Geomech. Geophys. Geo-energ. Geo-resour. (2016) 2:195–201
DOI 10.1007/s40948-016-0028-0

TECHNICAL NOTE

Investigation of the gravity data from Fethiye–Burdur fault zone using the Euler deconvolution technique

Günay Beyhan · Ayhan Keskinsezer

Received: 3 November 2015 / Accepted: 19 April 2016 / Published online: 26 April 2016

Abstract This study aims to determine the depths of geological structures in Fethiye–Burdur fault zone. This fault length, which is considered the landward continuation of the Pliny-Strabo trench, is an important feature in SW Turkey. The NW–SE extension is probably responsible for the formation of the Burdur Basin during Plio-Quaternary time. Study area is located in a region which has the potential seismic events along the Burdur tectonic lines. For this purpose, Euler deconvolution was applied on two separate cross-sections of the region's Bouguer gravity map and basement rock depth of the region were determined. Euler deconvolution yields fast and successful results in determining the depths of graben-type tectonic structures. The depths of geological structures were determined through different window sizes and structural index values. The maximum depth value determined in the region was approximately 13 km. The determined depths were used to reveal cross-sections of possible underground structures.

Keywords Fethiye–Burdur fault zone · Euler deconvolution · Gravity data

G. Beyhan (✉) · A. Keskinsezer
Department of Geophysical Engineering, Faculty of Engineering, Sakarya University, Sakarya, Turkey
e-mail: gbeyhan@sakarya.edu.tr

1 Introduction

Koçyiğit (1984) asserts that Burdur Lake and its surroundings contain areas of block faulting that are still active. Bozcu et al. (2007), on the other hand, maintain that Burdur graben basin is one that develops under the control of Fethiye–Burdur fault zone (FBFZ). Dolmaz et al. (2003) applied the power spectrum method on two cross-sections of the region's Bouguer gravity map, made depth calculations and built a model of the area. This study aims to determine the in-depth geometry of the Burdur sedimentation basin using Bouguer gravity data and Euler deconvolution as well as to compare the consequent results with the results achieved by Dolmaz et al. (2003). Euler deconvolution has come into wide use as an aid to interpreting profile or gridded gravity survey data. It provides automatic estimates of source location and depth. For more complex bodies (including the contact case), the Euler method is at best an approximation. Extended Euler provides better-constrained solutions for both gravity and magnetic bodies.

2 Geological and tectonic structure of the region

The study covers the Burdur Basin, also known as the Burdur Lake Basin, located in southwest Anatolia. Figure 1 contains a geological map of the region. The Burdur Basin is a Neogene basin. The Basin is mainly formed with Quaternary new alluvium and terrace

