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New high resolution aeromagnetic anomaly map of Türkiye and its various derivative-based maps

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Abstract: Since Türkiye's territory is mostly mountainous and forested, earth science studies in these areas have not been completed at an adequate level and with a satisfying resolution. However, due to the long time and cost of collecting measurements from land in large- and medium-scale studies and due to the inability to collect measurements in regular grid intervals in large-scale studies to be carried out on land, an airborne geophysical survey project was conducted in order to collect high-resolution magnetic and radiometric country-scale data. Total magnetic field and radiometry data were collected from the air between 2017 and 2022 within the scope of the country-wide Airborne Geophysics Surveys Project. The data collection flights were carried out in such a way as to follow the topography from an altitude of about 200 m above the ground. The flights were carried out considering the regular geometry of the flight profile and the general geological and tectonic structure of Türkiye in the direction of N-S with one-kilometer profile intervals. A total field magnetic anomaly map was obtained after applying the diurnal, tie line leveling, IGRF (model 2020), and differential reduction to magnetic pole (DRTP) corrections to the magnetic data. For the scope of this study, the total field magnetic anomaly and the regional total field magnetic anomaly maps were presented along with the structural boundary maps (tilt angle (TA), the total horizontal derivative (THDR) and the analytical signal (AS)) derived from these maps. During another stage of the study, the general tectonic structure of Türkiye and structural boundaries obtained from derivative-based maps (AS, TA, and THDR) were compared. General geophysical interpretation was also performed with magnetic-anomaly and derivative-based maps for the three regions characterized by high magnetic anomalies.

Key words: Aeromagnetic anomaly, magnetic, edge detection, Türkiye

1. Introduction

The magnetic method, which is a potential field method and is based on the differences in magnetic properties between underground structures, has been used quite widely for many years in different earth science studies, such as geological, tectonic, and archaeological research and metallic mine exploration. In areas where geography and weather conditions do not allow for the collection of geophysical measurements by land, such as some regions of Türkiye, airborne geophysical surveys are very important for the effective use of time and money. With airborne geophysical surveys, high-resolution data can be obtained across very large areas in a very short time. Geological and geophysical research institutions in many countries of the world collect geophysical data from the air in order to solve geological problems.

The Department of Geophysical Research of the General Directorate of Mineral Research and Exploration of Türkiye (MTA) started airborne magnetic studies in 1978 and ended them in 1989 in order to search for subsurface resources throughout Türkiye. As part of the project, which lasted about 11 years, 446,700 km of profile flights were made, including the entire land of Türkiye, lakes, gulfs, and the Marmara Sea, and the total component of the Earth's magnetic field across the territory of 813,634 km^2 was measured. The flight altitude was selected as an average of 2000 feet (~600 m). Magnetic data was measured at different orientations within previously determined sectors and at variable profile intervals of one to five kilometers. According to the borderland agreements, it was not possible to approach the country's borders more than 15 km. The flights were conducted by fixed-wing aircraft belonging to the MTA. A large number of scientific studies were carried out using these data. Ateş et al. (2003) carried out a structural interpretation for the Marmara region (northwestern Türkiye), which is a seismically active region, with the help of airborne magnetic, gravity, and seismic data. Ateş et al. (2005) performed a Curie depth calculation for Central Anatolia using the early

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MTA airborne magnetic data. Büyüksaraç et al. (2005) interpreted the airborne magnetic and gravity data for the Cappadocia region (central Türkiye) region, which is characterized by volcanic units. Dolmaz et al. (2005) obtained the Curie point depth for the West Anatolian Extensional Province by conducting spectral analysis on early airborne data. Aydın et al. (2005) prepared a Curie point depth distribution map for Türkiye using old airborne data. Bilim (2007) conducted tectonic and thermal structure research using seismological, gravity, and airborne magnetic data for the Kütahya–Denizli region (western Anatolia). Büyüksaraç (2007) conducted tectonic studies with gravity and airborne magnetic data for eastern Anatolia. Dolmaz (2007) conducted tectonic studies with the help of gravity and airborne magnetic data for the Burdur-Isparta region (southwestern Anatolia). For the eastern Anatolian collisional zone, Dolmaz et al. (2008) investigated low-seismicity areas using airborne magnetic, seismological, and geological data. Maden (2009) researched the thermal properties of the Central Pontides (northern Türkiye) with airborne magnetic data. Maden (2010) performed Curie depth and heat flux calculations for the Erciyes stratovolcano (central Türkiye) and its surroundings. Bektaş et al. (2007) investigated the geothermal structure of eastern Anatolia with the help of gravity and airborne magnetic data. Ekinci and Yiğitbaş (2012) performed different analyses on gravity and airborne magnetic data for the Biga Peninsula (NW Türkiye). Bektaş (2013) investigated the thermal structure of the crust in Inner East Anatolia using old MTA airborne data and gravity data. Hisarlı et al. (2012) used airborne magnetic and borehole data for investigating the thermal structure in the Thrace region (northwestern Türkiye). Ateş et al. (2012) investigated the crust structure of Türkiye with the help of gravity and airborne magnetic data. Aydemir et al. (2013) carried out a study on deep structure and hydrocarbon potential using gravity and airborne magnetic data in Van Lake surroundings (Eastern Türkiye). Pamukçu et al. (2014) calculated heat flow and Curie point depths (CPDs) using aeromagnetic data from MTA for eastern Anatolia. Koşaroğlu et al. (2016) modeled shallow structures in Cappadocia using airborne magnetic data. Ekinci et al. (2020) investigated the Nemrut stratovolcano (Bitlis, Eastern Türkiye) using airborne magnetic data. As it is known, airborne geophysical survey can be performed by flying from a constant elevation above sea level or drape flying (by following the topography). Ekinci (2021) investigated the possible effects of flight type to magnetic anomaly using theoretical data and aeromagnetic data of the Mount Nemrut stratovolcano (Bitlis, Eastern Türkiye). Ekinci (2021) stated that the two types of flight have advantages and disadvantages compared to each other. Erbek Kiran et al. (2021) investigated the upper crust structure of the Marmara region (northwestern Türkiye) with airborne magnetic data.

Between 2017 and 2022, MTA collected total magnetic field and radiometry airborne data within the scope of the country-wide Airborne Geophysics Surveys Project. The general tectonic and morphological structure of Türkiye is given in Figure 1. This project is very important for Türkiye due to the fact that most of the country's territory is covered by mountainous and forested areas; thus, earth science studies were not completed at a sufficient level and with a satisfactory resolution due to the high time and money requirements for measuring the land in big and middle-scaled studies and the impracticability of collecting measurements in regular grid points in big-scaled studies. For the scope of the project, diurnal correction and differential reduction to magnetic pole (DRTP) were applied to the airborne magnetic data collected. The total magnetic field anomaly map was obtained by subtracting the International Geomagnetic Reference Field (IGRF), published in 2020, from the diurnal corrected magnetic field data, taking into account the flight heights and dates. For the scope of this study, the total magnetic anomaly map, the regional magnetic anomaly map, and the derivative-based maps (tilt angle map, total horizontal derivative, and analytical signal) were used.

2. General tectonics of Türkiye

The Arabian plate is moving northward, towards the Eurasian plate. The Arabian plate moves towards the north and continues towards the Eurasian plate (Figure 1). As a result of this motion, the Anatolian block is compressed in the N-S direction. Because of the N-S squeeze, the Anatolian Plate starts moving westward along the right-lateral strike-slip North Anatolian Fault Zone (NAFZ) and the left-lateral East Anatolian Fault Zone (EAFZ) (Şengör and Yılmaz, 1981; Şengör et al., 1985, Barka, 1992; McKenzie, 1972, 1976; Dewey et al., 1986; Le Pichon et al., 1995; McClusky et al., 2000). Depending on the movement, the Anatolian plate moves westward by 20 mm/year with respect to Eurasia (Barka, 1992; Westaway, 1994; Straub and Kahle, 1995; Reilinger et al., 1997; Kahle et al., 1998; Reilinger et al., 2006). Being quite active in terms of seismicity and located at the Alpine-Himalayan seismic belt, the neotectonic of Türkiye is generally controlled by the Aegean-Cyprus arc, the NAFZ, and the EAFZ (Papazachos et al., 1971; McKenzie, 1978; Bozkurt, 2001). Four distinct regions were formed by these main structures: the Eastern Anatolian contractional zone, the Northern Anatolian province, the west Anatolian extensional province, and the Central Anatolian "Ova" province (Şengör, 1985).

