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STRUCTURAL INTERPRETATION OF BULDAN REGION IN WESTERN ANATOLIA BY USING MAGNETIC AND GRAVITY DATA

Altınoğlu F.F.

Faculty of Engineering, Department of Geophysics, Pamukkale University
Kınıklı Campus, 20017, Denizli, Turkey: faltinoglu@pau.edu.tr

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Summary. The western Anatolia is an extension region and many horst-graben systems were developed under this tectonic regime. The Buldan region is located in the northern part of Denizli region between Denizli and Alaşehir grabens where seismic activity is observed. The subsurface structure of this area was investigated by using aeromagnetic and Bouguer gravity data. The derivative based edge detection techniques; the horizontal gradient, tilt angle and Theta map were used to define the tectonic lineaments. The sediment basement relief map of the study area was enhanced by 3D inversion of gravity data using Parker-Oldenburg algorithm. The final gravity and magnetic lineaments map of the study area is presented by the joint interpretation of the results of the edge detection process with the sediment basement relief map, the existing geology map and the topographical elevation map of the study area. The sediment thickness ranges between 0.2 km and 2.2 km and the sediment deposits thickness is 2.2 km in the northern part of Denizli basin. NW-SE trending reliefs were detected between the Alaşehir and Denizli grabens in the sediment basement relief map, and NW-SE directional lineaments such as fault/fracture which are bounding basement reliefs were detected. The new lineaments are strongly compatible with the regional geological trend and sediment basement relief. Based on the findings of this study, new detected gravity and magnetic lineaments will be lighten up the new research in the future studies to understand the tectonic structure, geothermal potential, mineralisation of the region.

Introduction

Western Anatolia is a tectonic extension region where many graben-horst systems were developed under this extension-compression regime. E-W trending Büyük Menderes and Alaşehir grabens and NW-SE trending Denizli graben are the main tectonic structures of this complex tectonic region. Buldan is situated in the junction point of these grabens in the northern part of the Denizli graben. The main tectonic structure map of the region and study area is given in Fig.1. The complex tectonic structure of western Anatolia and its evaluation were the subject of many studies in the literature (Seyitoglu and Scott, 1996; Koçyiğit et al., 1999; Yılmaz et al., 2000; Bozkurt, 2003; Bozkurt and Sözbilir, 2004; Kaymakcı 2006; Gessner et al., 2013). Two-stage extension in Western Anatolia was stated by Bozkurt and Sözbilir (2004). The first stage of extension started in Late Oligocene – Early Miocene, and the second stage – in Pliocene (Bozkurt, 2001). Denizli graben is the southeast continuation of the main grabens that are bounded by the NW-SE trending faults (Koçyiğit, 2005).

The geophysical studies for Denizli graben area, such as Yüksel, 2005; Bilim, 2007; Irmak, 2013; Kaypak and Gökkaya, 2012, are poor. Bilim (2007) studied tectonic structure by using potential field data of eastern and western Anatolia in regional scale, Irmak (2013) determined the fault mechanisms of small-moderate earthquakes in Denizli graben, Kaypak and Gökkaya (2012) constructed upper crust velocity structure by earthquake tomography. The northern part is a less focused area in Denizli basin. The Buldan region is an important area that just situated in the junction point of graben systems and has high seismic activity. Hançer (2013) noticed the high seismic potential of the region by investigating the earthquake risk of the Buldan region. The study area of this paper is located between 38.00°N–38.20°N latitude and 28.75°E–28.95°E longitude with an approximate area of about 400 km^2. Buldan region is located in the northern branch of the Denizli Basin and in the south-eastern part of the Menderes Massif metamorphics which are the Paleozoic aged basement rocks of Western Anatolia. The Denizli basin lies in a NW-SE direction which extends to the

Alaşehir Basin that is bounded by normal faults and divided by the Buldan horst in the north (Fig.1). The basement Menderes metamorphics are exposed in the Buldan horst, in the western, north-western and northern part of the study area as given in the geology map of the study area in Fig. 2b. This study aims to investigate the subsurface structure of the Buldan region based on potential field data. The shallow crust structures and linear features of the region were presented to better understand the tectonic framework by the joint interpretation of gravity and magnetic data with topography (Fig 2a) and geology maps (Fig. 2b).

Geology of the region

The basement rocks of the Denizli basin are Paleozoic – Mesozoic aged Menderes Massif metamorphic rocks. The Menderes Massif covers a large area in western Turkey, and is composed of various metamorphic rocks, which are mostly composed of schist, quartzite and marble, occasionally amphibolite and quartzite. Neogene sediments generally consist of clay stone, marl, mudstone, siltstone and partly sand. Neogene bedrock of the Denizli basin is exposed at its northwestern Menderes Massif metamorphic rocks (Bozkurt, 2001; Ten Veen et al., 2009; van Hinsbergen and Schmid, 2012). The Neogene and Quaternary basin-fills of the Denizli Basin is consisting of alluvial-fan, fluvial, and lacustrine deposits (Brogi et al., 2014). The geology map of the study area is given in Fig. 2b.

Data

The aeromagnetic anomaly and the Bouguer gravity anomaly data of the study area were obtained from the General Directorate of the Mineral Research and Exploration (MTA) of Turkey. The aeromagnetic anomaly map of the study area shown in Fig.3 indicates a strong positive anomaly up to 170 nT along the NW-SE direction in the northern part of the study area representing the effect of magmatic rocks and negative anomalies up to -70 nT along the NW-SE direction in the western and southern parts of the study area representing the effect of the quaternary alluvial deposits. The high amplitude anomalies are in the NW–SE directions in the SW and northern part of the map which are related with the metamorphic palaeozoic basement and the plio-quaternary granitoids. Due to the low susceptibility sediments, strong negatives anomalies are seen in the Denizli and Alaşehir basins.

