiolites under undifferentiated Quaternary deposits in the Adana depression and Iskenderun Gulf. DR maps show two important faults which reflect the tectonic framework in the study area: (1) the Karatas–Osmaniye Fault extending from Osmaniye to Karatas in the south between Adana and Iskenderun depressions and (2) Amanos Fault (southern part of East Anatolian Fault) in the Hatay region running southward from Turkoglu to Amik Basin along Amanos Mountain forming the actual plate boundary between the Anatolian block (part of Eurasian plate) and Arabian plate.

Key words: East Mediterranean, SE Anatolia, gravity and magnetic methods.

1. Introduction

The study area, seismically active, is located in the eastern corner of the Eastern Mediterranean region (Fig. 1). The Eastern Mediterranean region began to form after the subduction between Eurasia and Arabian platforms terminated the western section of the Southern Neotethys during the Late Cretaceous (Yilmaz 1993; Robertson 2002; Inwood 2005). There is generally a consensus about the northward subduction of the southern Neotethys, but the timing of collision (i.e., ocean closure) between the Taurides as overriding continent and the Arabian continental margin is debatable: Late Cretaceous (Karig and Kozlu 1990), Late Eocene (Boulton et al. 2006; 2007), or Late Oligocene–Early Miocene (Yilmaz 1993; Robertson 1998, 2000; Robertson et al. 2004). The ophiolites forming as a result of the northward subduction of Southern Neotethys were emplaced along the Anatolian platform as the Tauride allochthon (Akinci et al. 2015) and were exposed in a large area during post-Cretaceous tectonic processes (e.g., ophiolites of Kizildag, Musabeyli–Nurdagi, Mersin, Karsanti, in Turkey, Troodos in Cyprus and Bear–Bassit in Syria) (Yilmaz 1993; Unlugenc and Demirkol 1987; Robertson 2002).

The post-cretaceous tectonics of the Eastern Mediterranean region have resulted from the relative motions of the African, Arabian and Eurasian plates giving rise to crustal thickening in eastern Turkey, crustal thinning in western Turkey and westward escape of Anatolia (McKenzie 1972, 1978; Le Pichon and Angelier 1979; Sengor 1979; Jackson and McKenzie 1984; Dewey et al. 1986). The right-lateral North Anatolian Fault Zone (NAFZ), the left-lateral East Anatolian Fault Zone (EAFZ), Dead Sea Fault Zone (DSFZ) and Hellenic and Cyprus arcs accommodate the relative motions of the Arabian, African and Eurasian plates during the neotectonic period (Arpat and Saroglu 1972; Le Pichon and Angelier 1979; Sengor et al. 1985; Dewey et al. 1986; Bozkurt 2001;). In SE Turkey, the continuation of the EAFZ and the interaction among the active belts is still a matter of debate (McKenzie 1972; Robertson et al. 2004; Over et al. 2004a; Alp et al. 2011).

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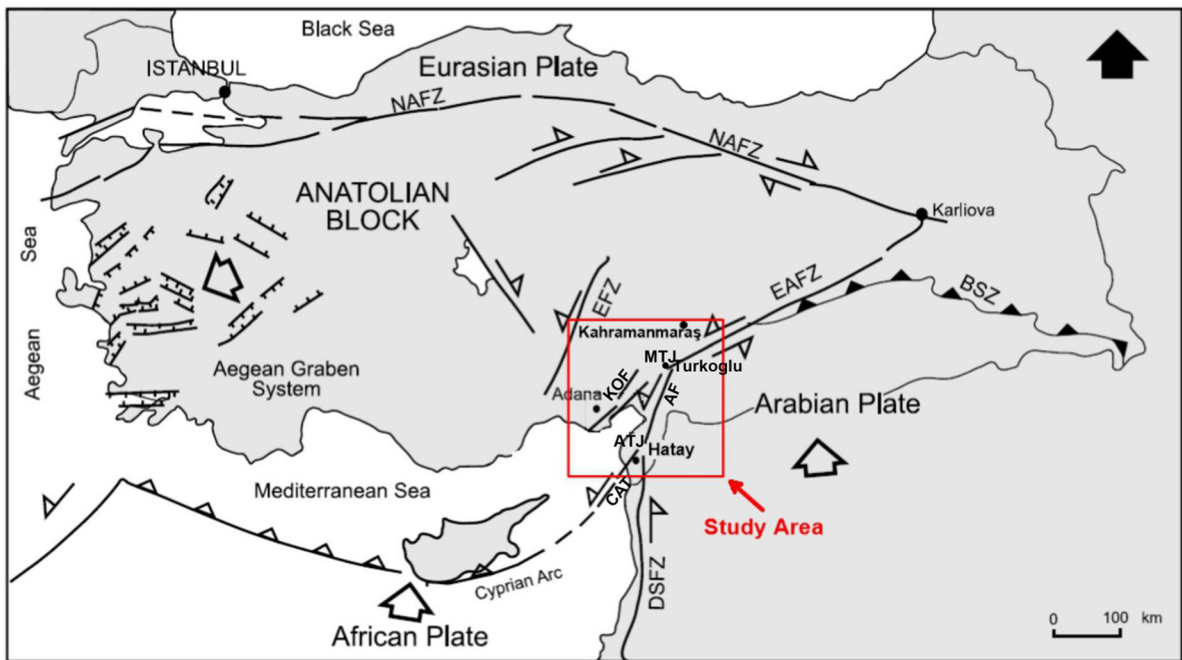[3] Department of Geography, Mustafa Kemal University, 31100 Antakya, Hatay, Turkey.

Figure 1
Study area within the tectonic framework of the eastern Mediterranean region (modified from Sengor 1979; Gursoy et al. 1998; Over et al. 2004b). *AF* Amanos Fault, *KOF* Karatas–Osmaniye Fault, *MTJ* Maras Triple Junction, *ATJ* Antakya Triple Junction, *CAT* Cyprus–Antakya Transform Fault

The complex tectonics gave rise to different geological deposits containing the basement units (i.e., ophiolites, volcanic units) of the tertiary–quaternary sedimentary assemblage in the Adana Basin area which developed between the Taurides and Hatay ophiolites (Aksu et al. 2005). Several geophysical studies based on gravity and magnetic data suggest that the anomalies in the eastern Mediterranean area are caused by the mafic, ultramafic, volcanic rocks (Ben-Avraham et al. 1976) and ophiolites extending over a large area from the Taurides in Turkey through Troodos in Cyprus to the Bear–Bassit in Syria (Robertson and Woodcock 1980). These anomalies of the Late Cretaceous Kizildag ophiolite and basaltic units within or beneath the ophiolites are considered to be the basement unit for the Miocene basins (Alp et al. 2011).

Analyzing the aeromagnetic data, Bilim et al. (2017) asserted there was high-intensity anomalies located in the Iskenderun Gulf. Using wavelet transform technique for gravity data, Alp et al. (2011) showed the presence of positive anomalies in Adana Basin and surroundings.

The aim of this paper is to contribute to the geological evolution of the region in light of geophysical data. Gravity and magnetic data are used to contribute to the understanding of the main tectonic features where the debate is still ongoing (e.g., continuation of EAFZ and relationships between active belts) in SE Anatolia. This permits us to also examine the correlation between geological structures and the geophysical anomaly field. As shown in some previous studies (e.g., Makris et al. 1998; Ansari and Alamdar 2009; Alp et al. 2011; Erbek and Dolmaz 2014; Albora et al. 2006; Bilim et al. 2017), geophysical data provides a window to understand the tectonic and structural fabric of the region and to correlate it with seismic activity.

2. Global Geological Setting

2.1. Tectonic Setting

The deformation pattern in the eastern Mediterranean region is rather complex, as is typical of continental convergence/collision zones. The eastern Mediterranean occupies parts of the Africa–Eurasia convergence and Arabia–Eurasia collision zones (Fig. 1). The study area is located at the intersection of three active belts: the southern end of the left-lateral EAFZ, the northern end of the sinistral DSFZ, and the Cyprus arc accommodating the relative motions between Arabia/Anatolia, Arabia/Africa and Africa/Anatolia, respectively (McKenzie 1972, 1978; Le Pichon and Angelier 1979; Sengor 1979; Jackson and McKenzie 1984; Dewey et al. 1986; Over et al. 2004a). EAFZ, DSFZ, Amanos Fault (AF), Karataş–Osmaniye Fault (KOF) and Cyprus–Antakya Transform Fault (CAT) (Fig. 1) are the main seismically active structures in the study area (Over et al. 2002, 2004a, b).