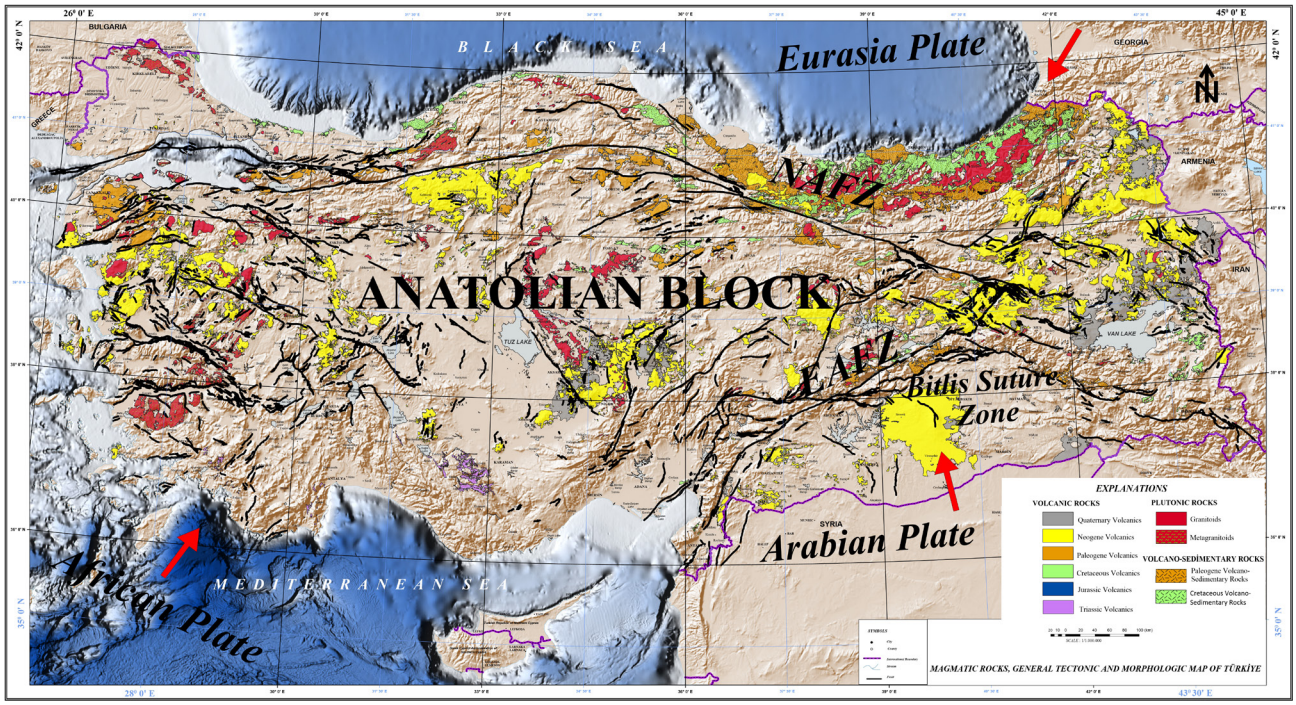

Figure 1. Magmatic rock, general morphological and tectonic structure of the study area (EAFZ: East Anatolian Fault Zone: NAFZ: North Anatolian Fault Zone). The thin black lines represent the tectonic unit of the Anatolian block from Emre et al. (2013, 2018). The red arrow shows the representative plate motions (magmatic rock map modified from Akbaş et al. (2011)).

The NAFZ, one of the largest active strike-slip fault zones in the world, is located in the north of the Anatolian block and extends from eastern Türkiye to the Saroz Bay located in the north of the Aegean Sea, having an approximate length of 1200 km (Şengör et al., 2005). After the occurrence of Erzincan earthquake in 1939 (Mw = 7.8), many destructive earthquakes happened along the NAFZ that migrated westward (Barka, 1999). These are mainly 1939 Erzincan, 1942 Erbaa-Niksar, 1943 Tosya, 1944 Bolu-Gerede, 1957 Abant, 1967 Mudurnu Valley, and 1999 Kocaeli earthquakes (Tatar et al., 2013) (Figure 1). The NAFZ crosses with another giant structure, the EAFZ at the Bingöl-Karlıova Triple junction, almost in the northwest-southeast direction (McKenzie, 1976; Dewey et al., 1986; Le Pichon et al., 1995; McClusky et al., 2000). The EAFZ is a transform fault formed between the Anatolian and Eurasian, the Arabian and African plates (Allen, 1969; Westaway, 1994). It is assumed that there is a unified structure between EAFZ and NAFZ extending from Karlıova to Kahramanmaraş (McKenzie, 1970; Arpat and Şaroğlu, 1972; Şengör et al., 1985; Bozkurt, 2001). EAFZ is the second largest tectonic structure in the Anatolian plate, with a length of about 550 km and consisting of six segments (McKenzie, 1976). The Northeastern Anatolian Fault Zone (NEAFZ), one of the most important tectonic structures of eastern Anatolia, is about 350 km long (Bozkurt, 2001). This fault is also known as the Erzurum-Bitlis Fault (Westaway, 1994; Bozkurt, 2001). The approximate direction of the Dead Sea Fault Zone (DSFZ) is north-south. This fault is a strike-slip fault with a length of 1000 km (Quennell, 1958; Freund et al., 1970; Muehlberger, 1981; Dewey et al. 1985; Mart and Rabinowitz, 1986). In terms of plate tectonics, the DSFZ is considered the transform-type plate boundary separating the African Plate in the west from the Arabian Plate in the east (Quennell, 1958; Muehlberger, 1981; Mart and Rabinowitz, 1986; Bozkurt, 2001). During the Middle Miocene and Early Late Miocene, the Arabian and Eurasian plates were crossed along the Bitlis-Zagros suture zone (Şengör and Yılmaz, 1981). This caused mountains to rise along the suture zone and shallow sea environments to turn into molasses basins. The suture zone is a complex continental-continental and continental-oceanic collision boundary extending from Türkiye to the Zagros mountains in Iran and is located on north of the fold and thrust belt of the Arabian platform (Şengör and Yılmaz, 1981; Hempton, 1984, 1985; Şengör, 1979; Şengör et al., 1979; Aktaş and Robertson, 1984; Yılmaz, 1993; Yılmaz et al., 1993; Yiğitbaş and Yılmaz, 1996a, 1996b; Bozkurt, 2001). Lastly, the West Anatolian extensional province is deforming under the control of two main factors; the Aegean suprasubduction system and the peak movement of the Arabian plate to Anatolia along the Bitlis suture

zone (Şengör., 1981; Şengör et al, 1985; Koçyiğit et al., 1999; Yılmaz, 2000). These structures create the N-S extensional system and east-west developing grabens. In general, all of the structures described above indicate that the Anatolian plate has been deforming continuously by different types of deformation. The duration, types, and recent forms of the deformation is investigated by different disciplines using various methodology.

3. Airborne magnetic data collecting and processing

Türkiye is located at the 36°–42° north latitude and 26°–45° east longitude. Surrounded by sea on three sides, the surface area of Türkiye is 783.562 km². Total magnetic field and radiometry measurement flights started in 2017 and were completed in 2022 as part of the country-wide Airborne Geophysics Surveys Project. The total field magnetic anomaly map was prepared with the data collected within the scope of the Türkiye Airborne Geophysics Surveys Project, which was conducted under the coordination of the Department of Geophysical Surveys of the General Directorate of the MTA and whose flights were carried out by two Cessna Grand Caravan EX model aircraft between 2017 and 2022.

3.1. Data collection of airborne magnetic survey

A total of four Cesium-type magnetic sensors were used to collect magnetic data, two on the wings and two on the tail for vertical gradient measurement (Figure 2). The sampling interval varies with the type of magnetometer on the aircraft. Magnetic measurements were collected with a sampling interval of 10 Hz. During the project, we used Geometrics system G824A Cesium magnetometers, with a sampling rate of 10 measurements per second and a heading error less than 0.15 nT. These magnetometers provided higher sensitivities and minimal heading errors. The aircrafts were equipped with GPS and radar altimeters to determine the aircraft's position and distance from the ground. The magnetic noise of the aircraft was measured in real time. With the compensation system, the magnetic effect of the aircraft is removed during flight. The flight of the normal lines was along the north-south direction while flight of tie lines was along the west-east direction. The flight surveys were planned as 1/100,000 scale layouts throughout Türkiye. The width of the layout is approximately 47.5 km (x-direction) × 57.5 km (y-direction) (Figures 3 and 4). Since the line spacing was 1 km, an average of six tie-lines were flown in each flight plan for tie line corrections (Figures 3 and 4). Tie-line leveling was performed in order to remove any errors caused by variation in flight height. After tie correction, we prepared all grids using normal lines data without tie line data.