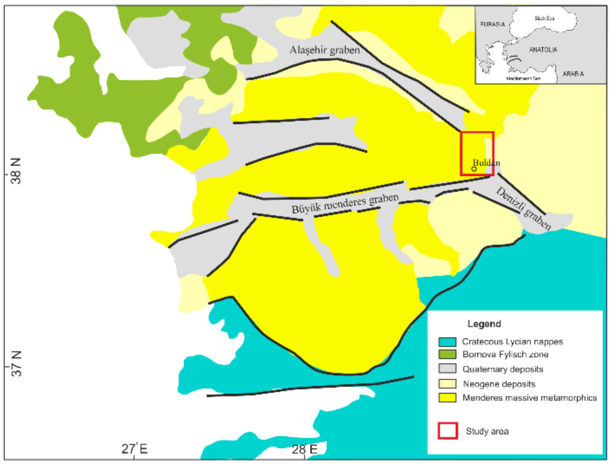
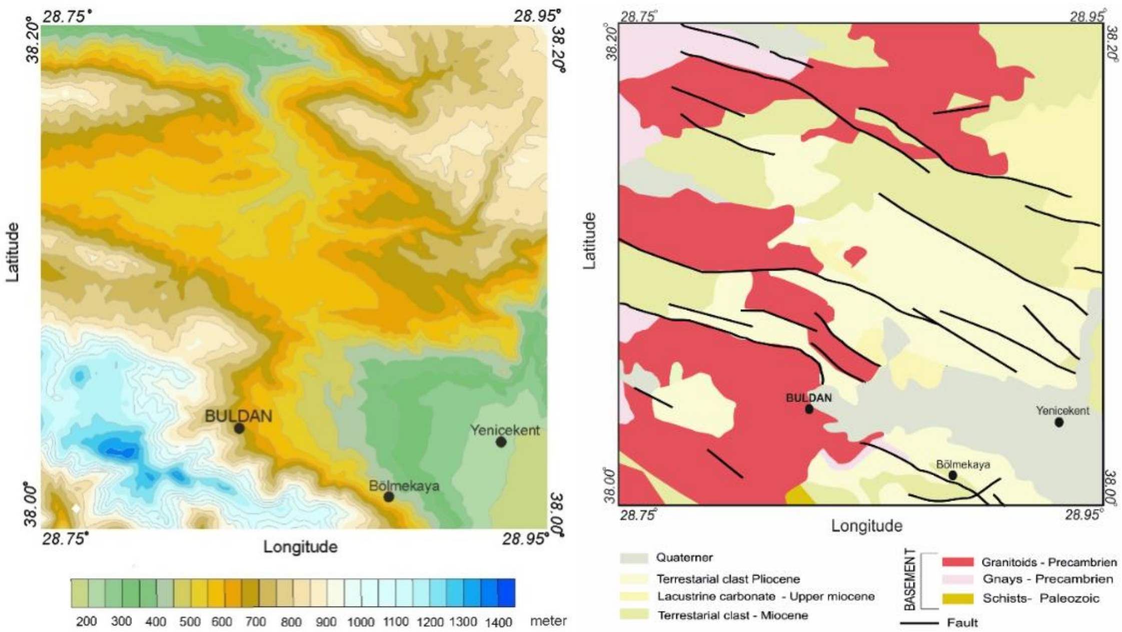


Fig. 1. The main tectonic settings of the western Anatolia (modified from Konak and Şenel, 2002), the study area is shown in the red rectangle



a

b

Fig. 2. a) Topographic elevation map and **b)** Geology map of the study area

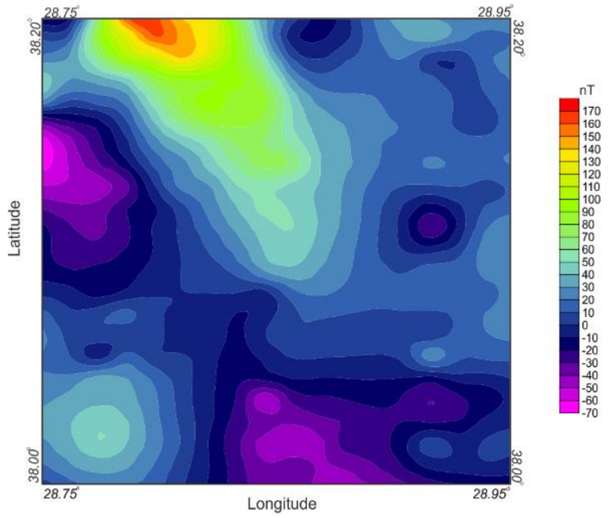


Fig. 3. The aeromagnetic anomaly contour map

The Bouguer gravity anomaly map of the study area is given in Fig.4, the anomaly values range between -36 mGal and 6 mGal. The gravity highs (positive anomalies) reflect the effect of high-density Menderes Massif granitoids hosted in the Buldan horst in the W and SW part of the study field. The maximum negative gravity anomalies implies the low-density sedimentary deposits of the Denizli graben in the SE part of the study region.

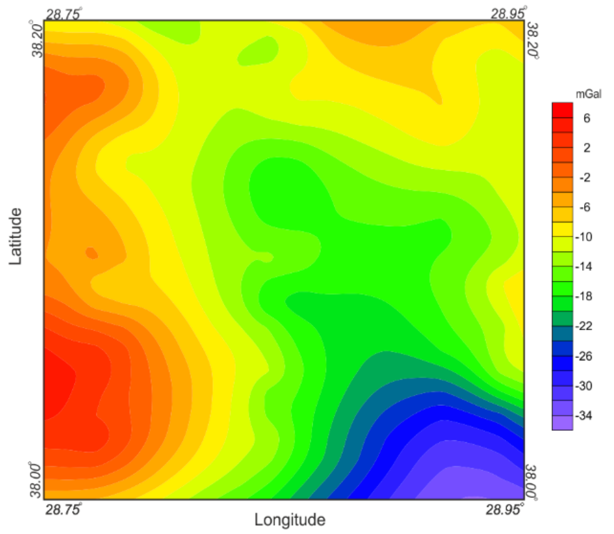
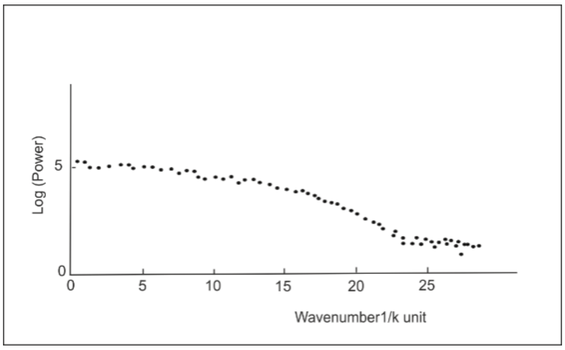


Fig. 4. The Bouguer gravity anomaly map of the study area data

Methods

To remove the deeper sources effects from aeromagnetic and Bouguer gravity anomalies, regional-residual separation was done by frequency domain filtering. The radially averaged power spectrum of aeromagnetic and gravity data were performed and given in Fig. 5a and 5b, respectively. To obtain residual magnetic anomaly map a Butterworth high-pass filter with kc=0.105 Hz was used. Some researches, e.g. Blakely (1995), Milligan and Gunn (1997), Ramotoroko et al. (2016), indicated that reduced-to-the-pole anomaly maps are more correlated with the near surface geology. So, to simplify the interpretation of magnetic data, residual aeromagnetic anomalies were reduced-to-the-pole with using 55ºN inclination and 4ºE declination angles. A Butterworth low pass filter with kc=0.409 Hz for gravity anomaly was used to improve the quality of the regional gravity anomaly data; then, the regional anomaly data was subtracted from the gravity data to improve the quality of the residual gravity anomaly map.