The EAFZ runs southwestward for about 500 km from Karliova in eastern Anatolia, where it meets the right-lateral North Anatolian Fault (NAF), to Turkoglu (Kahramanmaras). From that point, the continuation of the EAFZ is still under debate. Some researchers argue that the EAFZ continues in a southwestern trend from Karliova after passing Turkoglu, through Osmaniye and Iskenderun Gulf to northern Cyprus (McKenzie 1972; Jackson and McKenzie 1984, 1988; Hempton 1987; Taymaz et al. 1991) or through Osmaniye–Karatas to northern Cyprus (Boulton et al. 2006; Robertson et al. 2004) representing the Arabia/Anatolia boundary (McKenzie 1972; Arpat and Saroglu 1972; Perincek and Cemen 1990). Some authors suggest that the DSFZ connects to the EAFZ and the KOF at Turkoglu (Kahramanmaras) forming a triple junction (MTJ) (Fig. 1) (Gulen et al. 1987; Karig and Kozlu 1990; Lyberis et al. 1992).Some other researchers proposed that the EAFZ passes along Amanos Mountain to reach Amik Basin near Antakya (Over et al. 2004a). Based on fault kinematic analysis, Over et al. (2004a) suggest the Amik Basin as the most obvious tectonic feature for the location of a triple junction: the AF considered as the southern continuation of the EAFZ

(representing Arabia–Anatolia boundary), the DSFZ (representing Arabia–Africa boundary) that ends near the Amik Basin and the CAT (representing Africa–Anatolia boundary) intersect near Antakya forming an ATJ triple junction between Anatolia, Arabia and Africa (Fig. 1). Mahmoud et al. (2012) and Masson et al. (2010) proposed FFT-type (Fault–Fault transform) geometry for this triple junction.

2.2. Distribution of Ophiolites in the Region

The geological map published by the General Directorate of Mineral Research and Exploration (MTA) (Fig. 2) shows the spatial distribution of outcropping ophiolites/ophiolitic mélanges that are remnants of the southern Neotethys lithosphere (Inwood 2005). As shown on the geological map, ophiolitic rocks extend along the Amanos Mountain. The Hatay massif, or southern part of Amanos Mountain, is composed of an ophiolite sequence known as the Kizildag ophiolites (serpentinized peridotites and harzburgites, layered gabbros, sheeted dyke complex and pillow lavas) (Inwood 2005). The Kizildag ophiolites are composed of tectonic peridotites, isotropic gabbros and pillowed volcanic rocks (Tekeli and Erendil 1986) or are considered as an ophiolitic melange (Unlugenc and Demirkol 1987; Tinkler et al. 1981). The ophiolites, covered transgressively by sedimentary sequences ranging from Upper Cretaceous to Quaternary in age, are believed to have been generated by a supra-subduction zone spreading in the southernmost basin of the Mesozoic Neotethys (Inwood 2005; Piskin et al. 1986). The Miocene series (extensive conglomerate horizon with abundant ophiolitic detritus) is always transgressive on the older sedimentary sequences and the ophiolite. The Pliocene sediments consist of sandstones, marly limestone, clays and salty clays with a thickness between 100 and 400 m and the Quaternary sediments are conglomerates with angular or rounded fragments that are poorly cemented, travertines, alluvium and beach sand (Piskin et al. 1986). The ophiolites of both Hatay (Kizildag, Duziçi–Turkoğlu, Musabeyli–Nurdagi, in Fig. 2) and Adana (e.g., Karsanti and Mersin ophiolites, in Fig. 2) formed within the Southern Neotethys and accreted to the Tauride active margin (Demirkol 1989; Akinci et al.
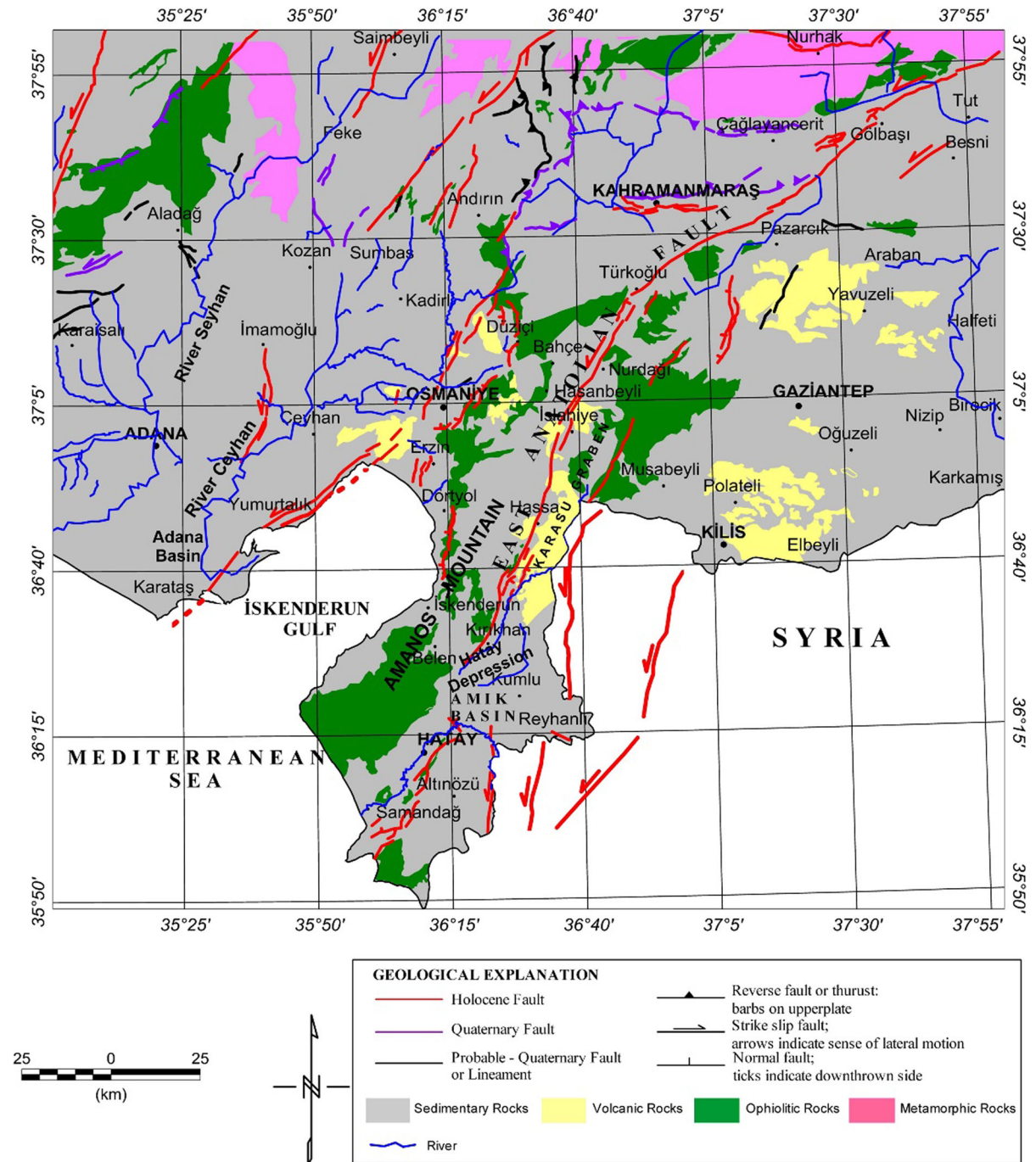
Figure 2
Simplified geological map of the study area (simplified from 1/500,000 scale Adana and Hatay sheets, MTA 2002)

2015) and seem to have been emplaced in SE Turkey by post-Cretaceous tectonics.

Unlugenc et al. (1990) emphasized that structural pattern of the Neogene fill on the irregular sea floor topography created by Pre-Miocene geologic units

indicated extensional basin characteristics in the Adana Basin during the Early Miocene. Early Miocene sediments uncomfortably overlie the Pre-Miocene units; Paleozoic basement, Lower Cretaceous limestone and dolomites (Cehennemdere Formation), Upper Cretaceous planktonic-bearing limestone (Yavca Formation), Upper Cretaceous Mersin Ophiolite (harzburgites, ultramafic cumulates, alkaline and tholeiitic basalts) and Upper Cretaceous–Paleocene Findik pinari Ophiolitic Melange (gabbro, serpentinized peridodite, amphibolite, basalt radiolarite, pyroxenite and sedimentary blocks of mostly limestone) (Demirtasli et al. 1984; Gulen et al. 1987; Ozer et al. 2004). The Plio-Quaternary deposits uncomfortably overlie all of the older sequences (i.e., ophiolites/ophiolitic melange) in the Adana depression (Gul 2007).