During the project, the total component of the magnetic field included in the scope of magnetic measurements was measured. Parameters of flight altitudes, directions, and line spacing varied depending on the physical and geometrical structures of the geological structure of interest. In addition, while determining the flight parameters, parameters such as time, cost, and flight safety were also taken into account. The data collection flights were carried out in such a way as to follow the topography from an altitude of about 200 m above the ground in accordance with regional studies. The flights were carried out considering the regular geometry of the flight profile and the general geological and tectonic

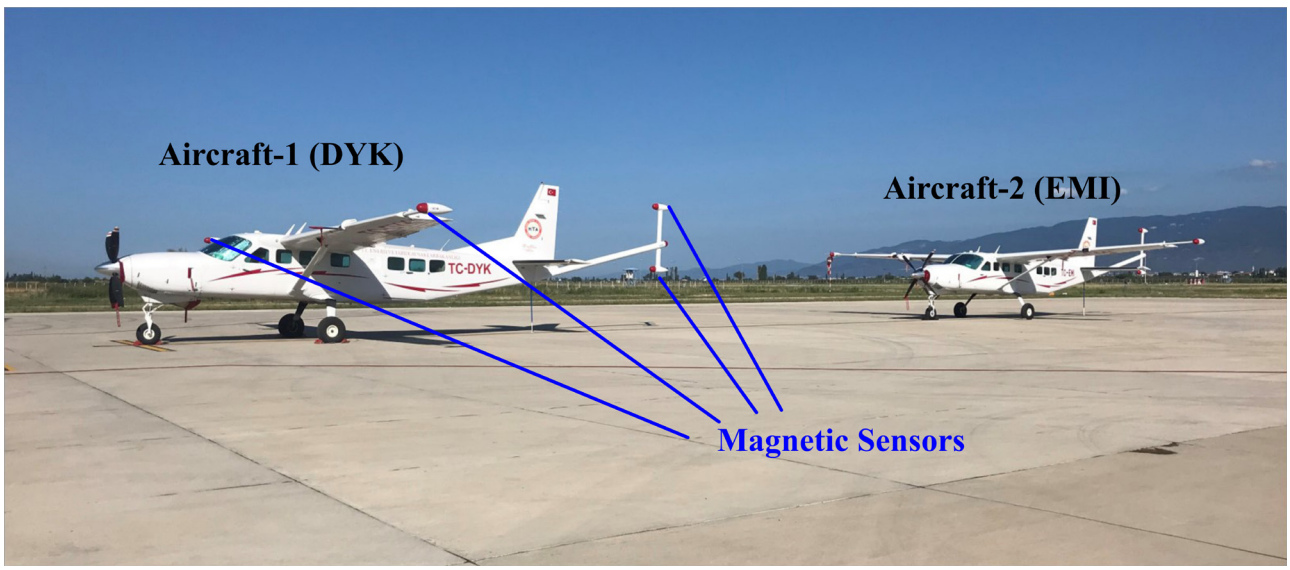

Figure 2. Aircraft used in flights and the positions of magnetic sensor.

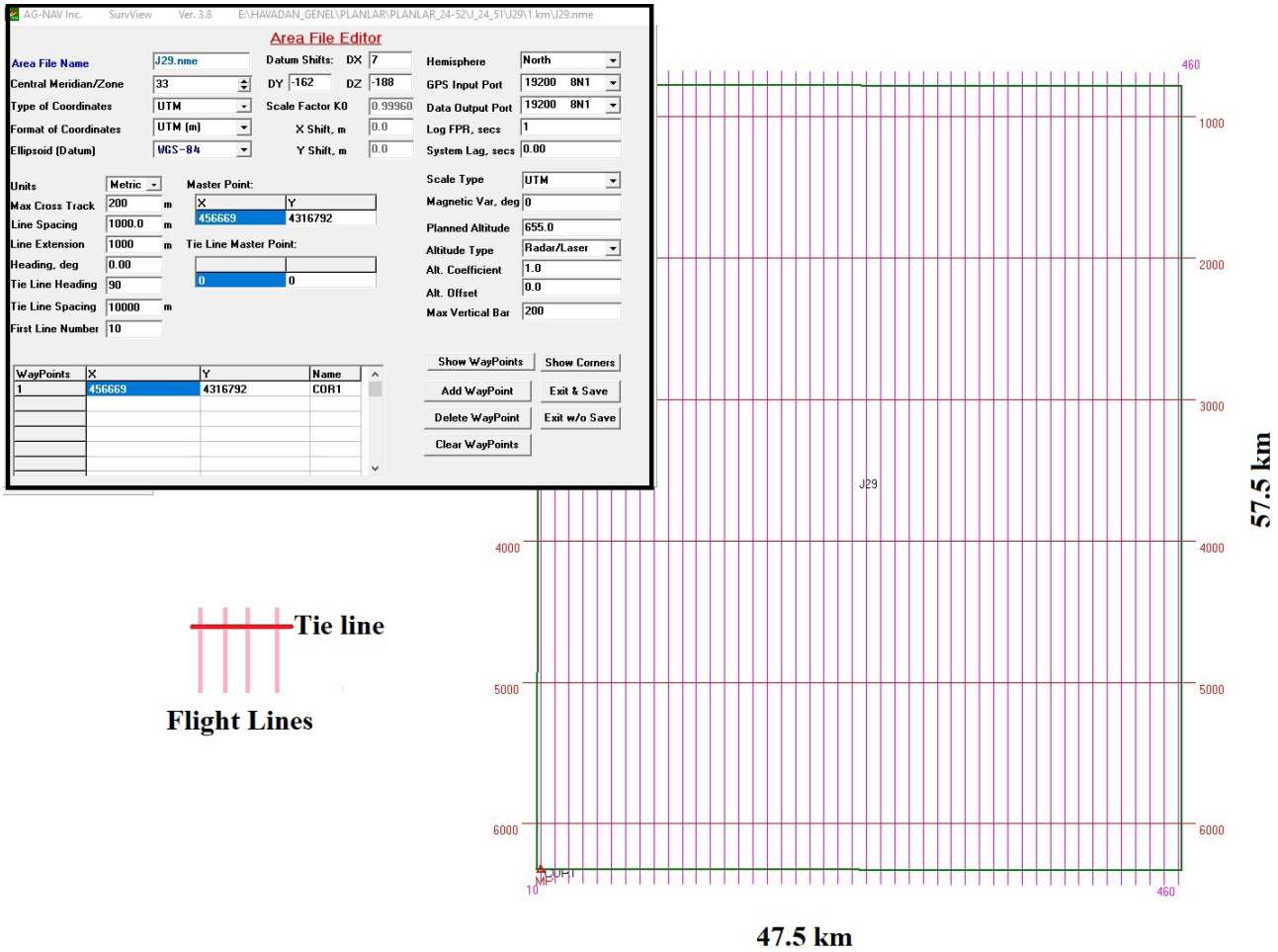

Figure 3. a) Türkiye-wide flight index, b) an example of flight geometry with flight and tie lines.

structure of Türkiye along the north-south direction and with a line spacing of 1 km (Figures 3 and 4). The average flight speed was 250 km/h. Assuming that the speed of the aircraft was 250 km/h, one piece of magnetic data was obtained approximately every 7.5 m along the N-S direction. The line spacing along the N-S direction was 1 km and magnetic data was gridded using a 300 m × 300 m grid size. In the national border areas, according to bilateral agreements with neighboring countries, the border could be approached up to a certain distance.

3.2. Data processing of airborne magnetic data

As it is known, the Earth's magnetic field varies depending on factors such as solar activity. The effects of these changes had to be removed from the magnetic data and from the measurements. The flight zones were determined as to be diameter of approximately 150 km. For this, a base station was placed away from cultural noise within the flight zones. The effects were eliminated by subtracting the data delivered from this base station from the collected data. An example of diurnal variation records is given for 24/08/2022 in Figure 5a. In addition, base station data were analyzed before diurnal correction. In this analysis, daily changes of 2nT per 2 min and 3 nT per 5 min were controlled for the reliability using the magnetic base data (Figure 5b).