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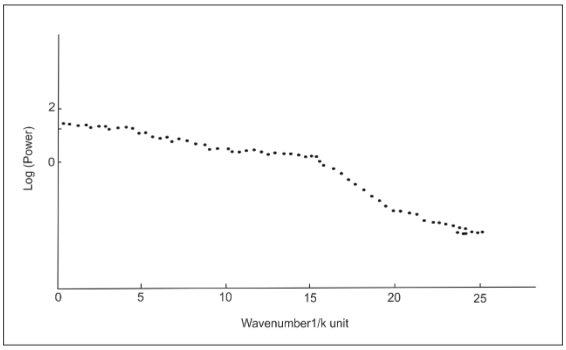


b

Fig. 5. The radial power spectrum of **a)** magnetic anomaly and **b)** gravity anomaly data

Edge detection methods

In potential field methodology, defining the boundaries of the causative body that causes gravity and magnetic anomalies is an important task. Many derivative based edge detection techniques were usually proposed and used to solve this problem in the literature (Verduzco et al., 2004; Cooper and Cowan, 2006; Ma and Li, 2012; Ferreira et al., 2013; Zhou et al., 2013; Ma, 2013; Yuan et al., 2014; Wang et al., 2014; 2015; 2017; Du et al., 2017; Rezaie et al., 2017).

Horizontal gradient

Horizontal gradient method (Blakely, 1995; Cordell, 1979; Cordell and Grauch, 1985) is the oldest and widely used edge detection technique to define the boundaries of density contrast and magnetic susceptibility from potential field data. Given as:

$$\mathrm{HG} = \sqrt{\left(\frac{\partial g}{\partial x}\right)^2 + \left(\frac{\partial g}{\partial y}\right)^2} \quad (1)$$

Tilt angle

The tilt angle method (Miller and Singh, 1994) is based on the relation between vertical and horizontal derivative, zero values located over the source boundaries. Tilt angle is given as:

$$\emptyset = \tan^{-1}\left[\frac{\frac{\partial g}{\partial z}}{\sqrt{\left[\left(\frac{\partial g}{\partial x}\right)^2 + \left(\frac{\partial g}{\partial y}\right)^2\right]}}\right], \quad (2)$$

where $\emptyset$ indicates the tilt angle parameter.

The tilt angle is positive over a source and zero values reflect the source edges (Miller and Singh, 1994). This method is useful in enhancing edges of anomalies for both shallow and deep sources.

Theta map

Wijns et al. (2005) proposed the theta map method that is the normalization of horizontal gradient and is given as:

$$\cos(\theta) = \frac{\sqrt{\left(\frac{\partial g}{\partial x}\right)^2 + \left(\frac{\partial g}{\partial y}\right)^2}}{\sqrt{\left(\frac{\partial g}{\partial x}\right)^2 + \left(\frac{\partial g}{\partial y}\right)^2 + \left(\frac{\partial g}{\partial z}\right)^2}} \quad . \quad (3)$$

The maxima of the theta map corresponds to source edge (Wijns et al., 2005; Cooper and Cowan, 2008).

3D inversion

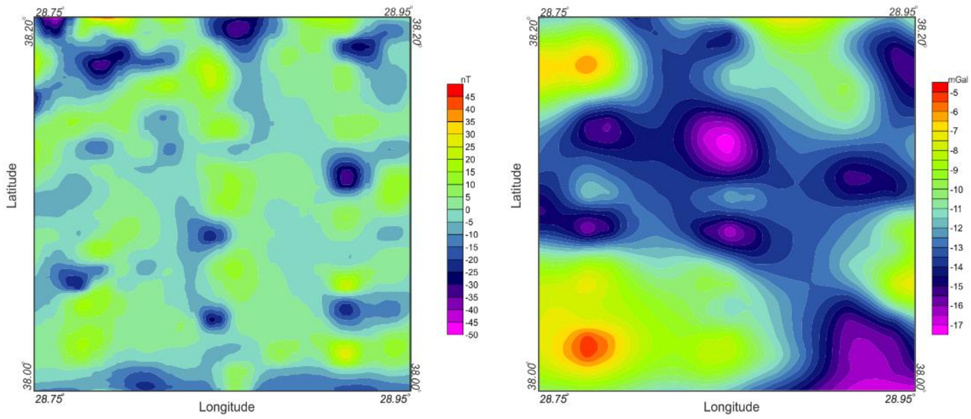
To image the sediment basement relief, 3D inversion of gravity data was conducted using a code written by Pham et al. (2018), which used the algorithm of Granser (1987) and the technique of Cordell and Henderson (1968). The code does not demand a mean depth or filter in the inversion process.

Results

The residual magnetic anomaly map is characterized by positive and negative anomalies given in Fig. 6a, high positive anomaly values up to 70 nT are observed in NW part of the study area and the observed high positive values are concerned with the Menderes Massif granitoids and gnays based on the study area. E-W trending maximum values are observed in the eastern part of the study area that may reflect the effect of buried magnetic sources below the Neogene deposits in Fig.2b. The NW-SE trending low gravity anomalies in the residual gravity map in Fig.6b are observed in the central and southeastern parts of the study area while the high anomalies range between - 5 mGal to -10 mGal in SW, NW and NE parts of the area that reflect the effect of high-density Menderes massif granitoids; however, low anomalies reflect the quaternary sedimentary deposits. The residual gravity map correlates in a good manner with the geological map of the coverage area. The residual gravity and magnetic anomaly maps are in accordance with the general regional trend. In order to determine the buried structural boundaries and discontinuities in the study area, horizontal gradient, tilt angle and theta map edge detection techniques were applied to the residual gravity and residual magnetic maps. The enhanced maps of edge detection techniques to residual magnetic map are presented in Fig. 7a-c. The maximum of horizontal gradient map and theta map that indicate source body boundaries are drawn by black lines and the zero contour of the tilt angle is drawn by a white line in the tilt angle map. The general trend of the defined magnetic lineaments is NW-SE for magnetic data, and also E-W and NE-SW directional lineaments are observed in the centre, E, SE, SW parts of the study area. The enhanced maps from the application of edge detection techniques to residual gravity data are shown in Fig. 8a-c. The maximum value of horizontal gradient map (Fig. 8a) is given with black lines indicating the density discontinuities. The zero contours of the tilt angle map are drawn by a white line exhibited in Fig. 8b. The maximum values of the theta map represent the discontinuities. They are drawn by black lineaments. The horizontal gradient, tilt angle and theta maps reveal NW-SE and E-W directed gravity lineaments that reflect the main structure of the study area. The tilt angle and theta maps (Fig. 8b and Fig. 8c) of the gravity map give detailed information about the geologic units and lineaments of the region. The results of tilt and theta angle derivative methods are compared with the existing surface faults in five different derivation methods.