The ophiolites are exposed mostly along the top of Amanos Mountain (Fig. 2). The NE–SW trending Kizildag (Hatay) ophiolite is one of the best preserved remnants of the Late Cretaceous oceanic lithosphere of the southern Neotethys. The Kizildag (Hatay) ophiolite, which is 25 km wide, 45 km long, and up to 7 km thick and covers an area of approximately 950 km^2, is a representative part of the same Peri-Arabian ophiolite belt that includes the Troodos and the Baër–Bassit ophiolites (Tekeli and Erendil 1986).

3. Data and Methods

The measurement of regional gravity data in Turkey was carried out by MTA during the period 1973–1988. In addition to the data surveyed by MTA, some data was obtained from the General Command of Mapping (GCM) and the Turkish Petroleum Corporation (TPAO).

Under patronage of the MTA and the Department of Geophysical Research aeromagnetic survey were completed between 1978 and 1989, obtaining about 460,000 km of airborne data, to provide the basis for the search of underground resources in Turkey. Flight, in each so-called sector, was carried out at an average altitude of 2000 feet, partly due to topographic height, often taking into account geological features. The aeromagnetic data are reduced to the pole (RTP) according to International Geomagnetic Reference Field (IGRF) for 1985. The aeromagnetic data were surveyed from MTA. The grid interval of data is 2 km. Flight line of aircraft is 610 m from ground surface. Gravity and magnetic anomaly maps of the area cover Adana Basin, Iskenderun Gulf, Amanos Mountain and Hatay area altogether (Fig. 2). Bouguer, reduced to pole (RTP), pseudo-gravity transformation image of DR and first vertical maps were prepared.

3.1. Bouguer Map

Bouguer anomalies depict underground mass distributions. For this reason, Bouguer anomalies are commonly used to reveal geological structures. The Bouguer anomaly reflects "anomalous mass", masses with density above or below 2670 kg/m^3. The choice of 2670 kg/m^3 as an average crustal density is appropriate for most geological situations. In certain studies, such as over young volcanic terrain or sedimentary basins, another density may be more normal (Blakely 1996).

3.2. Reduced to the Pole (RTP)

Magnetic anomalies usually do not overlap with the structure causing, but the gravity anomaly coincides with the structure.

RTP is applied to the magnetic field converted from the measurements in the northern magnetic polemagnetic anomalies usually do not overlap with the structure causing, but the gravity anomaly coincides with the structure. RTP is an operator that transforms the asymmetric form into a symmetric form for reproducing the magnetic anomaly from vertical magnetization (Ansari and Alamdar 2009).The magnetization of the structure depends to the orientation of the ground magnetic field so, the RTP filter is applied to magnetic field data at wave number domain (Blakely 1996).

3.3. Pseudo-Gravity Transformation (PGT)

The relationship between magnetic and gravitational potentials is called Poisson relationship (Garland 1951). Poisson's relationship between

gravity and magnetic potentials has been used extensively to convert magnetic anomalies to pseudo-gravity anomalies (Baranov 1957). The multiplication result is given by a low-pass filter established in the wavelet environment (Baranov 1957; Blakely 1996). The gravity anomaly of the underground structure that causes magnetic anomalies can also be obtained from the magnetic data. Simplifying complex magnetic anomalies the PGT permit to reveal deep magnetic structures (Blakely 1996).Using the fast Fourier transform (FFT) techniques, the pseudo-gravity transformation can be an effective method for detecting the magnetic anomaly at depth. This transformation is an excellent interpretation tool for the detection of magnetic anomaly at depth from an artificial gravity model using conventional FFT tools (Pratt and Shi 2004). The pseudo-gravity transform was applied to the total magnetic intensity grid using the FFT filter package available in Oasis Montaj. PGT shows the relationships between both shallow and deep magnetic sources. The pseudo-gravity transformation has several important applications (i.e., Pratt and Shi 2004; Feumoe et al. 2012; Erbek and Dolmaz 2014). Some geological units may be both highly magnetic and anomalously dense. A mafic pluton surrounded by sedimentary rocks, for example, may produce both a gravity and magnetic anomaly.

3.4. Derivative Ratio (DR)

The DR which is among the geophysical models that can be used are also applied to the gravity and magnetic data, The DR filter has become a preferred method for finding lineaments because it is non-directional, makes relatively low-amplitude marks clearer and has short calculation time (Cooper and Cowan 2006). The orientation of the lineaments on the DR map and the trends of the faults are similar. The results of geological studies based on surface observations do not include the parameters of underground structures that are relatively more intricate and therefore, unobservable. Geophysical methods are very important for clarifying geological problems at this point. In this context, it is a fact that many linear effects observed in the DR map represent the limits of geological structures that cannot be seen on the surface.

The use of directional derivatives and relief maps in linearity studies using potential field data is common. These methods only strengthen the signals of underground structures in the direction perpendicular to the azimuth angle of the filter and it is insufficient to strengthen low-amplitude signals. Cooper and Cowan (2007) suggested the DR filter using the following ratio:

$$DR = \tan^{-1}\left(\frac{\frac{df}{dx}}{\left|\frac{df}{dy}\right|^n}\right),$$

where df/dx: x derivative, df/dy: y derivative, n: the factor n allows the strength of the filter to be controlled. In this study the n value is taken as 0.05 giving the best solution.

4. Data Analysis and Discussion

The Bouguer gravity anomalies of eastern corner of Eastern Mediterranean region can be divided in the areas of positive and negative values ranging between -118 and $+74 \times 10^{-5}$ m/s^2 (Fig. 3). The negative gravity anomaly with -118×10^{-5} m/s^2, corresponding probably to the relatively low density rocks of sedimentary and metamorphic origin on the northern border of the area we investigated. Figure 3 also shows a negative gravity anomaly of approximately -40×10^{-5} m/s^2, extending from Erzin, Osmaniye to Duzici–Bahce, located along the central part of the Amanos Mountain. A similar negative gravity anomaly is also obtained in the Amik Basin, located to the east of the Amanos Mountain.