The data processing step from raw magnetic data to final magnetic and derivative-based maps is explained in detail on a layout 1/100,000 (Figures 6–8). After tie line leveling and diurnal correction (Figures 6a and 6b) the total field magnetic anomaly map was obtained by subtracting the International Geomagnetic Reference Field (IGRF), published in 2020, from the diurnal corrected magnetic field data, taking into account the flight heights and dates (Figures 6c and 6d).

The standard reduction to pole (RTP) is a very useful method for areas smaller than 100 km^2 for eliminating the phenomenon of bipolarity in magnetic data (Rajaram and Anand, 2014). As it is known, only one inclination value and one declination value were used in the RTP method. The RTP method is very useful for small areas

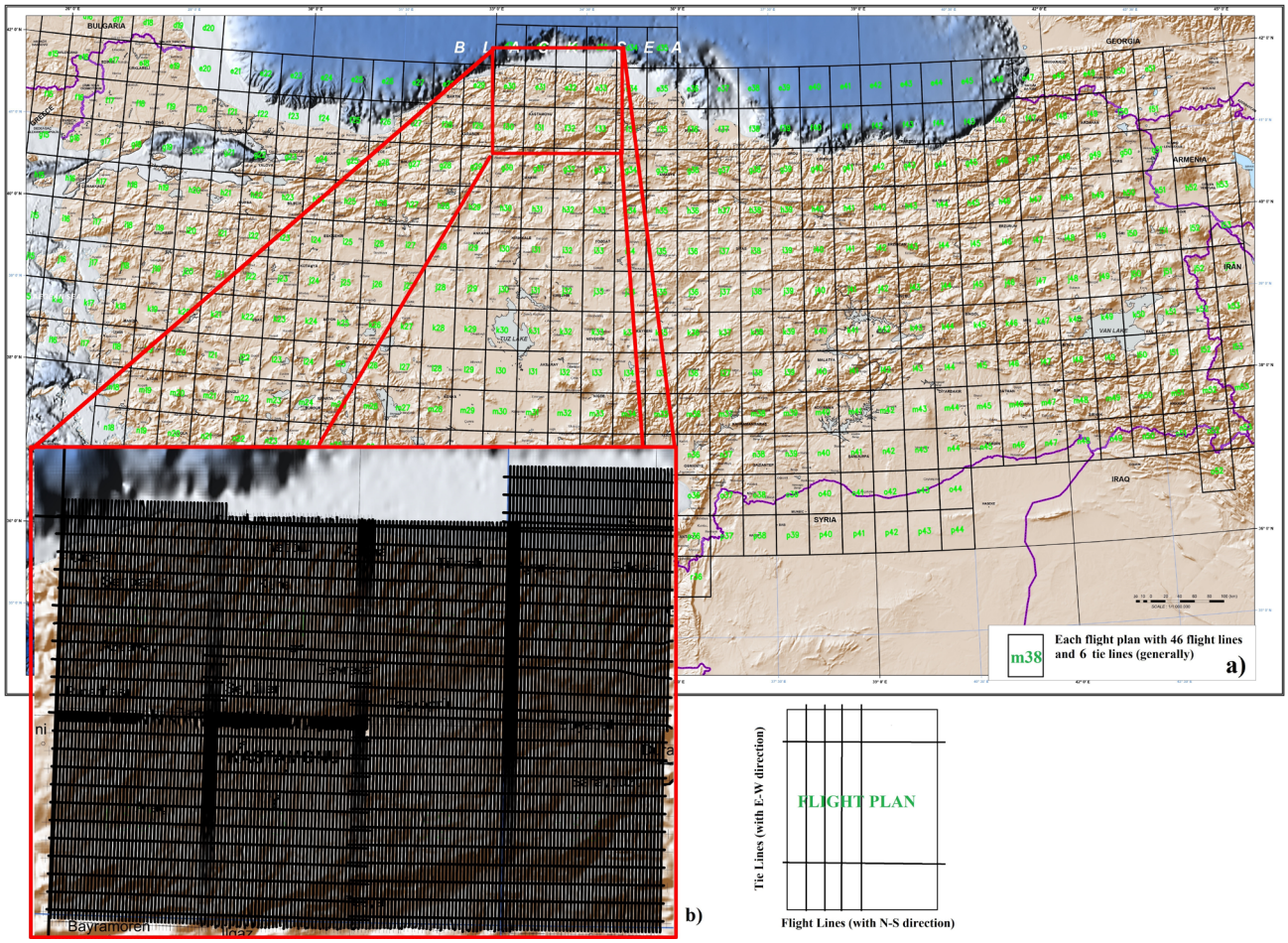

Figure 4. An example of preparing of flight plan using Survview program for a layout of 1/100,000 scale.

because the direction of the Earth's magnetic field does not change very quickly. This study was carried out for the entirety of Türkiye and the angles of inclination ranged from 53.1 to 60.5. The DRTP method, developed by Arkani-Hamed (1988, 2007), was used to correct the phenomenon of bipolarity in magnetic data. This method calculates inclination and declination angle values for each measurement site. Figure 7 shows the total field magnetic anomaly the applied DRTP and without DRTP.

The Gaussian filtering technique was used for regional-residual separation in the DRTP total field magnetic anomaly map. For this purpose, fast Fourier transform (FFT) was applied to the DRTP magnetic anomaly map in order to obtain the power spectrum (Figure 8). The cut-off wavelength of the low-pass Gaussian filter was determined as 6000 m in power spectrum with first slope (Figure 8a). In order to reveal the general geological and tectonic structures of Türkiye, the 1st-degree low-pass Gaussian filter was applied with a cut-off wavelength 6000 m and the regional magnetic anomaly map is given in Figure 8b. In this study, the derivation maps were obtained from the regional magnetic anomaly values since the magnetic map will be presented for Türkiye as a whole. For this study, a grid size of 300 m × 300 m was chosen for creating all maps. Figure 9 shows the DRTP total field magnetic anomaly map and the regional DRTP magnetic anomaly map.

3.3. Derivative-based maps of regional DRTP total field magnetic anomaly

Revealing the boundaries of buried geological structures is very important for modeling and interpreting magnetic anomalies, which is a potential field technique. There are a large number of methods based on the derivatives of the data that are widely used for these analyses. Methods such as analytical signal (AS), total horizontal derivative (THDR), 3D Euler deconvolution, and tilt angle (TA) have been used for boundary analysis for many years.

The analytical signal (AS) developed by Roest et al. (1992) is calculated by the square root of the sum of the horizontal and vertical derivatives of the magnetic anomaly (Formula-1).