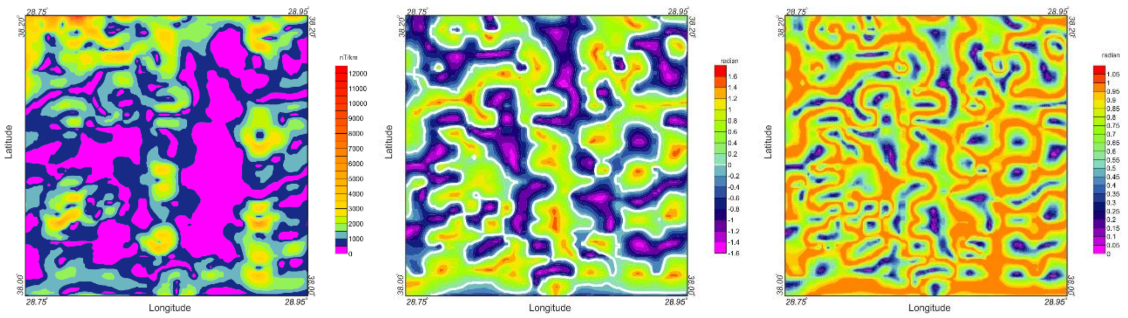
To better understand the tectonic structure, the sediment basement topography was modelled from residual gravity anomaly data by using Pham et al. (2018) Matlab code. Density contrast ($\Delta\rho$) is − 0.3 g/cm^3 and decay constant (λ) is 0.001 g/cm^3 and the enhanced basement relief map is given in Fig.9. In the sediment topography map, the general regional NW-SE direction tectonic trend can be seen easily, and maximum thickness is observed in the northern end of the Denizli basin. The sediment basement topography map indicates that the maximum depth levels are observed in the southeastern part of the Denizli basin and northwestern part of the Alaşehir basin. In the centre of the map, small basins structures were observed parallel to each other with 2 km depth nearly in E-W direction. The linear features which bordered these parallel basin structures were detected by edge detection methods from gravity and magnetic data. The sediment thickness ranges between -0.2 and -2.2 km and the sediment deposits thickness is 2.2 km in the northern part of Denizli basin. This result is coincide with Turgay et al. (1980) geoelectric studies which indicate 2 km depth for the basement in the Sarayköy-Denizli areas; Sarı and Şalk (2006) gravity studies indicate 1.5-2 km in northern Denizli basin and Altinoglu (2012) gravity studies defined 2-3 km.

The new tectonic lineament map of the study area was generated by the joint interpretation of the results of edge detection process, the enhanced sediment basement relief map, geology map and topography map of the study area. Many new lineaments were proposed for the region by the interpretation of the available data. The new defined magnetic lineaments are given in blue and the gravity lineaments are given in red colour in Fig. 10. The general trends of magnetic alignments are in E-W and NW-SE direction and the gravity lineaments are in NW-SE direction that coincide with the regional tectonic trend.



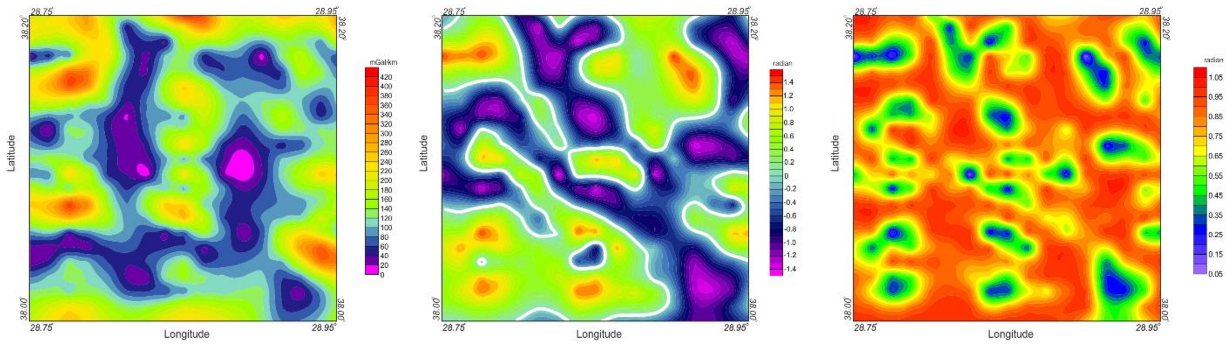
a **b**

Fig. 6. a) Residual magnetic anomaly **b)** residual gravity anomaly maps



a **b** **c**

Fig. 7. The enhanced **a)** horizontal gradient, **b)** tilt angle, **c)** theta map of the residual magnetic anomaly map of the study field



a **b** **c**

Fig. 8. The enhanced **a)** horizontal gradient, **b)** tilt angle, **c)** theta map of residual gravity anomaly map of the study field

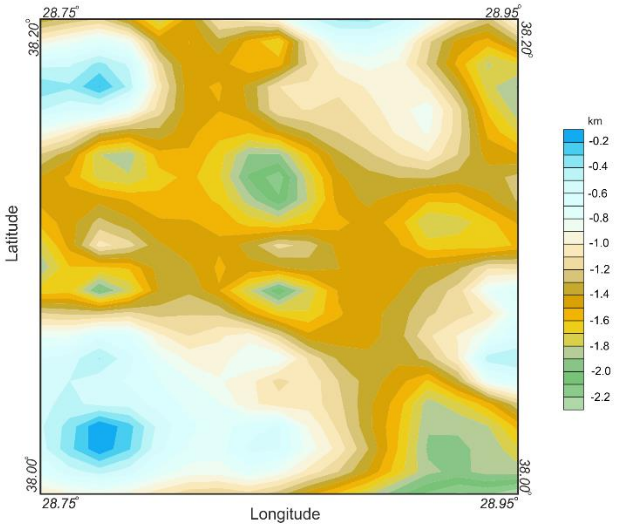


Fig. 9. The sediment basement relief map enhanced by 3D inversion of gravity data of the study area