The gravity anomalies with high amplitude (ranging from $+10$ to $+74 \times 10^{-5}$ m/s^2) were detected in both NW and SE of Iskenderun Gulf (Fig. 3). Two significant highly positive anomalies are observed on the Bouguer map: (1) one that is maximum positive gravity anomaly with approximately $+74 \times 10^{-5}$ m/s^2 is detected in the southern part of the Amanos Mountain (SE of Iskenderun Gulf). This anomaly corresponding to a high density structure is clearly derived from the Kızıldag
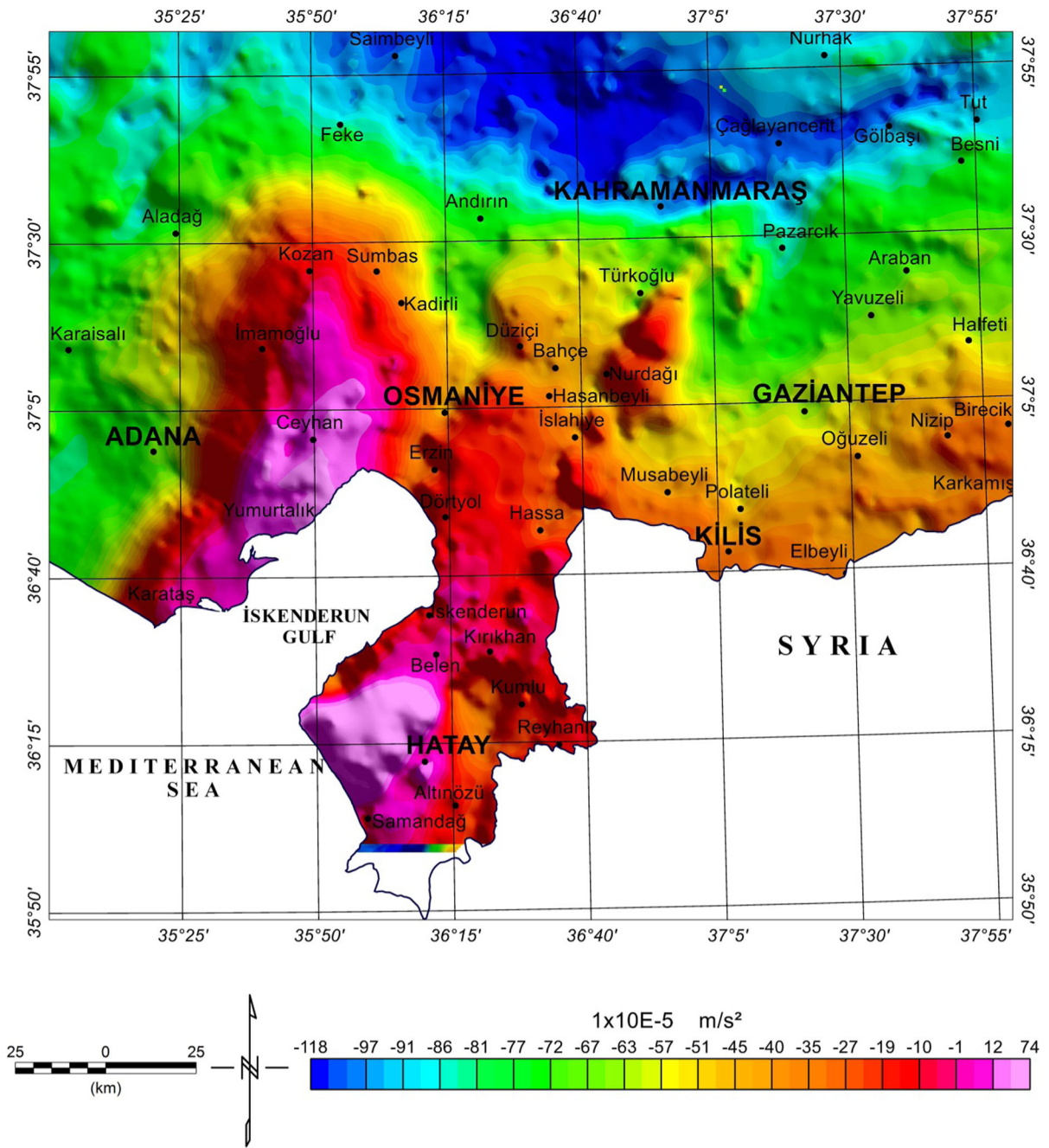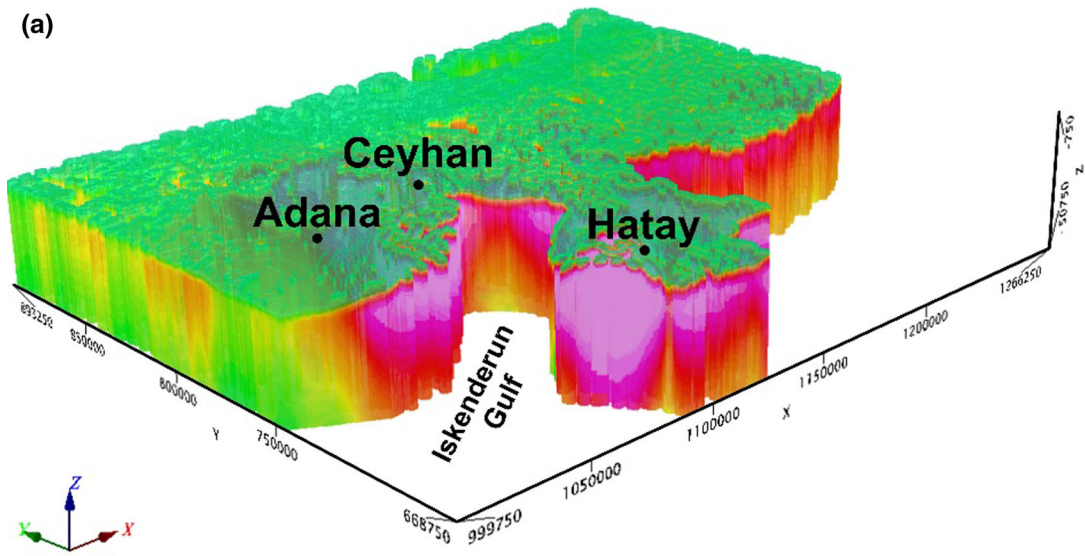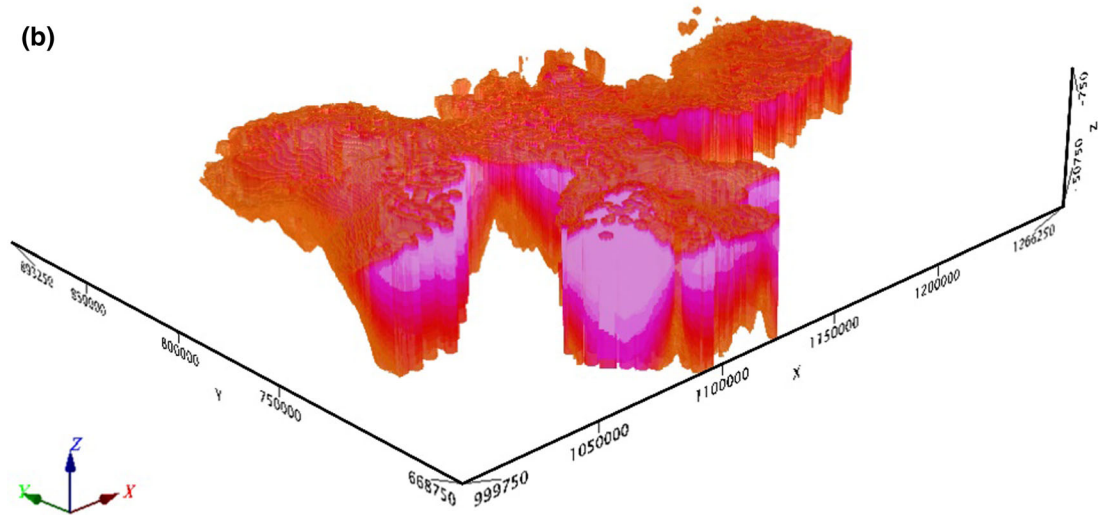
Figure 3
Gravity anomaly map of the study area

ophiolites, (2) the other positive gravity anomaly with approximately $+ 25 \times 10^{-5}$ m/s^2 is found in Adana Basin (NW of Iskenderun Gulf).This positive anomaly is believed to be caused by a relatively high density structure, probably deep ophiolite rocks overlapped by younger sedimentary units. Akin (2016) proposed a 3D gravitational apparent density model for different depths in Turkey. Using the data
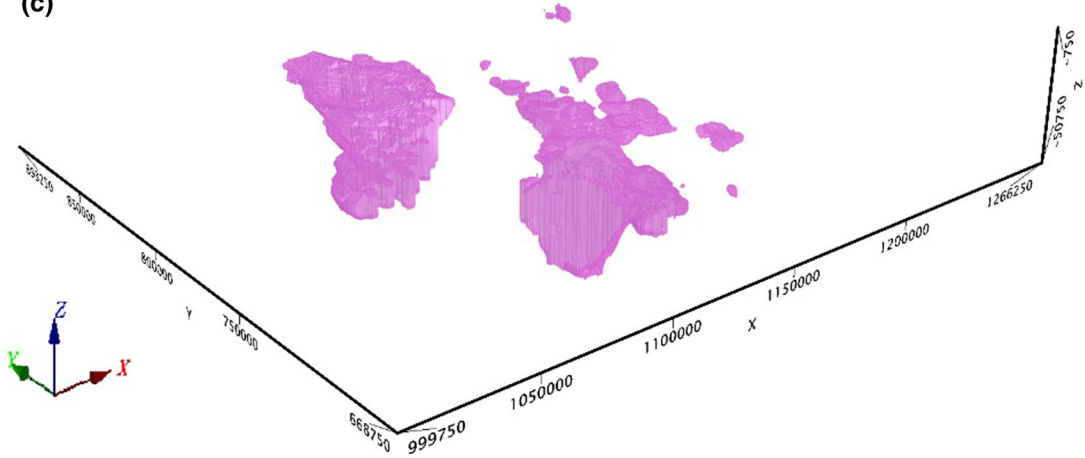
◄Figure 4

3D image of the apparent gravity density of study area. (X East, Y North, Z depth). **a** 2670 kg/m³, **b** 2750 kg/m³, **c** 2820 kg/m³

proposed by Akin (2016), different 3D models of both Kizildag and buried ophiolites are obtained according to selected density values: 2670 kg/m³ (Fig. 4a), 2750 kg/m³ (Fig. 4b) and 2820 kg/m³ (Fig. 4c). The 2820 kg/m³ is the highest density value that prevents the Kizildag ophiolite from losing its position on the geological map (Fig. 2) and preserves its projection. The Kizildag ophiolite was determined to be more rooted and thicker than the buried ophiolite (Fig. 4c). The length and width of the buried ophiolite is 110 km and 35 km, respectively (Fig. 4c).