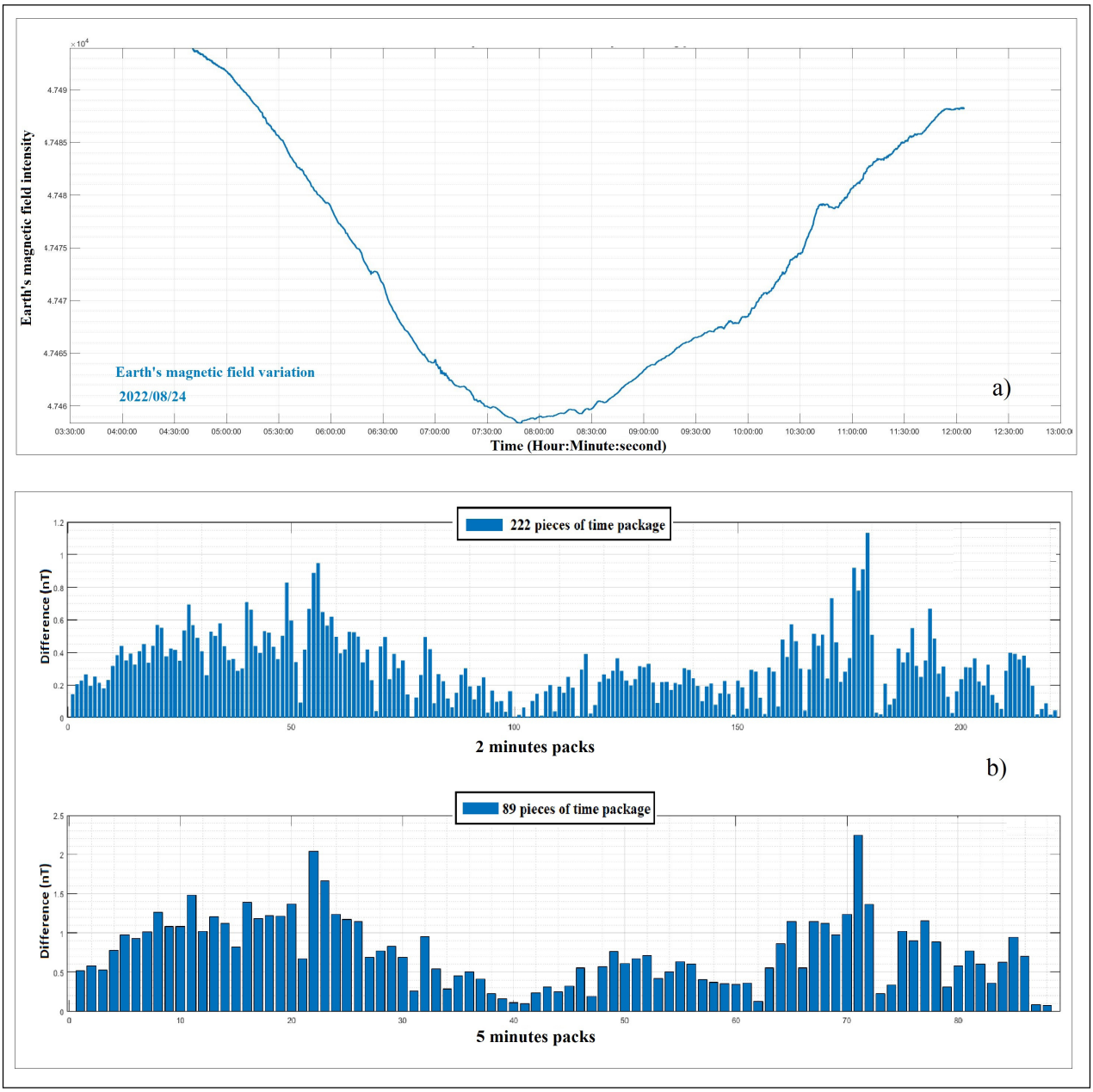

Figure 5. a) The diurnal variation records is 24/08/2022 b) pockets of daily magnetic field changes of 2nT per 2 min and 3 nT per 5 min.

$$|AS| = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \quad (1)$$

where M corresponds to the magnetic anomaly and ∂M/∂x, ∂M/∂y, and ∂M/∂z correspond to the derivatives of the data, in the x, y, and z directions, respectively.

The total horizontal derivative (THDR) proposed by Cordell and Grauch (1985), the maximum value of which corresponds to the structure limit, can be calculated using Formula-2:

$$THDR = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2} \quad (2)$$

The zero contour of the Tilt Angle (TA) which is the ratio of the vertical derivative to the total horizontal derivative of the data corresponds to the boundary of

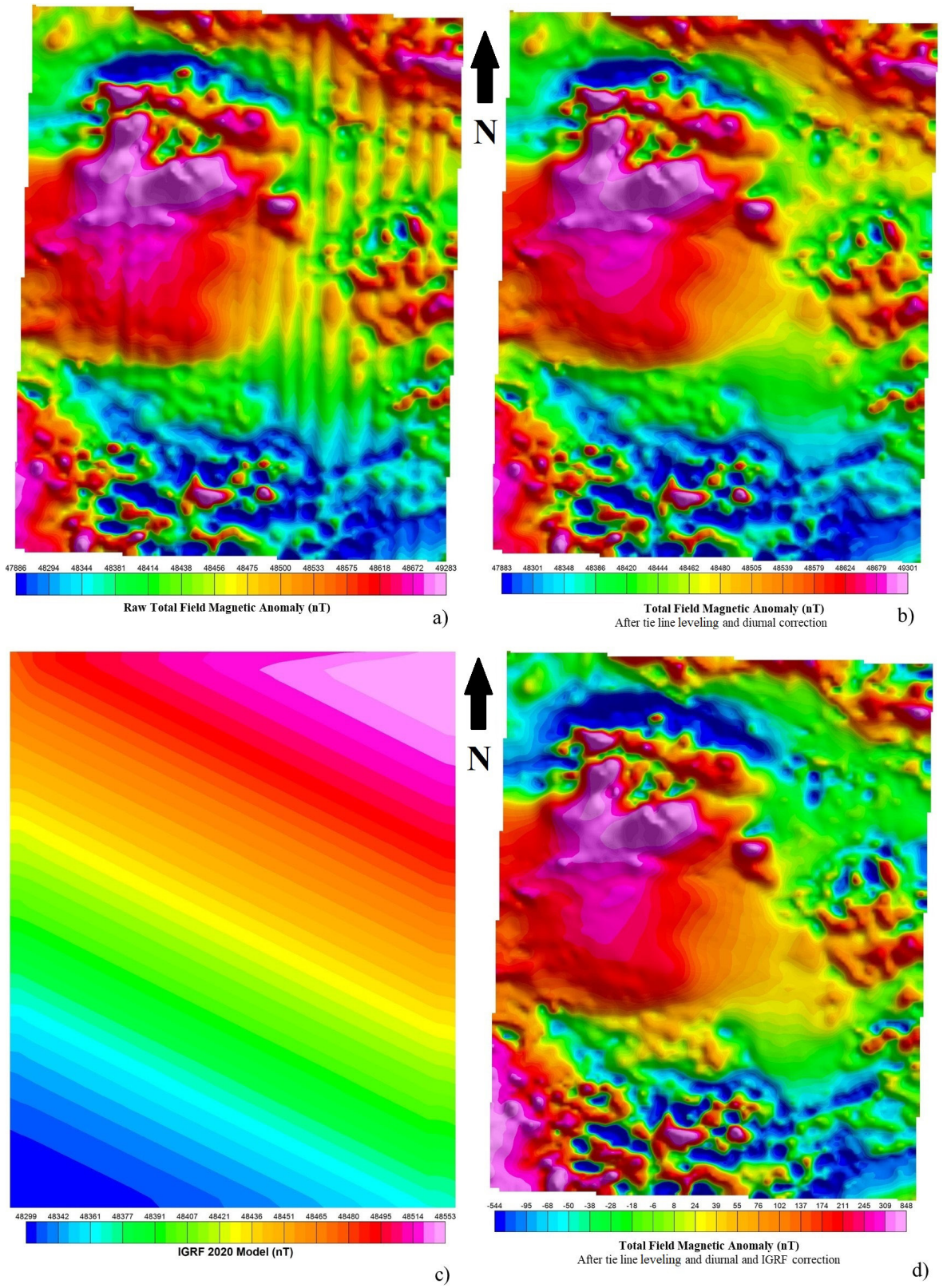

Figure 6. An example of a) raw total field magnetic anomaly, b) the total field magnetic anomaly after tie lie leveling and diurnal corrections, c) IGRF 2020 model of the area, d) final total field magnetic anomaly on a layout of 1/100,000 scale (size of 47.5 km (x-direction) × 57.5 km (y-direction)) with grid cell size of 300 m × 300 m.