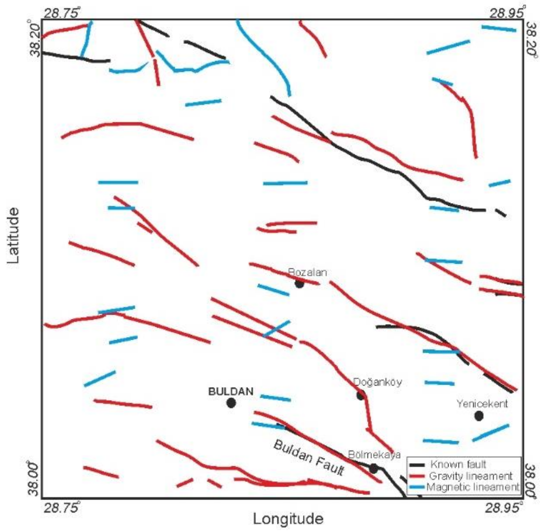


Fig. 10. The new lineament map of the study area, the known faults in the area drawn in black, new proposed gravity lineament in red and magnetic lineament in blue color

Discussion and Conclusion

The derivative based edge detection techniques are essential tools in potential field data to delineate the lineaments, buried faults, contacts etc. The aeromagnetic and gravity data were used together for the first time in the study area. Horizontal gradient, tilt angle and theta map edge detection tools were used to image structural features in the Buldan region, Denizli. In the sediment topography map, the general regional NW-SE direction tectonic trend can be seen easily, and maximum thickness is observed in the northern end of the Denizli basin. The sediment basement topography map indicates that the maximum depth levels are observed in the southeastern part of the Denizli basin and northwestern part of the Alaşehir basin. In the centre of the map, small basins structures were observed parallel to each other with 2 km depth nearly in E-W direction. The linear features which bordered these parallel basin structures were detected by edge detection methods from gravity and magnetic data.

By using derivative based edge detection methods to each data separately, many linear features mainly in NW-SE and E-W directions were identified. The results of horizontal gradient, tilt angle and theta map and 3-D inversion modeling process showed well correlation with known NW-SE trending faults and some new lineaments were identified which are controlling the basement structure. This study clearly indicates that the interpreted structural lineaments from magnetic and gravity data are strongly affected and controlled in the study area. In this study, the sediment basement relief map and new structural map were also proposed for the Buldan region that may shed light on future mining, geothermal, tectonic research.

REFERENCES

Altinoglu F.F. Investigation of tectonics of Western Anatolia by geophysical methods. PhD Dissertation, University of Pamukkale, Denizli, Turkey, 2012, 225 pp. (in Turkish).

Blakely R.J. Potential theory in gravity and magnetic applications. Cambridge University Press. Cambridge, 1995, 441 p.

Bilim F. Investigation into the lineaments and thermal structure of Kütahya-Denizli Region, Western Anatolia, from using aeromagnetic, gravity and seismological data. Physics of the Earth and Planetary Interiors, Vol.165, No. 3-4, 2007, pp. 135-146.

Bozkurt E. Neotectonics of Turkey – a synthesis. Geodinamica Acta, Vol. 14, No. 1-3, 2001, pp. 3-30.

Bozkurt E. Origin of NE-trending basins in western Turkey. GeodinamicaActa, Vol. 16, No. 2-6, 2003, pp. 61-81.

Bozkurt E., Sözbilir H. Tectonic evolution of the Gediz Graben: field evidence for an episodic, two-stage extension in Western Turkey. Geological Magazine, Vol. 141, No. 1, 2004, pp. 63-79.

Brogi A., Capezzuoli E., Alçiçek M.C., Gandin A. Evolution of a fault-controlled travertine fissure-ridge in the western Anato-

LITERATURE

Altinoğlu F.F. Batı Anadolu tektoniğinin jeofizik yöntemlerle incelenmesi. Doktora tezi, Batı Anadolu'nun tektoniğinin jeofizik yöntemlerle araştırılması. DoktoraTezi Pamukkale Üniversitesi, Türkiye, Ankara, 2012, 225 s.

Blakely R.J. Potential theory in gravity and magnetic applications. Cambridge University Press. Cambridge, 1995, 441 p.

Bilim F. Investigation into the lineaments and thermal structure of Kütahya-Denizli Region, Western Anatolia, from using aeromagnetic, gravity and seismological data. Physics of the Earth and Planetary Interiors, Vol. 165, No. 3-4, 2007, pp. 135-146.

Bozkurt E. Neotectonics of Turkey – a synthesis. Geodinamica Acta, Vol. 14, No. 1-3, 2001, pp. 3-30.

Bozkurt E. Origin of NE-trending basins in western Turkey. GeodinamicaActa, Vol. 16, No. 2-6, 2003, pp. 61-81.

Bozkurt E., Sözbilir H. Tectonic evolution of the Gediz Graben: field evidence for an episodic, two-stage extension in Western Turkey. Geological Magazine, Vol. 141, No. 1, 2004, pp. 63-79.