The interpretation of aeromagnetic anomalies may be quite complex because the Earth's magnetic field and body magnetizations may cause disorientations to polarities of the magnetic anomalies. These disorientations can be removed from the anomalies by the reduction to the pole (RTP) transformation so

the magnetized body is assumed to be at the magnetic pole in the vertical direction. In this region, orientations of anomalies on the magnetic map (Fig. 5a) are similar to those on the RTP map (Fig. 5b). For this reason, the RTP map can be approved as representative of the aeromagnetic anomalies.

The magnetic anomaly values calculated from RTP values vary between − 648 and 701 nT in the study area (Fig. 5b). Along the Amanos Mountain, two highly positive magnetic anomalies were obtained: one corresponds to the Kizildag ophiolites with + 450 nT and the other with + 650 nT is due the small ophiolite block located near an area between Bahce, Duzici and Turkoglu (north of Amanos Mountain) (Fig. 5b). A remarkable negative anomaly with a value of – 648 nT is observed in the central part of the Amanos Mountain. The negative magnetic anomaly is probably due to sedimentary sequences with carbonate rocks. Another significant negative anomaly with – 350 nT is obtained for the Plio-Quaternary Amik Basin (i.e., Hatay depression) east of the Amanos Mountain (Fig. 5b). Figure 5b shows another positive magnetic anomaly in the area
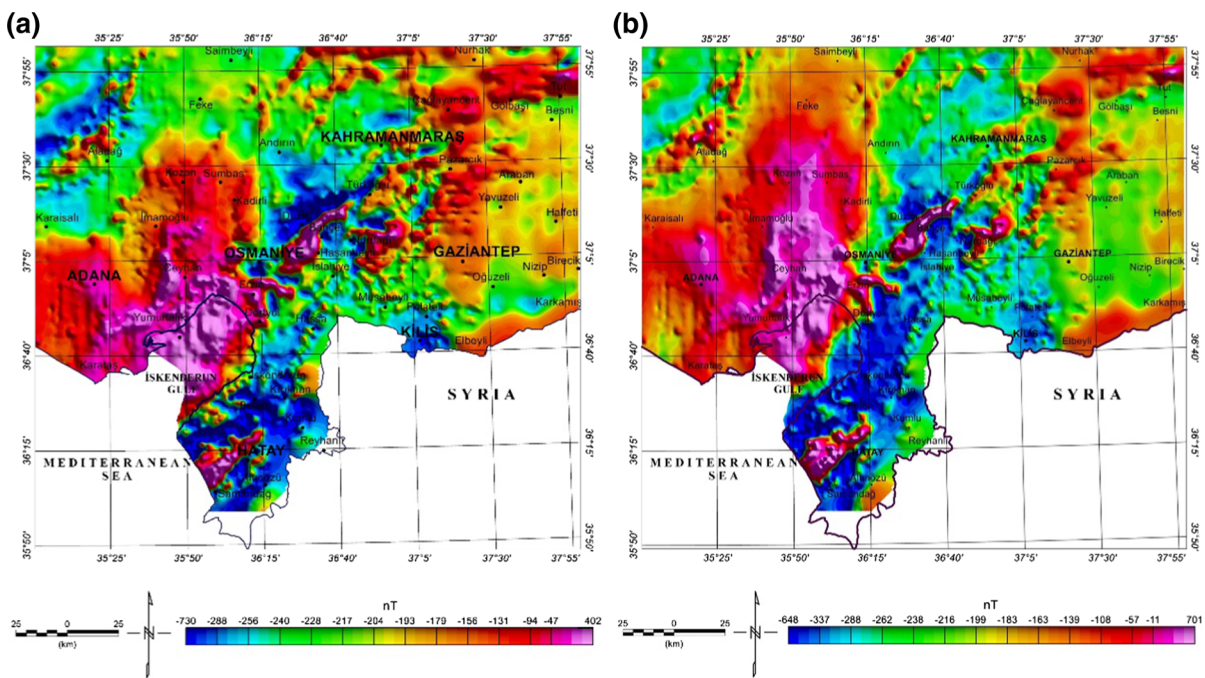

Figure 5

Total field aeromagnetic anomaly map (**a**), the reduced to the pole (RTP) magnetic anomaly map (**b**)
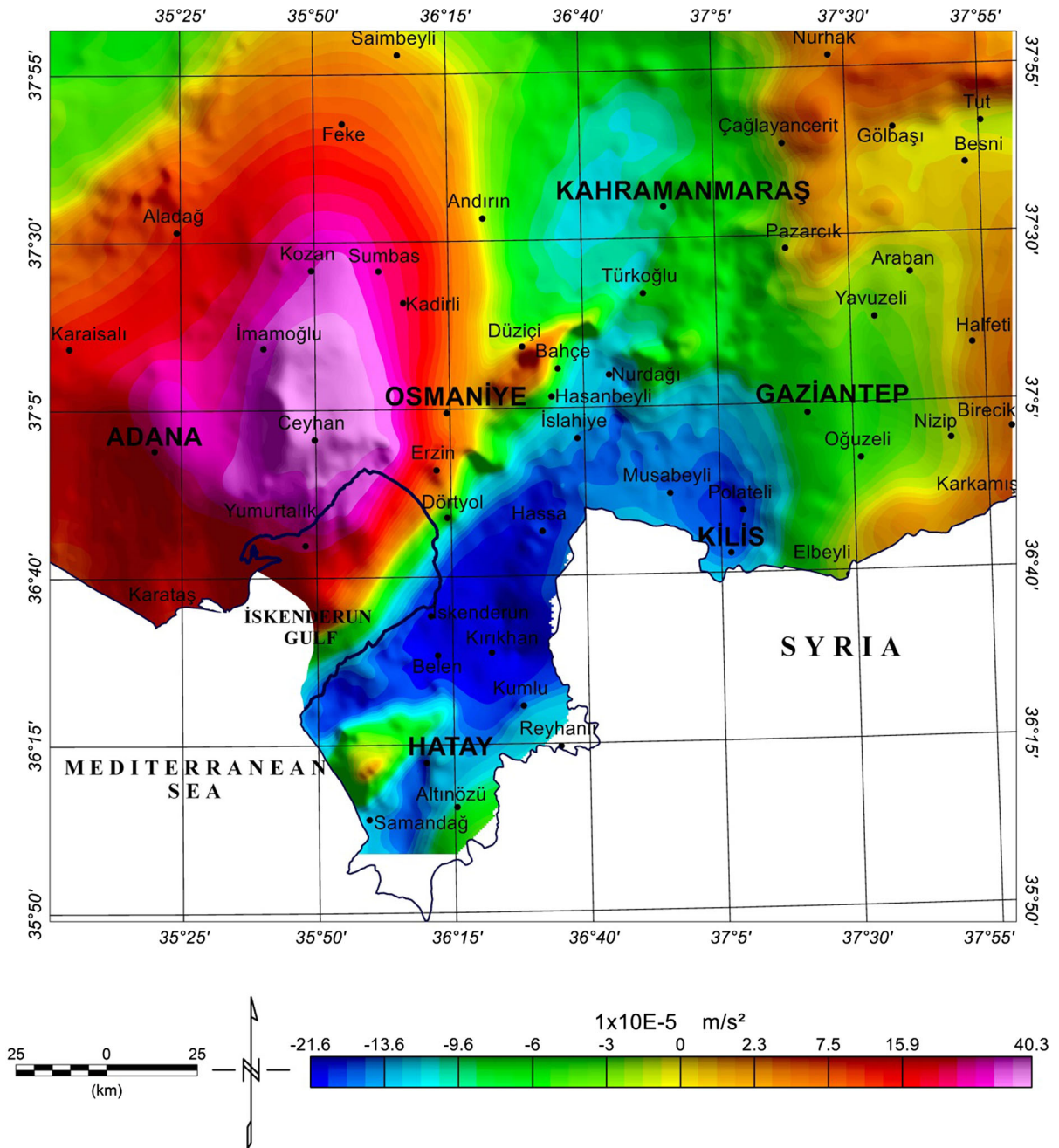
Figure 6
Pseudo-gravity map of total field magnetic of the study area

between Ceyhan (Adana Basin) and Iskenderun Gulf infilled by young sediments (Quaternary deposits). This anomaly indicates a buried structure which corresponds to the ophiolites (Fig. 4c). The previous geophysical studies (Alp et al. 2011; Bilim et al. 2017) detected also positive gravity and magnetic anomalies in the Adana and Iskenderun areas without mentioning their origin with certainty. The processing of both gravity and magnetic data indicates that the buried positive anomaly structure is probably

ophiolitic units covered by young sediments in Adana Basin.