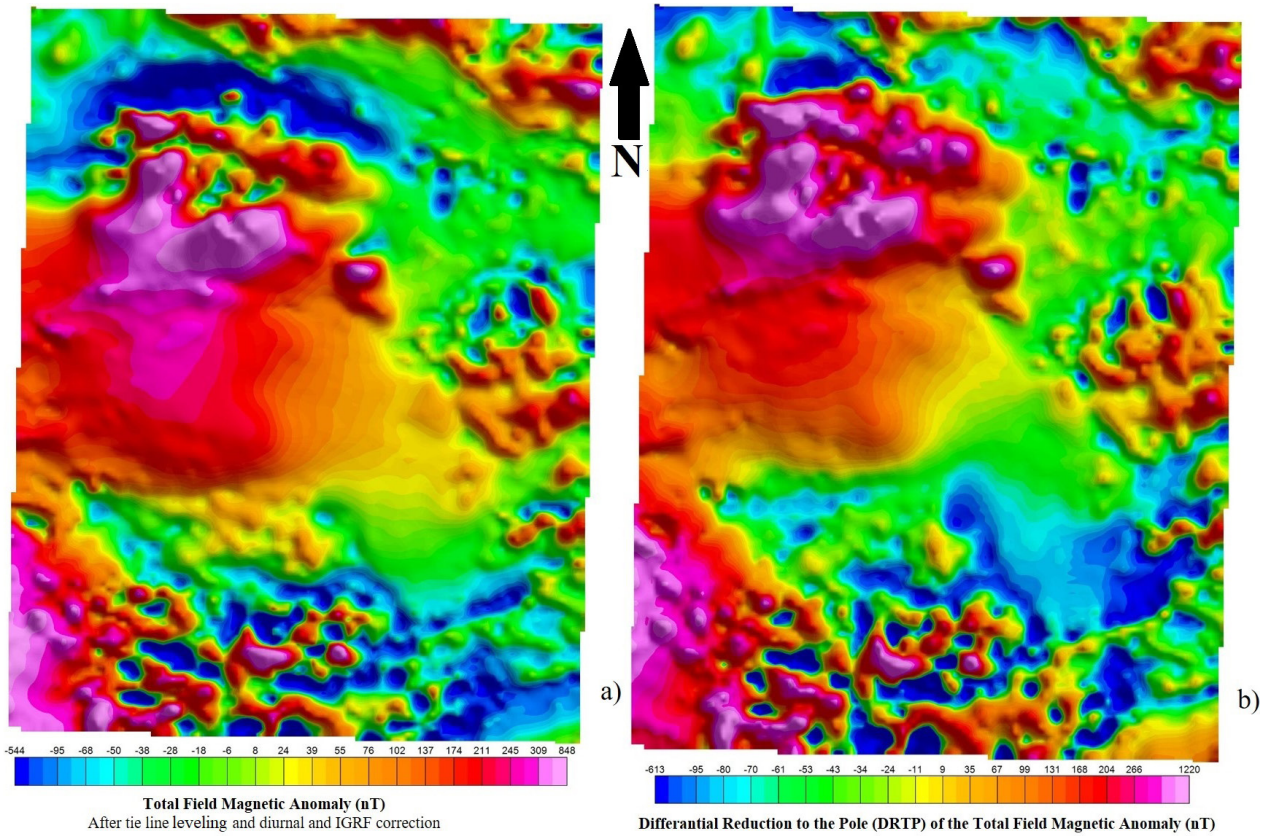

Figure 7. An example of the total field magnetic anomaly a) before DRTP process and b) after DRTP process on a layout of 1/100,000 scale.

geological structures (Miller and Singh, 1994) (Miller and Singh, 1994) (Formula-3):

$$TA=tan^{-1}\left(\frac{\frac{dM}{dz}}{THDR}\right) \quad (3)$$

Figures 10a–10c show the AS, THDR, and TA maps of the DRTP total field magnetic anomaly.

4. Results and discussion

The bipolar phenomenon of magnetic data was corrected by using the DRTP method, and the DRTP total magnetic anomaly map is given in Figure 9a. In the examination of this map, it was observed that the magnetic anomaly values range between –3129 nT and 2768 nT. The regional magnetic anomaly map was obtained using the low-pass Gaussian filtering process (cut-off wavelength 6000 m) and is given in Figure 9b. The regional magnetic anomaly values range from –1298 nT to 1311 nT. The high magnetic anomaly values are compatible with the general lithology.

In the second stage of the study, boundary analysis techniques (THDR, AS, TA) were applied to determine the magnetic source boundaries on the regional magnetic anomaly map. As it is known, high amplitude locations on the AS map indicates a magnetic source. AS values range from 0.002 to 0.064 nT/m (Figures 10a and 11c). Magmatic rocks located in the northeast of Türkiye were clearly characterized by a high amplitude on the AS map. The boundaries of the Kırşehir massive, located in Central Anatolia, have become clear with AS. Similarly, the boundaries of the Bitlis-Zagros suture zone are evident on the AS map. The boundaries of magmatic rocks located in the Kırşehir massive within the Sakarya zone have also been clearly determined. Magmatic rocks in the Eastern Anatolia region have presented a high amplitude of AS. Values vary between 0.01 and 0.047 nT/m in the total horizontal derivative map, which is another boundary analysis method (Figure 10b). In general, it demonstrates high similarity with the AS map.

The tilt angle (TA), the value of which varies from $-\pi/2$ to $+\pi/2$, is zero at the boundary position of the magnetic source, and outside the source it is negative (Salem et al., 2007; Oruç and Selim, 2011). Therefore, it is quite widely used in determining the boundaries of geological structures. The TA map applied to the regional DRTP magnetic anomaly map is given in Figure 5c. When the TA map is examined, it can be seen that it is generally

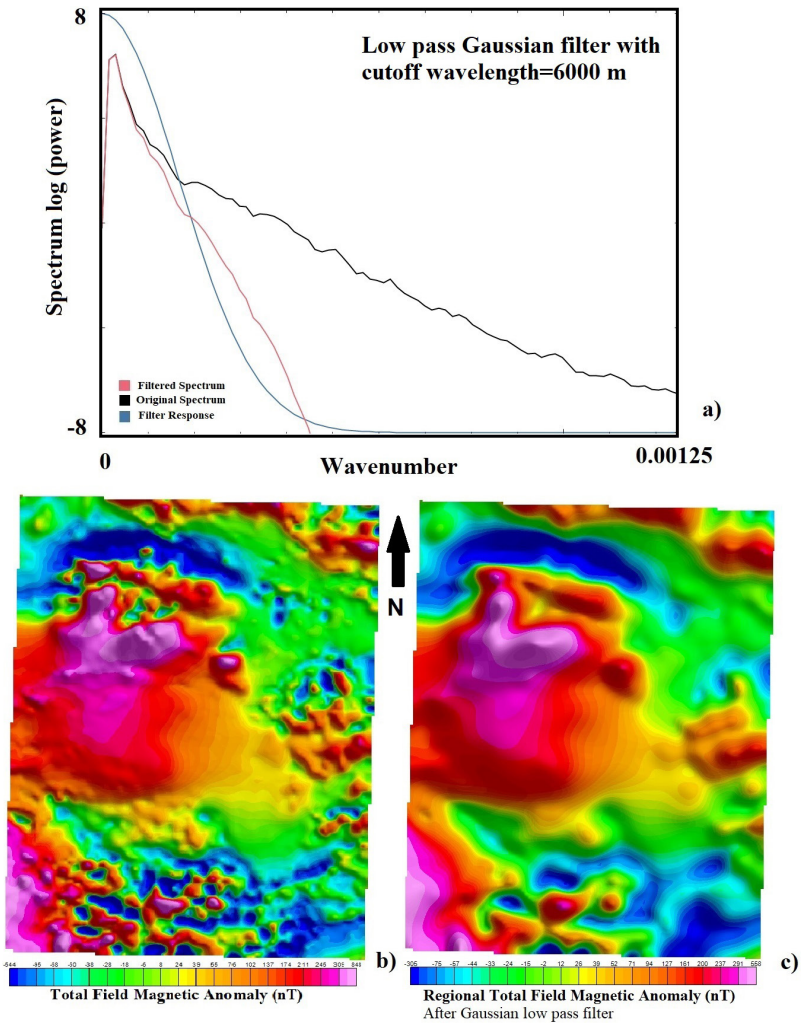

Figure 8. An example of a) power spectrum of DRTP total field magnetic anomaly, b) the total field magnetic anomaly after tie and diurnal corrections, c) the regional total field magnetic anomaly after low-pass Gaussian filter on a layout of 1/100,000 scale.

compatible with the general fault distribution of Türkiye. The zero contour of the TA clearly delineates the NAFZ. The EAFZ with a northeast-southwest extension is also compatible with the zero-contour pattern of the TA. In the west of Türkiye, inbound zero contours are east-west-oriented. In Central Anatolia, the northwest-southeast-oriented structure around the Salt Lake is remarkable. It is compatible with the zero contours of the NAFZ and TA continuing in the Sea of Marmara (Figures 10c and 11b). In Figure 11b, the general tectonic elements of Türkiye are shown together with the TA values. The boundaries of the Kırşehir massive have been obtained markedly in the zero contours of the tilt angle. The Bitlis-Zagros suture zone between the Arabian the Anatolian Plates is compatible with the zero contours of the tilt angle. Located to the west of the Anatolian plate, the northwest-southeast-oriented Afyon and Tavşanlı zones are evident on the TA map.

Within the scope of the study, the magnetic anomaly maps obtained from derivative-based methods were interpreted for three selected areas in Türkiye (Figure 11a). Area-A covers the Biga Peninsula, located in the northwest of Türkiye. Okay et al. (2001) stated that the Late Cretaceous to Early Eocene period was tectonically active. In addition, Okay et al. (2001) stated that the Tethys evolution of Western Anatolia is characterized by ophiolitic thrusting, high pressure/low temperature metamorphism, subduction, arc magmatism, and continental-continental collision. Depending on this, different tectonic units and belts are observed in this region (Şengör and Yılmaz, 1981; Okay, 1989; Okay et al., 1996, 2001; Okay and Tüysüz, 1999; Aydın et al., 2019).