lia extensional province: the Çukurbağ fissure-ridge (Pamukkale, Turkey). J. Geol. Soc., Vol. 171, 2014, pp. 425-441.
Cooper G.R.J., Cowan D.R. Enhancing potential field data using filters based on the local phase. Computers & Geosciences, Vol. 32, No. 10, 2006, pp. 1585-1591.
Cooper G.R.J., Cowan D.R. Edge enhancement of potential-field data using normalized statistics. Geophysics, Vol. 73, No. 3, 2008, pp. 1-4.
Cordell L. Gravimetric expression of graben faulting in Santa Fe Country and the Espanola basin, New Mexico. In: Ingersoll R.V. (ed.) Guidebook to Santa Fe Country, 30th Field Conference. New Mexico: Geological Society, 1979, pp. 59-64.
Cordell L., Grauch V.J.S. Mapping basement magnetization zones from aeromagnetic data in the San Juan basin, New Mexico. In: Hinze W.J. (ed.) The utility of regional gravity and magnetic anomaly maps. Tulsa: Society of Exploration Geophysics, 1985, pp. 181-197.
Cordell L., Henderson R.G. Iterative three-dimensional solution of gravity anomaly data using a digital computer. Geophysics, Vol. 33, No. 4, 1968, pp. 596-601.
Du W., Wu Y., Guan Y., Hao M. Edge detection in potential filed using the correlation coefficients between the average and standard deviation of vertical derivatives. Journal of Applied Geophysics, Vol. 143, 2017, pp. 231-238.
Ferreira F.J., de Souza J., Bongiolo A.B.S., de Castro L.G. Enhancement of the total horizontal gradient of magnetic anomalies using the tilt angle. Geophysics, Vol. 78, No. 3, 2013, pp. 33-41.
Gessner K., Gallardo L.A., Markwitz V., Ring U., Thomson S.N. What caused the denudation of the Menderes Massif: review of crustal evolution, lithosphere structure, and dynamic topography in southwest Turkey.Gondwana Research, Vol. 24, No.1, 2013, pp. 243-274.
Granser H. Three-dimensional interpretation of gravity data from sedimentary basins using an exponential density-depth function. Geophysical Prospecting, Vol. 35, No. 9, 1987, pp. 1030-1041.
Hançer M. Study of the structural evolution of the Babadag-Honaz and Pamukkale fault zones and the related earthquake risk potential of the Buldan region in SW Anatolia, East of the Mediterranean. Journal of Earth Science, Vol. 24, No. 3, 2013, pp. 397-409.
Irmak T.S. Focal mechanisms of small-moderate earthquakes in DenizliGraben (SW Turkey). Earth Planets Space, Vol. 65, No. 9, 2013, pp. 943-955.
Kaymakcı N. Kinematic development and paleostress analysis of the Denizli Basin (Western Turkey): Implications of spatial variation of relative paleostress magnitudes and orientations. Journal of Asian Earth Sciences, Vol. 27, No. 2, 2006, pp. 207-222.
Kaypak B., Gökkaya G. 3-D imaging of the upper crust beneath the Denizli geothermal region by local earthquake tomography, western Turkey. Journal of volcanology and geothermal research, Vol. 211-212, 2012, pp. 47-60.
Koçyiğit A., Yusufoğlu H., Bozkurt E. Evidence from the Gediz Graben for episodic two-stage extension in Western Turkey. J. Geol. Soc., London, Vol. 156, No. 3, 1999, pp. 605-616.
Koçyiğit A. The Denizli graben-horst system and the eastern limit of Western Anatolian continental extension: basin fill, structure, deformational mode, throw amount and episodic evolutionary history, SW Turkey. GeodinamicaActa, Vol. 18, No. 3-4, 2005, pp. 167-208.
Konak N., Şenel M. Geological map of Turkey in 1/500.000 scale: Denizli sheet. Ankara, Publication of Mineral Research and Exploration Directorate of Turkey (MTA), 2002.
Ma G.Q. Edge detection of potential field data using improved local phase filter. Exploration Geophysics, Vol. 44, No.1, 2013, pp. 36-41.
Brogi A., Capezzuoli E., Alçiçek M.C., Gandin A. Evolution of a fault-controlled travertine fissure-ridge in the western Anatolia extensional province: the Çukurbağ fissure-ridge (Pamukkale, Turkey). J. Geol. Soc., Vol. 171, 2014, pp. 425-441.
Cooper G.R.J., Cowan D.R. Enhancing potential field data using filters based on the local phase. Computers & Geosciences, Vol. 32, No.10, 2006, pp. 1585-1591.
Cooper G.R.J., Cowan D.R. Edge enhancement of potential-field data using normalized statistics. Geophysics, Vol. 73, No. 3, 2008, pp. 1-4.
Cordell L. Gravimetric expression of graben faulting in Santa Fe Country and the Espanola basin, New Mexico. In: Ingersoll R.V. (ed.) Guidebook to Santa Fe Country, 30th Field Conference. New Mexico: Geological Society, 1979, pp. 59-64.
Cordell L., Grauch V.J.S. Mapping basement magnetization zones from aeromagnetic data in the San Juan basin, New Mexico. In: Hinze W.J. (ed.) The utility of regional gravity and magnetic anomaly maps. Tulsa: Society of Exploration Geophysics, 1985, pp. 181-197.
Cordell L., Henderson R.G. Iterative three-dimensional solution of gravity anomaly data using a digital computer. Geophysics, Vol. 33, No. 4, 1968, pp. 596-601.
Du W., Wu Y., Guan Y., Hao M. Edge detection in potential filed using the correlation coefficients between the average and standard deviation of vertical derivatives. Journal of Applied Geophysics, Vol. 143, 2017, pp. 231-238.
Ferreira F.J., de Souza J., Bongiolo A.B.S., de Castro L.G. Enhancement of the total horizontal gradient of magnetic anomalies using the tilt angle. Geophysics, Vol. 78, No. 3, 2013, pp. 33-41.
Gessner K., Gallardo L.A., Markwitz V., Ring U., Thomson S.N. What caused the denudation of the Menderes Massif: review of crustal evolution, lithosphere structure, and dynamic topography in southwest Turkey.Gondwana Research, Vol. 24, No.1, 2013, pp. 243-274.
Granser H. Three-dimensional interpretation of gravity data from sedimentary basins using an exponential density-depth function. Geophysical Prospecting, Vol. 35, No. 9, 1987, pp. 1030-1041.
Hançer M. Study of the structural evolution of the Babadag-Honaz and Pamukkale fault zones and the related earthquake risk potential of the Buldan region in SW Anatolia, East of the Mediterranean. Journal of Earth Science, Vol. 24, No. 3, 2013, pp. 397-409.
Irmak T.S. Focal mechanisms of small-moderate earthquakes in DenizliGraben (SW Turkey). Earth Planets Space, Vol. 65, No. 9, 2013, pp. 943-955.
Kaymakcı N. Kinematic development and paleostress analysis of the Denizli Basin (Western Turkey): Implications of spatial variation of relative paleostress magnitudes and orientations. Journal of Asian Earth Sciences, Vol. 27, No. 2, 2006, pp. 207-222.
Kaypak B., Gökkaya G. 3-D imaging of the upper crust beneath the Denizli geothermal region by local earthquake tomography, western Turkey. Journal of volcanology and geothermal research, Vol. 211-212, 2012, pp. 47-60.
Koçyiğit A., Yusufoğlu H., Bozkurt E. Evidence from the Gediz Graben for episodic two-stage extension in Western Turkey. J. Geol. Soc., London, Vol. 156, No. 3, 1999, pp. 605-616.
Koçyiğit A. The Denizli graben-horst system and the eastern limit of Western Anatolian continental extension: basin fill, structure, deformational mode, throw amount and episodic evolutionary history, SW Turkey. GeodinamicaActa, Vol. 18, No. 3-4, 2005, pp. 167-208.
Konak N., Şenel M. Geological map of Turkey in 1/500.000 scale: Denizli sheet. Ankara, Publication of Mineral Research and Exploration Directorate of Turkey (MTA), 2002.
Ma G.Q. Edge detection of potential field data using improved local phase filter. Exploration Geophysics, Vol. 44, No.1, 2013, pp. 36-41.

Ma G., Li L. Edge detection in potential fields with the normalized total horizontal derivative. Computer Geoscience, Vol. 41, 2012, pp. 83-87.

Miller H.G., Singh V. Potential field tilt-a new concept for location of potential field sources. Journal of Applied Geophysics, Vol. 32, No. 2-3, 1994, pp. 213-217.

Milligan P.R., Gunn P.J. Enhancement and presentation of airborne geophysical data. AGSO J. Of Australian Geology and Geophysics, Vol. 172, 1997, pp. 63-75.