A pseudo-gravity filter was applied to the magnetic data for obtaining a deep structure effect (Fig. 6). The PGT image shows a concentric-shaped an anomaly about 100 km in diameter centered in the Ceyhan (Adana Basin) area. This wide structure, which corresponds to the long wavelength anomalies, is reflected in the deep structure probably indicating the ophiolites beneath the young sediments. All the maps obtained in this study show that the buried structure is ophiolite.

In Fig. 7, the DR filter is applied to both gravity and magnetic data to obtain significant lineaments as shown in Fig. 7a, b, respectively. The complex tectonic framework of the region is reflected in both the gravity and magnetic DR maps. Compared to the gravity map (Fig. 7a), the magnetic map (Fig. 7b) presents a little more complexity. The total component of the ground magnetic field is distributed over a wide amplitude range. The DR method applied to both sets of data reveals higher wave numbers showing the effect of the features near surface. Both

DR maps show a few lineaments with NNE–SSW direction which are significant in the context of the tectonic framework of the region. On the magnetic DR map a NNE–SSW line of discontinuity with about 50 km length passing through Yumurtalik, Ceyhan, and Imamoglu settlements is clearly visible. Another NNE–SSW orientation line extends to Dortyol, Erzin and Bahce (Fig. 7a, b). Tectonic indications show that these lines, which are active, can be considered as faults. The fault that passes through Ceyhan to Imamoglu seems to limit the buried ophiolites revealed by gravity and magnetic maps (Figs. 3, 5b, 6). Figure 7a, b indicate clearly an important lineament which runs from Yumurtalik to Duzici through Osmaniye named as the Karatas–Osmaniye Fault (KOF, in Fig. 1) (Gulen et al. 1987; Over et al. 2004b). Some authors (e.g., Gulen et al. 1987; Lyberis et al. 1992) propose that the DSFZ connects to the EAFZ and the KOF at Turkoglu (Kahramanmaras) forming Maras triple junction (MTJ). Fault kinematic analysis carried out in the study area also shows that no fault was measured between Duzici and Turkoglu (Over et al. 2004b, c).
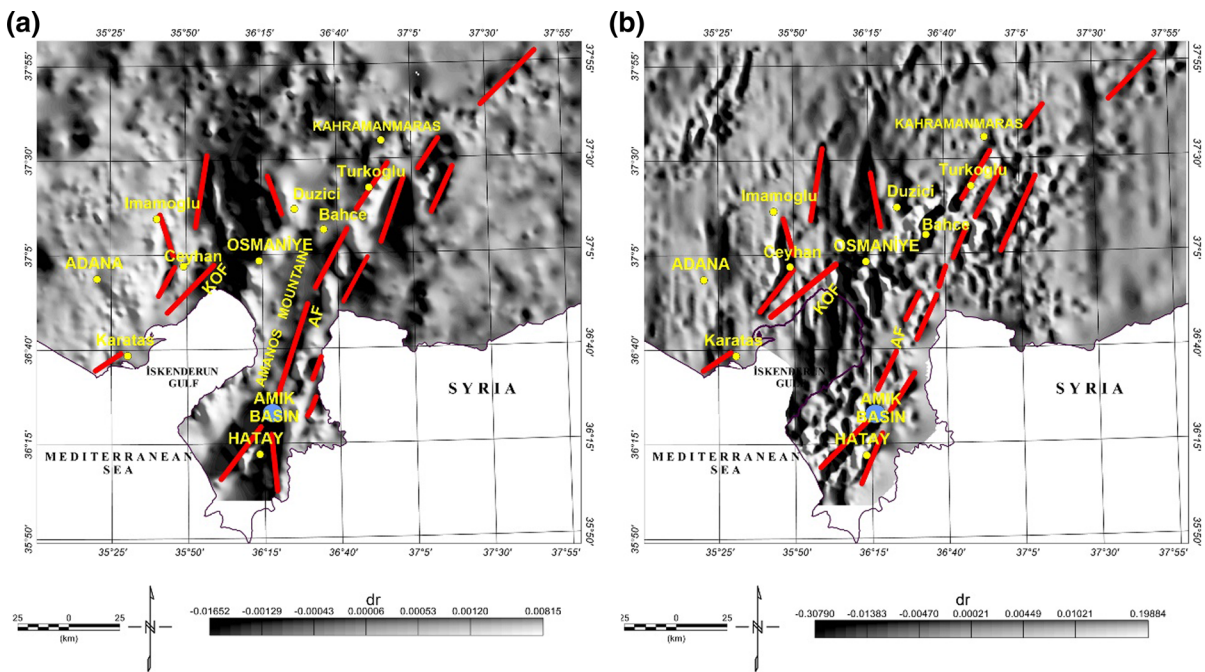

Figure 7
Derivative ratio (DR) images from gravity data (**a**) and from magnetic data (**b**)
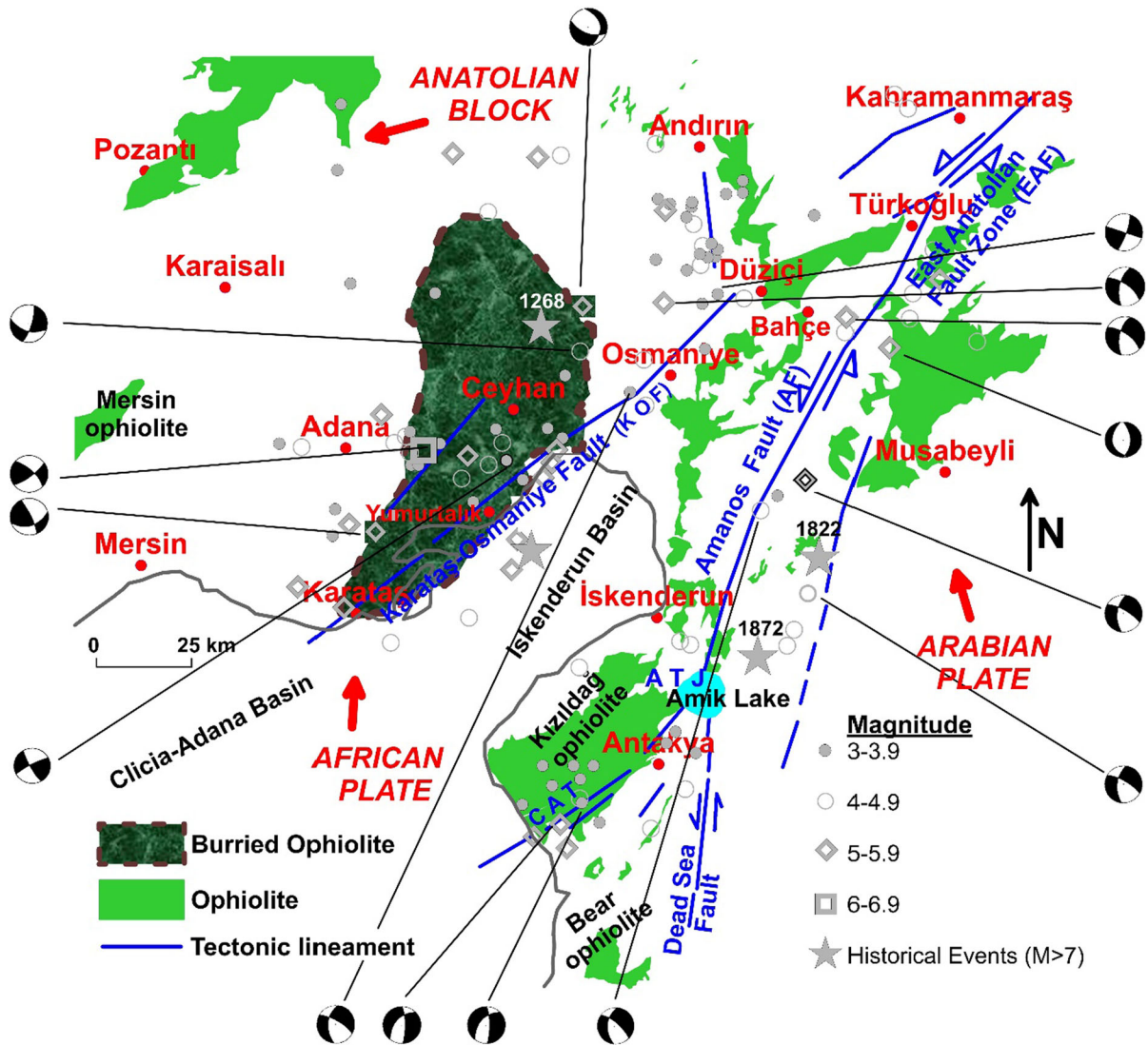
Figure 8

The sketched map shows all the results of this study together. The balloons show the solutions of some earthquakes (modified from Over et al. 2004b)

They concluded also that the EAFZ does not continue toward Adana region in the west.