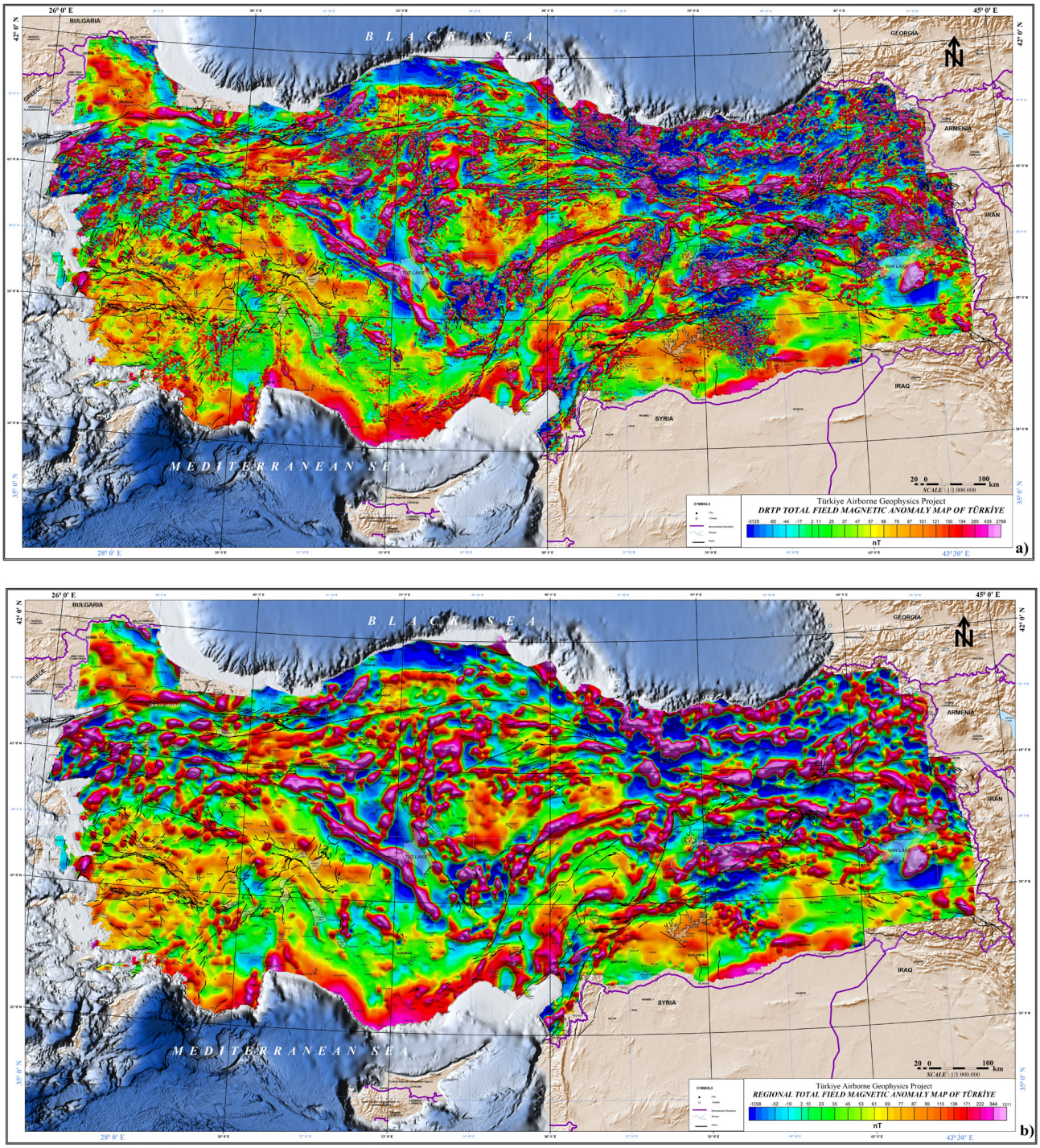

Figure 9. a) Differential reduction to the pole (DRTP) of the total field aeromagnetic map of Türkiye and b) regional component of the DRTP total field aeromagnetic map of Türkiye using low-pass Gaussian filter with cut-off wavelength 6000 m.

The Biga Peninsula consists of two different tectonic unions that separated from each other through the Intra-Pontide suture zone, the Rhodope-Istranca massif in the north, and the Sakarya union in the south (Aydın et al., 2019). The Biga Peninsula consists of metamorphic, magmatic, and sedimentary rocks of different geological ages (from Paleozoic to Cenozoic) and has a complex geology (Aydın et al., 2019). When the magnetic anomaly map obtained in this region was examined, it was found that the anomaly pattern of high magnetic

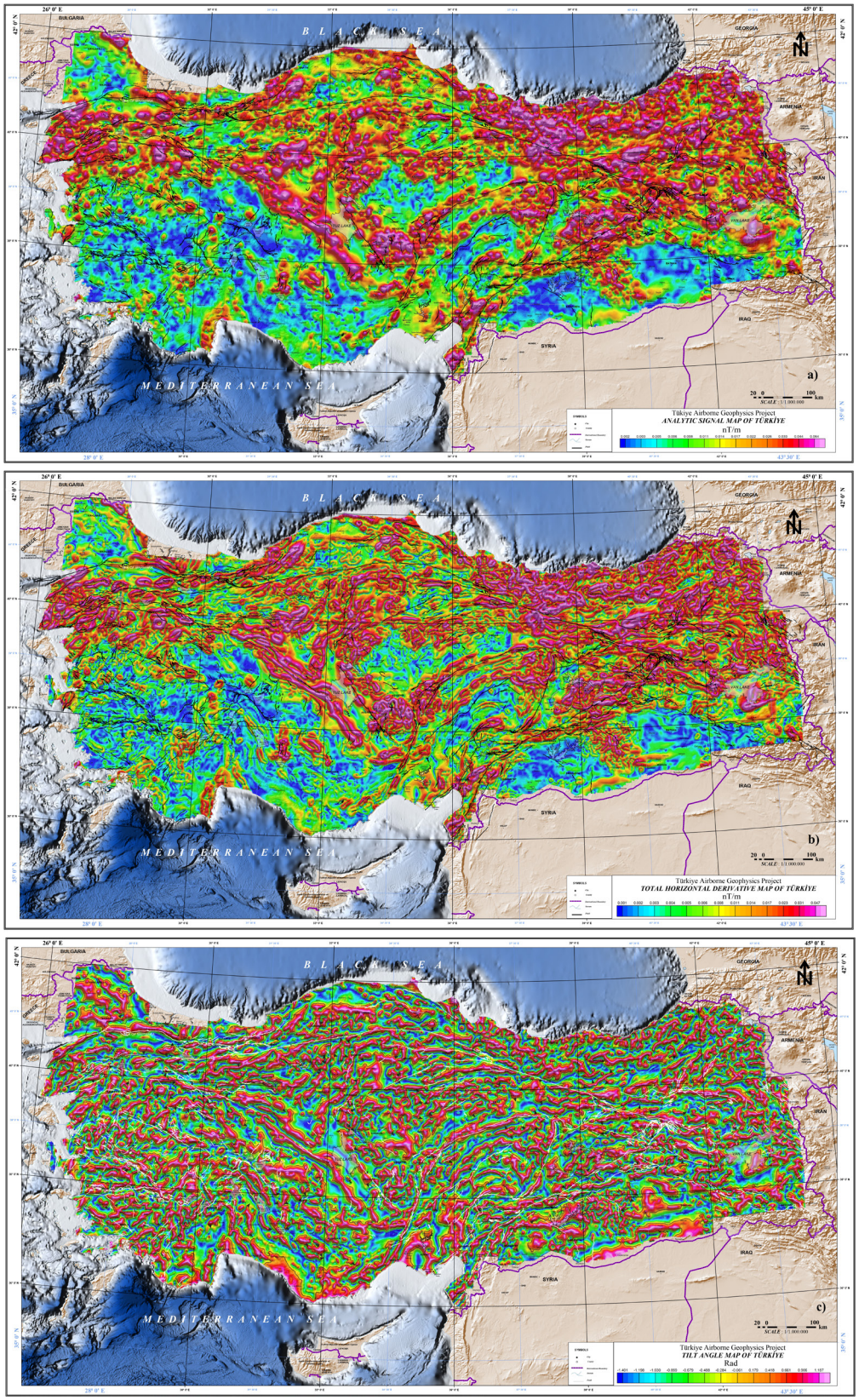

Figure 10. Edge detection analysis maps of DRTP total field magnetic anomaly to a) analytic signal (AS), b) total horizontal derivative (THDR), c) tilt angle (TA) maps.