Pham L.T., Oksum E., Do T.D. GCH_gravinv: a MATLAB-based program for inverting gravity anomalies over sedimentary basins. Computers and geosciences, Vol. 120, 2018, pp. 40-47.

Ramotoroko C.D., Ranganai R.T., Nyabeze P. Extension of the Archaean Madibe-Kraaipan granite-greenstone terrane in southeast Botswana: Constraints from gravity and magnetic data. Journal of African Earth Sciences, Vol. 123, 2016, pp. 39-56.

Rezaie M., Moradzadeh A., Kalate A.N., Aghajani H., Kahoo A.R., Moazam S. 3D modelling of Trompsburg Complex (in South Africa) using 3D focusing inversion of gravity data. Journal of African Earth Sciences, Vol. 130, 2017, pp. 1-7.

Sarı C., Şalk M. Sediment thicknesses of the western Anatolia graben structures determined by 2D and 3D analysis using gravity data. Journal of Asian Earth Sciences, Vol. 26, No. 1, 2006, pp. 39-48.

Seyitoglu G., Scott B.C. The cause of N-S extensional tectonics in western Turkey: tectonic escape vs. back-arc spreading vs. orogenic collapse. J. Geodyn., Vol. 22, No. 1, 1996, pp. 145-153.

Ten Veen J.H., Boulton S.J., Alçiçek M.C. From palaeotectonics to neotectonics in the Neotethys realm: The importance of kinematic decoupling and inherited structural grain in SW Anatolia (Turkey). Tectonophysics, Vol. 473, No. 1-2, 2009, pp. 261-281.

Turgay I., Özgüler M.E., Şahin H. Denizli-Buldan-Pamukkale geothermal energy searches resitivity study. Ankara, MTA Report No. 6958, 1980 (in Turkish).

Yuan Y., Huang D., Yu Q., Lu P. Edge detection of potential field data with improved structure tensor methods. Journal of Applied Geophysics, Vol. 108, 2014, pp. 35-42.

Van Hinsbergen D.J.J., Schmid S.M. Map-view restoration of Aegean-west Anatolian accretion and extension since the Eocene. Tectonics, Vol. 31, No. 5, 2012, TC5005.

Verduzco B., Fairhead J.D., Green C.M., MacKenzie C. New insights into magnetic derivatives for structural mapping. The Leading Edge, Vol. 23, No. 2, 2004, pp.116-119.

Wang J., Meng X., Li F. Improved curvature gravity gradient tensor with principal component analysis and its application in edge detection of gravity data. Journal of Applied Geophysics, Vol. 118, 2015, pp. 106-114.

Wang J., Meng X.H., Guo L.H., Chen Z.X., Li F. A correlation-based approach for determining the threshold value of singular value decomposition filtering for potential field data denoising. J. Geophys. Eng., Vol. 11, No. 5, 2014, 055007.

Wang J., Meng X., Li F. New improvements for lineaments study of gravity data with improved Euler inversion and phase congruency of the field data. Journal of Applied Geophysics, Vol. 136, 2017, pp. 326-334.

Wijns C., Perez C., Kowalczyk P. Theta map: edge detection in magnetic data. Geophysics, Vol. 70, No. 4, 2005, pp. 39-43.

Yüksel F.A. Filtering of Western Anatolian Bouguergravite anomalies and study of earth crust thickness distribution. Pamukkale University, Journal of Engineering Sciences. Vol. 11, No.1, 2005, pp.1-13 (in Turkish).

Zhou W., Du X., Li J. The limitation of curvature gravity gradient tensor for edge detection and a method for overcoming it. Journal of Applied Geophysics, Vol. 98, 2013, pp. 237-242.

Ma G., Li L. Edge detection in potential fields with the normalized total horizontal derivative. Computer Geoscience, Vol. 41, 2012, pp. 83-87.

Miller H.G., Singh V. Potential field tilt-a new concept for location of potential field sources. Journal of Applied Geophysics, Vol. 32, No.2-3, 1994, pp. 213-217.

Milligan P.R., Gunn P.J. Enhancement and presentation of airborne geophysical data. AGSO J. of Australian Geology and Geophysics, Vol. 172, 1997, pp. 63-75.

Pham L.T., Oksum E., Do T.D. GCH_gravinv: a MATLAB-based program for inverting gravity anomalies over sedimentary basins. Computers and geosciences, Vol. 120, 2018, pp. 40-47.

Ramotoroko C.D., Ranganai R.T., Nyabeze P. Extension of the Archaean Madibe-Kraaipan granite-greenstone terrane in southeast Botswana: Constraints from gravity and magnetic data. Journal of African Earth Sciences, Vol. 123, 2016, pp. 39-56.

Rezaie M., Moradzadeh A., Kalate A.N., Aghajani H., Kahoo A.R., Moazam S. 3D modelling of Trompsburg Complex (in South Africa) using 3D focusing inversion of gravity data. Journal of African Earth Sciences, Vol. 130, 2017, pp. 1-7.

Sarı C., Şalk M. Sediment thicknesses of the western Anatolia graben structures determined by 2D and 3D analysis using gravity data. Journal of Asian Earth Sciences, Vol. 26, No. 1, 2006, pp. 39-48.

Seyitoglu G., Scott B.C. The cause of N-S extensional tectonics in western Turkey: tectonic escape vs. back-arc spreading vs. orogenic collapse. J. Geodyn., Vol. 22, No. 1, 1996, pp. 145-153.

Ten Veen J.H., Boulton S.J., Alçiçek M.C. From palaeotectonics to neotectonics in the Neotethys realm: The importance of kinematic decoupling and inherited structural grain in SW Anatolia (Turkey). Tectonophysics, Vol. 473, No. 1-2, 2009, pp. 261-281.

Turgay I., Özgüler M.E., Şahin H. Denizli-Buldan-Pamukkale jeotermal enerji aramaları rezitivite etüdü. Ankara, MTA Rapor No. 6958, 1980.

Yuan Y., Huang D., Yu Q., Lu P. Edge detection of potential field data with improved structure tensor methods. Journal of Applied Geophysics, Vol. 108, 2014, pp. 35-42.

Van Hinsbergen D.J.J., Schmid S.M. Map-view restoration of Aegean-west Anatolian accretion and extension since the Eocene. Tectonics, Vol. 31, No. 5, 2012, TC5005.

Verduzco B., Fairhead J.D., Green C.M., MacKenzie C. New insights into magnetic derivatives for structural mapping. The Leading Edge, Vol. 23, No. 2, 2004, pp.116-119.

Wang J., Meng X., Li F. Improved curvature gravity gradient tensor with principal component analysis and its application in edge detection of gravity data. Journal of Applied Geophysics, Vol. 118, 2015, pp. 106-114.