Figure 7a, b show a few lineaments in the Hatay region. All lineaments are grouped parallel to Amanos Mountain. The most obvious line extends along Amanos Mountain and is known as the Amanos Fault (Over et al. 2004a) or Karasu Fault (Lyberis et al. 1992; Over et al. 2004b). As shown in Fig. 8, the seismically active lineament seems to be the southern continuation of the EAFZ as defined by SPOT image

analysis (Over et al. 2004a). Based on both fault kinematics and focal mechanisms analysis, the Amanos Fault is considered as the present-day boundary between Anatolian block (i.e., part of Eurasian plate) and the Arabian Plate. The AF, DSFZ and CAT plate boundaries meet each other to form the Antakya triple junction (ATJ) near Amik Basin (Over et al. 2004c). Using the wavelet transformation on gravity data, Alp et al. (2011) detected a tectonic

border in the Hatay region and suggested a triple junction present near Hatay.

Note that all lineaments shown in Fig. 7, in particular KOF (in Adana region) and AF (in Hatay region), are also clearly visible in the obtained maps (Figs. 3, 5b, 6). Note also that the distribution of the earthquakes shows that most of the lineaments traced in Fig. 7a, b, are seismically actives and can be considered as faults (Fig. 8). The inversion of focal mechanisms shows that the present-day tectonic regimes is dominantly a transtension (combined strike-slip and extension) along major fault systems, i.e., East Anatolian Fault, Amanos Fault, Karatas–Osmaniye Fault (Over et al. 2004b, c).

5. Conclusions

The extensive work of processing the gravity and magnetic data is presented here to contribute to understanding the global tectonic/geodynamic evolution of the eastern Mediterranean region. Integrating these data with other available geophysical and geological data, it is possible to summarize the very complex tectonic evolution of the eastern Mediterranean area within the general framework of the oblique subduction/collision (e.g., western corner of Arabian Platform) between Arabia and Eurasia as follows:

1. This study indicates that the Upper Cretaceous ophiolites resulting from subduction of the Southern Neotethys occupy more area than mapped on both the MTA geological map (Fig. 2) and previous studies. The gravity and Magnetic anomaly maps indicate the presence of buried ophiolites in the Adana depression and Iskenderun Bay.
2. The KOF, extending from Karatas in the south to the Osmaniye in the north, does not pass northward through Duzici–Bahce region to joint EAFZ in Turkoglu. This indicates that the EAFZ does not continue toward the southwest to Adana depression meaning that the KOF is not a continuation of the EAFZ. The DR images clearly show that the AF which is considered as continuation of the EAFZ runs southward from Turkoglu to Amik Basin along Amanos Mountain, forming a

boundary between the Anatolian block (part of Eurasia) and Arabian plate.

REFERENCES

Akin, U. (2016). Investigation of the seismic velocity distribution and crustal structure of Turkey by means of gravity data. *Bulletin of the Research and Exploration., 153,* 185–202.

Akinci, A. C., Robertson, A. H., & Unlugenc, U. (2015). Late Cretaceous subduction–collision history of the Southern Neotethys: New evidence from the Çağlayancerit area, SE Turkey. *International Journal of Earth Sciences (Geologische Rundschau), 105*(1), 315–337.

Aksu, A. E., Hall, J., & Yaltirak, C. (2005). Miocene to recent tectonic evolution of the eastern Mediterranean: New pieces of the old Mediterranean puzzle. *Marine Geology, 221,* 1–13.

Albora, A. M., Sayin, N., & Ucan, O. N. (2006). Evaluation of tectonic structure of Iskenderun Basin (Turkey) using steerable filters. *Marine Geophysical Research, 27,* 225–239.

Alp, H., Albora, A. M., & Tur, H. (2011). A view of tectonic structure and gravity anomalies of Hatay Region Southern Turkey using wavelet analysis. *Journal of Applied Geophysics, 75*(3), 498–505.

Ansari, A. H., & Alamdar, K. (2009). Reduction to the pole of magnetic anomalies using analytic signal. *World Applied Sciences Journal, 7,* 405–409.

Arpat, E., & Saroglu, F. (1972). The East Anatolian fault system: Thoughts on its development. *Bulletin of Mineral Research and Exploration of Turkey, 78,* 33–39.

Baranov, V. (1957). A new method for interpretation of aeromagnetic maps: Pseudogravimetric anomalies. *Geophysics, 22*(2), 359–383.

Ben-Avraham, Z., Shoham, Y., & Ginzburg, A. (1976). Magnetic anomalies in the eastern Mediterranean and the tectonic setting of the Eratosthenes Seamount. *Geophysics Journal of the Royal Astronomical Society, 45,* 105–123.

Bilim, F., Aydemir, A., & Ates, A. (2017). Tectonics and thermal structure in the Gulf of Iskenderun (southern Turkey) from the aeromagnetic, borehole and seismic data. *Geotermics, 70,* 206–221.

Blakely, R. J. (1996). *Potential theory in gravity and magnetic applications* (p. 441). Cambridge: Cambridge University Press.

Boulton, S. J., Robertson, A. H. F., Ellam, R. M., Safak, U., & Unlugenc, U. C. (2007). Strontium isotopic and micropalaeontological dating used to redefine the stratigraphy of the Neotectonic Hatay Graben, southern Turkey. *Turkish Journal of Earth Sciences, 16,* 141–179.

Boulton, S. J., Robertson, A. H. F., & Unlugenc, U. C. (2006). Tectonic and sedimentary evolution of the Cenozoic Hatay Graben, Southern Turkey: A two phase, foreland basin then transtensional basin model. In A. H. F. Robertson & D. Mountrakis (Eds.), *Tectonic development of the Eastern Mediterranean Region* (pp. 613–634). London: Geological Society of London. **(Special Publication no. 260)**.

Bozkurt, E. (2001). Neotectonics of Turkey—A synthesis. *Geodinamica Acta, 14,* 3–30.

Cooper, G. R. J., & Cowan, D. R. (2006). Enhancing potential field data using filters based on the local phase. *Computers and Geosciences, 32*(10), 1585–1591.

Cooper, G. R. J., & Cowan, D. R. (2007). Enhancing linear features in image data using horizontal orthogonal gradient ratios. *Computers and Geosciences, 33*(7), 981–984.

Unlugenc U. C. & Demirkol, C. (1987). Kizildag Yayla (Adana) dolayının Stratigrafisi. TMMOB Jeoloji Mühendisleri Odası Publications.

Demirkol, C. (1989). The stratigraphy and geological development of the Carbonate platform in the Pozantı–Karsantı–Karaisalı (East Taurus) area. *Bulletin of the Mineral Research and Exploration, 109,* 25–36.

Demirtasli, E., Turhan, N., Bilgin, A. Z., & Selim, M. (1984). Geology of the Bolkar Mountains. In: O. Tekili & M. C. Göncüoğlu (Eds.) *Geology of the Taurus Belt*. Proceedings of the International Symposium. Mineral Research and Exploration Institute of Turkey (MTA), Ankara, pp. 125–141.

Dewey, J. F., Hempton, M. R., Kidd, W. S. F., Saroglu, F., & Sengor, A. M. C. (1986). Shortening of continental lithosphere: The neotectonics of Eastern Anatolia—a young collision zone. In M. P. Coward & A. C. Ries (Eds.), *Collision tectonics*. London: Geological Society. **(Special Publication, 19, 3–36)**.

Erbek, E., & Dolmaz, M. N. (2014). Geophysical researches (gravity and magnetic) of the Eratosthenes Seamount in the Eastern Mediterranean Sea. *Acta Geophysica, 62*(4), 762–784.

Feumoe, A. N., Mbargai, T. N., Dicoum, E. M., & Fairhead, J. D. (2012). Delineation of tectonic lineaments using aeromagnetic data for the southeast Cameroon area. *Geofizika, 29*(2), 175–192.

Garland, G. D. (1951). Combined analysis of gravity and magnetic anomalies. *Geophysics, 16,* 51–62.

Gul, M. (2007). Effects of antecedent topography on reefal carbonate deposition: Early-Middle Miocene of the Adana Basin, S Turkey. *Journal of Asian Earth Sciences, 31,* 18–34.