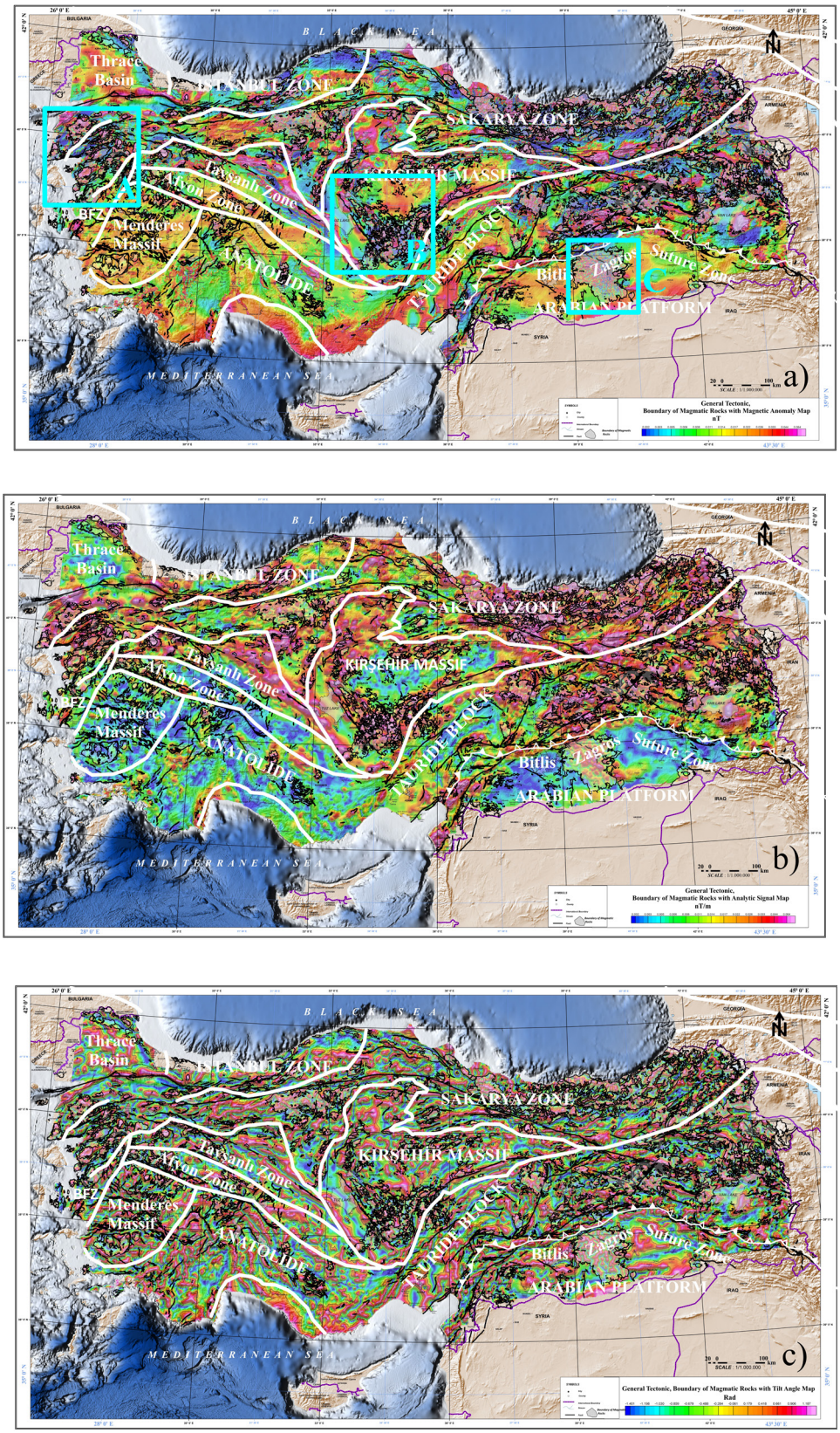

Figure 11. a) Boundary of magmatic rocks with the total field magnetic anomaly map, b) general tectonic structure of Türkiye with tilt angle map, c) general tectonic structure of Türkiye with analytic signal map. General tectonic boundaries shown as white lines modified from Okay and Tüysüz (1999).

amplitude in general is southwest-northeast-oriented. The orientation of magmatic rocks and active faults in this area is also generally in the same direction. When the analytical signal, tilt angle, and upward analytical extension maps are examined, it can be inferred that the southwest-northeast-oriented structures that cause magnetic anomalies in this region have both shallow and deep origins. Area-B is the Cappadocia region located in the central parts of Türkiye. The Central Anatolian Volcanic Province (OAVP), which includes the Cappadocia Volcanic Complex (CVC), is one of the most important Tertiary-Quaternary volcanic provinces of Türkiye, extending along the northeast-southwest direction and having a long axis of 250–300 km and a width of about 100–150 km (Aydın, 2009). The metamorphic rocks belonging to the Kırşehir Massive represent the basis of the Cappadocia region, which has a rather complex structure of surface geology. The Cappadocia region is mostly covered with volcanic rocks of different compositions ranging from dacitic to basaltic forms. The northwest-southeast-oriented Salt Lake and the northwest-southeast-oriented Ecemiş fractures have tectonically surrounded the region (Pasquare et al., 1988). The Quaternary volcanism in the Cappadocia region ended with the Hasan and Erciyes mountain volcanisms, which represent two stratovolcanoes. As a result of this volcanic activity, basaltic, andesitic, dacitic, and pyroclastic lavas were formed. Volcanism emerged as a result of the subduction of the oceanic plate under the Anatolian plate in the Miocene (Türkecan et al., 2004). The boundaries of this region are revealed both in magnetic anomaly maps and in maps of boundary analyses. The northwest-southeast- and northwest-southeast-oriented structures stand out in the magnetic anomaly map. The northwest-southeast-oriented Salt Lake and the northeast-southwest-oriented Ecemiş fault were compatible with the zero contours of the tilt angle. The Karacadağ Volcanism (Area-C), located on the Arabian plate, spans an area of approximately 10,000 km^2. This volcanism has not maintained its activity at a single level, and volcanites have surfaced in three activity cycles (Şaroğlu and Emre, 1987; Baba et al., 2019). The Karacadağ volcanism exhibited a complex structure of magnetic anomalies. The boundaries of this volcanism are revealed both on magnetic anomaly maps and AS as well as on THDR maps (Figures 11a and 11b).

In this study, the data collection flights were carried out in such a way as to follow the topography from an altitude of about 200 m above the ground. The airborne magnetic data with high resolution were obtained with 1 km line spacing and 10 Hz sample interval. Different maps obtained by processing high-resolution datasets will be used extensively for many years in geoscience research such as the determination of geological structural elements, mineral exploration, and investigations of Curie point depth.

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Tectonic units were digitized in the Geoscience Map viewer (Emre et al., 2013, 2018) and drawing editor licensed to the General Directorate of Mineral Research and Exploration (MTA). Oasis Montaj Software was used for data processing steps. Digital terrain and bathymetry model was produced by resampling GEBCO_2014 grid, version 29150318 data within 30 arc-second spatial resolution "www.gebco.net". SRTM worldwide elevation data (1 arc second resolution, SRTM Plus V3) were used in this study. The authors thank Dr M. Özgü Arısoy from MTA for providing the software about diurnal correction and his contributions during the initial phase of the project. The authors sincerely thank the editor Assoc. Prof. Dr Yunus Levent Ekinci, the reviewer Prof. Dr Z. Mümtaz Hisarlı and three anonymous reviewers for reviewing and improving the manuscript with their constructive feedback. The authors sincerely thank Assoc. Prof. Dr Şule Gürboğa from MTA for the editing in the section of general tectonics of Türkiye. The authors would like to thank the Ministry of Energy and Natural Resources and General Directorate of Mineral Research and Exploration of Türkiye for their contribution and support in the realization and maintenance of the project, which will provide significant contributions to the exploration of our country's mineral resources.

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