Wang J., Meng X.H., Guo L.H., Chen Z.X., Li F. A correlation-based approach for determining the threshold value of singular value decomposition filtering for potential field data denoising. J. Geophys. Eng., Vol. 11, No. 5, 2014, 055007.

Wang J., Meng X., Li F. New improvements for lineaments study of gravity data with improved Euler inversion and phase congruency of the field data. Journal of Applied Geophysics, Vol. 136, 2017, pp. 326-334.

Wijns C., Perez C., Kowalczyk P. Theta map: edge detection in magnetic data. Geophysics, Vol. 70, No. 4, 2005, pp. 39-43.

Yüksel F.A. Batı Anadolu Bouguer gravite anomalilerininsüzgeçlenmesi ve yerkabuğu kalinlik dağiliminin celenmesi. Pamukkale Üniversitesi, Mühendislik BilimleriDergisi, Vol. 11, No.1, 2005, pp.1-13.

Zhou W., Du X., Li J. The limitation of curvature gravity gradient tensor for edge detection and a method for overcoming it. Journal of Applied Geophysics, Vol. 98, 2013, pp. 237-242.

СТРУКТУРНАЯ ИНТЕРПРЕТАЦИЯ РЕГИОНА БУЛДАН ЗАПАДНОЙ АНАТОЛИИ С ИСПОЛЬЗОВАНИЕМ МАГНИТНЫХ И ГРАВИТАЦИОННЫХ ДАННЫХ

Алтыноглу Ф.Ф.
Факультет инженерии, отделение геофизики, Университет Памуккале
20017, Денизли, Турция, Кыныклы Кампус: faltinoglu@pau.edu.tr

Резюме. Западная Анатолия тектонически является регионом расширения, и многие системы горст-грабена были разработаны в этом тектоническом режиме. Район Булдан расположен в северной части области Денизли между Денизлинским и Алашехирским грабенами, где наблюдается сейсмическая активность и встречаются горячие источники. Структурное строение разрезов этого района было исследовано с помощью аэромагнитных и гравитационных данных Буге. Для определения тектонических линеаментов были использованы производные метода обнаружения краев (выделения границ); горизонтальный градиент, угол наклона и карта Тета. Карта рельефа подстилающих отложений изученного района была дополнена 3D инверсией гравитационных данных с использованием алгоритма Паркера-Ольденбурга. Окончательная карта гравитационных и магнитных линеаментов исследуемого района представлена как совместная интерпретация результатов процесса обнаружения краев (выделения границ) и карт – рельефа подстилающих отложений, существующей геологической, а также цифровой топографической карты рельефа исследуемого района. Толщина подстилающих пород колеблется в пределах от 0.2 км до 2.2 км, а осадочных пород в северной части бассейна Денизли достигает 2.2 км. Между грабенами Алашехир и Денизли на карте рельефа подстилающих отложений были обнаружены рельефы СЗ-ЮВ простирания, а также линеаменты, такие как сдвиг/трещина, СЗ-ЮВ направления, которые ограничивают рельеф подстилающих отложений. Новые линеаменты в значительной степени совместимы с региональной тенденцией геологического развития района и рельефом подстилающих отложений. Обнаруженные в результате этого исследования новые гравитационные и магнитные линеаменты облегчат понимание тектонического строения, геотермального потенциала, минерализации региона при проведении будущих исследований.
Ключевые слова: *Булдан, гравитационные и аэромагнитые данные, обнаружение краев (выделение границ), 3Д моделирование*

MAQNİT VƏ QRAVİTASİYA MƏLUMATLARINDAN İSTİFADƏ ETMƏKLƏ QƏRBİ ANADOLUNUN BALDAN REGİONUNUN STRUKTUR İNTERPRETASİYASI

Altınoğlu F.F.
Pamukkala Universiteti, mühəndislik fakültəsi, geofizika bölməsi
20017, Dənizli,Türkiyə, Kınıklı Kampus: faltinoglu@pau.edu.tr

Xülasə. Qərbi Anadolu tektonik cəhətdən genişlənmə regionudur və horst-qrabenin çoxlu sistemləri bu tektonik rejimdə işlənilmişdir. Buldan rayonu Dənizli və Alaşehirqrabenlərinin arasında Dənizli əyalətinin şimal hissəsində yerləşmişdir və burada seysmik fəaliyyət müşahidə edilir, isti bulaqlar rast gəlir. Rayonda kəsilişlərin struktur quruluşu Buqe aeromaqnit və qravitasiya məlumatlarının köməyi ilə tədqiq edilmişdir . Tektonik lineamentlərin təyini üçün kənarların aşkar olunması (sərhədlərin ayırılması) törəmə metodundan, horizontal qradiyent, meyil bucağı və Tet kartından istifadə edilmişdir. Öyrəlinən rayonun döşənən (ana, köklü) süxürlarının relyef xəritəsi Parker-Oldenburq alqoritmindən istifadə etməklə qravitasiya məlumatlarının 3D inversiyası ilə tamamlanmışdır.

Tədqiq olunan rayonun qravitasiya və maqnit lineamentlərinin yekun xəritəsi kənarların aşkar edilməsi (sərhədlərin ayırılması) prosesinin və döşənən (ana, köklü) çöküntülərin relyef xəritəsi, mövcud geoloji xəritə, həmçinin tədqiq olunan rayonun relyefinin rəqəmli topoqrafik xəritəsinin nəticələrinin birgə interpretasiyası kimi təmsil edilmişdir. Döşənən süxurların qalındığı 0.2-2.2 km hüdüdundadır, Dənizli hövzəsinin şimal hissəsindəki çökmə süxurların qalınlığı isə 2.2 km-ə çatır. Alaşehir və Dənizli qrabenləri arasında döşənən çöküntülərin relyef xaritəsində ŞmQ-CŞ uzanma relyefləri, həmçinin ŞmQ-CŞ istiqamətli tərpədilmə-çat lineamentlər aşkar edilmişdir və onlar döşənən çöküntülərin relyefini məhdudlaşdırırlar. Yeni lineamentlər rayonun geoloji inkişafının regional tendensiyası ilə və döşənən çöküntülərin relyefi ilə xeyli dərəcədə uyğunlaşır. Bu tədqiqat nəticasindı aşkar olunmuş yeni qravitasiya və maqnit lineamentləri gələcəkdə aparılacaq rədqiqatlarda regionun tektonik quruluşu, geotermal potensialı, minerallaşmasının dərk edilməsiniasanlaşdıracaqdır.
Açar sözlər: *Buldan, qravitasiya və aeromaqnit məlumatları, kənarların aşkar edilməsi (sərhədlərin ayırılması), 3D modelləşdirmə*