Gulen, L., Barka, A., & Toksoz, M. N. (1987). Kıtaların çarpışması ve ilgili kompleks deformasyon: Maras uclu eklemi ve cevre yapılari. *Yerbilimleri, 14,* 319–336.

Gursoy, H., Piper, J. D. A., Tatar, O., & Mesci, L. (1998). Paleomagnetic study of the Karaman and Karapınar volcanic complex, central Turkey: neotectonic rotation in the south central sector of the Anatolian Block. *Tectonophysics, 299,* 191–211.

Hempton, M. R. (1987). Constraints on Arabian plate motions; an extensional history of the Red sea. *Tectonics, 6,* 668–705.

Inwood, J. (2005). The tectonic evolution of the Hatay (Kızıl Dağ) ophiolite, southern Turkey. PhD thesis, University of Plymouth.

Jackson, J., & McKenzie, D. P. (1984). Active tectonics of the Alpine–Himalayan belt between western Turkey and Pakistan. *Geophysical Journal of Royal Astronomical Society, C77,* 185–264.

Jackson, J., & McKenzie, D. P. (1988). The relationship between plate motion and seismic moment tensors, and the rates of active deformation in the Mediterranean and Middle East. *Geophysical Journal of Royal Astronomical Society, 93,* 45–73.

Karig, D. E., & Kozlu, H. (1990). Late Paleogene–Neogene evolution of the triple Junction near Maras, South-Central Turkey. *Journal of the Geological Society London, 147,* 1023–1034.

Le Pichon, X., & Angelier, J. (1979). The Hellenic arc and trench system: A key to the neotectonic evolution of the eastern Mediterranean area. *Tectonophysics, 60,* 1–42.

Lyberis, N., Yurur, T., Chorowicz, J., Kasapoglu, E., & Gundogdu, N. (1992). The East Anatolian Fault: An oblique collisional belt. *Tectonophysics, 204,* 1–15.

Mahmoud, Y., Masson, F., Meghraoui, M., Cakır, Z., Alchalbi, A., Yavaşoğlu, H. Yönlü, Ö., Daoud, M., Ergintav, S., & İnan, S. (2012). Kinematic study at the junction of the East Anatolian fault and the Dead Sea fault from GPS measurements. *Journal of Geodynamics*. Retrieved May 18, 2012 from https://doi.org/10.1016/j.jog.2012.05.006.

Makris, J., Morelli, C., & Zanolla, C. (1998). The Bouguer gravity map of the Mediterranean Sea (IBCM-G). *Bollettino Di Geofisica Teorica and Aplicata, 39*(2), 79–98.

Masson, F., Mahmood, Y., Cakir, Z., Yavaşoğlu, H., Meghraoui, M., Alchalbi, A., Ergintav, S. (2010). GPS characterization of the triple junction between Arabia, Africa and Anatolia: New measurements in SE Turkey and in NW Syria. WEGENER 2010 15th General Assembly of Wegener. Programme and Book of Abstracts. September 14–17, 2010, Geodesy Department of Kandilli Observatory and Earthquake Research Institute of Bogazici University, Istanbul, Turkey, 47.

McKenzie, D. P. (1972). Active tectonics of the Mediterranean Region. *Geophysical Journal of Royal Astronomical Society, 30,* 109–185.

McKenzie, D. P. (1978). Active tectonics of the Alpine–Himalayan belt: The Aegean sea and surrounding regions (tectonic of Aegean region). *Geophysical Journal Royal Astronomical Society, 55,* 217–254.

MTA. (2002). *Geological map of Turkey (1:500.000 scale Adana and Hatay sheets)*. Ankara: General Directorate of Mineral Research and Exploration.

Over, O., Kavak, K., Bellier, O., & Ozden, S. (2004a). Is the Amik Basin (SE-Turkey) a triple junction area? Analyses of SPOT XS imagery and seismicity. *International Journal of Remote Sensing, 25*(00), 1–17.

Over, O., Ozden, S., & Unlugenc, U. C. (2004b). Quaternary stress regime change along the Misis Structural High (SE Adana Basin, Turkey). *Tectonics, 23,* TC3008. https://doi.org/10.1029/2002tc001455. **(1–19)**.

Over, S., Ozden, S., & Yilmaz, H. (2004c). Late Cenozoic stress state distributions along the Karasu Valley, SE Turkey. *Tectonophysics, 380,* 43–68.

Over, S., Unlugenc, U. C., & Bellier, O. (2002). Quaternary stress regime change in the Hatay region (SE Turkey). *Geophysical Journal International, 148,* 1–14.

Ozer, E., Koc, H., & Ozsayar, T. Y. (2004). Stratigraphical evidence for the depression of the northern margin of the Menderes–Tauride Block (Turkey) during the Late Cretaceous. *Journal of Asian Earth Sciences, 22,* 401–412.

Perincek, D., & Cemen, İ. (1990). The structural relationship between the East Anatolian and Dead Sea Fault Zones in Southeastern Turkey. *Tectonophysics, 172,* 331–340.

Piskin, O., Delaloye, M., Selcuk, H., & Wagner, J. J. (1986). Guide to Hatay geology, (SE Turkey). *Ofioliti, 11,* 87–104.

Pratt, D. A., & Shi, Z. (2004). An improved pseudo-gravity magnetic transform technique for investigation of deep magnetic source rocks. ASEG Extended Abstracts 2004: 17th Geophysical Conference, pp. 1–4.

Robertson, A. H. F. (1998). Mesozoic–Tertiary tectonic evolution of the easternmost Mediterranean area: Integration of marine and land evidence. In: A. H. F. Robertson, K.-C. Emeis, C. Richter, A. Camerlenghi (Eds.), *Proceedings of the Ocean Drilling Program, Scientific Results,* Ocean Drilling Program (Vol. 160, pp. 723–782). College Station, TX.

Robertson, A. H. F. (2000). Mesozoic-tertiary tectonic-sedimentary evolution of a south Tethyan oceanic basin and its margins in southern Turkey. In E. Bozkurt, J. A. Winchester, & J. D. A. Piper (Eds.), *Tectonics and magmatism in Turkey and the surrounding area*. London: Geological Society. **(Special Publications 173, 43–82)**.

Robertson, A. H. F. (2002). Overview of the genesis and emplacement of Mesozoic ophiolites in the Eastern Mediterranean Tethyan region. *Lithos, 65,* 1–67.

Robertson, A., Unlugenc, U. C., Inan, N., & Tasli, K. (2004). The Misis–Andırın Complex: A Mid-Tertiary melange related to late-stage subduction of the Southern Neotethys in S Turkey. *Journal of Asian Earth Sciences, 22,* 413–453.

Robertson, A. H. F., & Woodcock, N. H. (1980). Tectonic setting of the Troodos massif in the east Mediterranean. In A. Panayiotou (Ed.) Ophiolites: Proceedings, International Ophiolite Symposium, Cyprus, 1979, pp. 36–49.

Sengor, A. M. C. (1979). The North Anatolian transform fault: Its age, offset and tectonic significance. *Journal of Geological Society of London, 136,* 269–282.

Sengor, A. M. C., Gorur, N., & Saroglu, F. (1985). Strike-slip faulting and related basin formation in zones of tectonic escape: Turkey as a case study. In K. T. Biddle & N. Christie-Blick (Eds.), *Strike-slip deformation, basin formation and sedimentation*. Tulsa: Society of Economics Paleontology and Minerals. **(Special Publication, 37, 227–264)**.

Taymaz, T., Eyidoğan, H., & Jackson, J. (1991). Source parameters of large earthquakes in the East Anatolian Fault Zone (Turkey). *Geophysical Journal International, 106,* 537–550.

Tekeli, O., & Erendil, M. (1986). Kizildag ofiyolitlerinin jeoloji ve petrolojisi. *Maden Tetkik ve Arama Dergisi, 107,* 33–49.

Tinkler, C., Wagner, J. J., Delaloye, M., & Selçuk, H. (1981). Tectonic history of the Hatay ophiolites (South Turkey) and their relation with the Dead Sea rift. *Tectonophysics, 72,* 23–41.

Unlugenc, U. C., Kelling, G., & Demirkol, C. (1990). Aspects of basin evolution in the Neogene Adana Basin, SE Turkey. Proceedings of the International Earth Sciences Congress on Aegean Regions, İzmir, pp. 353–369.

Yilmaz, Y. (1993). New evidence and model on the evolution of the southeast Anatolian orogen. *Geological Society of America Bulletin, 105,* 251–271.