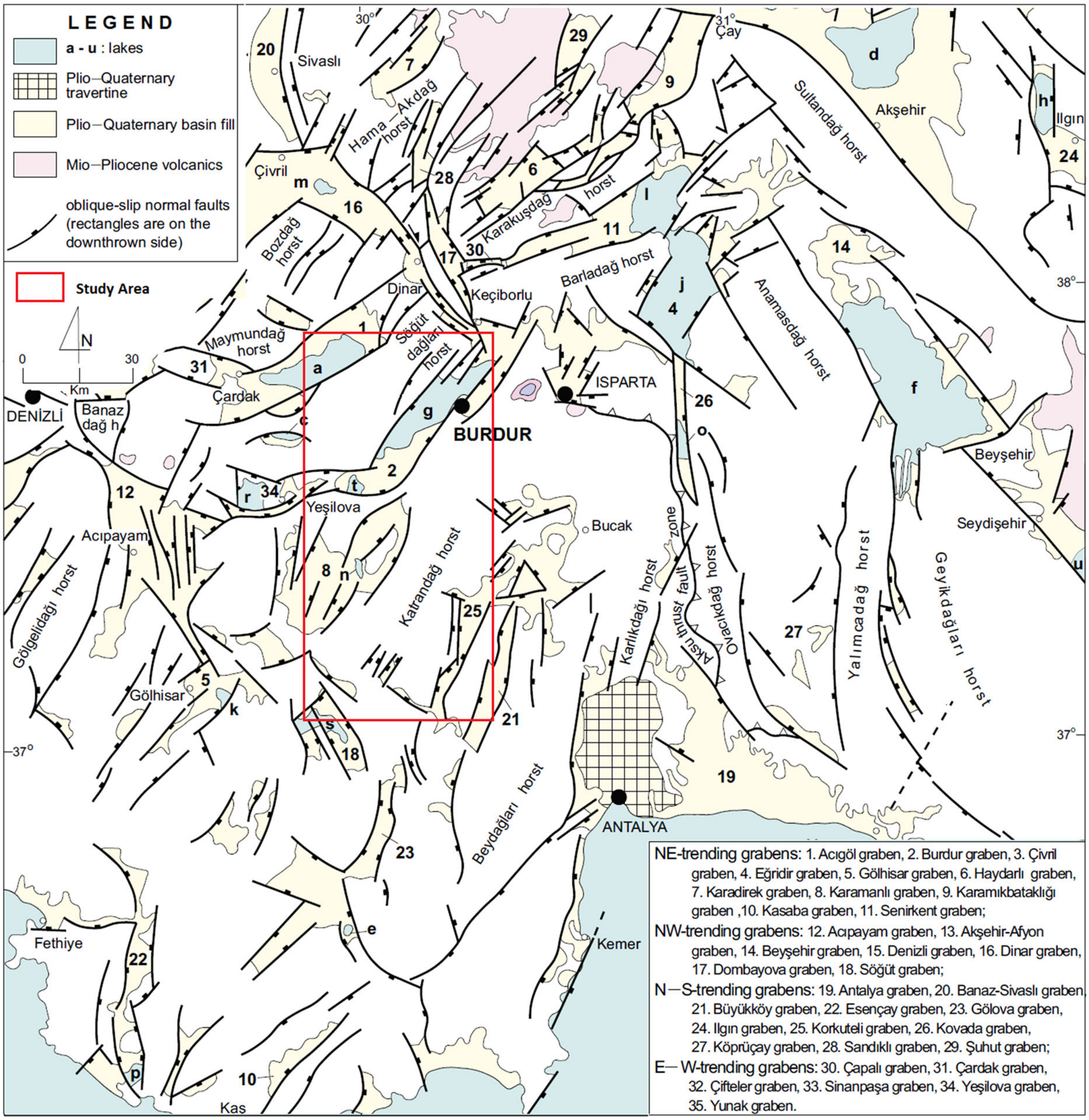

Fig. 1 Neotectonic map of the Burdur and environs (Koçyiğit and Deveci 2007)

deposits. A Neogene unit deposited transgressively over an ophiolitic sequence dominates the southeast of Burdur Lake. Koçyiğit (1984) asserts that the basin was formed as a result of being restricted by faults running parallel to the depression axis.

This zone, which is about 300 km in length, is characterized as a combination of a number of normal faults which has generally left lateral oblique-slip in feature. It is, also, characterized as being the most active fault system in Southwest Anatolia. FBFZ, normally, extends in NE–SW direction, but it was segmented in various lengths by several faults tilted in NW direction. Burdur and Tefenni segments, that are 60–70 km in length, are considered as the most active lines of these segments. It has been reported that two major earthquakes in 1914 and 1971 took place on these segments with a magnitude of 7.1 and 6.2, respectively (Bozcu et al. 2007). Burdur Basin (Temiz et al. 1997; Verheart et al. 2006) and in southwestern part of FBFZ, i.e., Çameli Basin (Alçiçek et al. 2006; Över et al. 2010) indicate a large extensional motion along this major fault. In the north, it links approximately NW–SE trending basins and associated normal fault systems such as the Dinar Basin and Dinar fault respectively. The Burdur,

Dinar, Çivril and Acıgöl basins are interpreted as half graben systems (Price 1989). The FBFZ is characterized by several segments of various ages which affected the Mesozoic sequence and ophiolites of Lycian nappes and the Plio-Quaternary deposits of the Burdur Basin (Bering, 1971; Price and Scott 1994).

The most important feature of the FBFZ is tectonic structure (Fig. 1). Block faulting can be best studied through the faults in our study area. It is also possible to observe normal faults and the relation between depressions and elevations that lie between these faults. Depression areas are filled with Upper Miocene-Pliocene old terrigenous deposits and alluvium according to Koçyiğit (1984). Furthermore, according to Taymaz and Price (1992), the Burdur Basin is also a depression area confined by this rhomboidal fault system.

3 Gravity data

The General Directorate of Mineral Research and Exploration (MTA 1989) prepared the Bouguer gravity data used in this study in 1989 (Fig. 2). Dolmaz et al. (2003) made the depth measurements taking A–A′ and B–B′ cross-sections in the same directions on the same Bouguer maps. In this study, the Euler deconvolution technique was applied to the cross-section to obtain depth measurements of the causative sources and the results were compared to those obtained by Dolmaz et al. (2003).

4 Euler deconvolution

Euler deconvolution is used to determine the depths and locations of original masses that cause potential fields anomalies. The method was applied to magnetic profile data by Thompson (1982). Reid et al. (1990) developed the system further and applied it to gridded magnetic data. The Euler deconvolution was applied to gravity data by Wilsher (1987), Corner and Wilsher (1989), Klingele et al. (1991), Marson and Klingele (1993), Fairhead et al. (1994), and Huang et al. (1995). According to Keskinsezer (1997), Euler deconvolution is a technique that produces automatic depth solutions from gravity and/or magnetic data defined by the structural index parameter and the size of the moving window used in the calculation. Thus, the depths and locations of subsurface structures that were causing the anomalies were determined by applying the Euler deconvolution technique to Bouguer gravity data. The determined depths were used to reveal the possible subsurface structure of the region. Durrheim and Cooper (1998) and Cooper (2002) applied Euler deconvolution to potential field data.

The following 3-dimensional Euler formula was devised by Reid et al. (1990).

$$(x - x_0)\frac{\partial g}{\partial x} + (y - y_0)\frac{\partial g}{\partial y} + (z - z_0)\frac{\partial g}{\partial z} = \eta(\beta - g) \quad (1)$$

The Extended Euler deconvolution (Mushayandebvu et al. 2001; Nabighian and Hansen 2001) follows from the observation that potential fields are also invariant under rotations. This leads to two new equations for the 3-dimensional case. A distinction is made between a Hilbert Transform in the local East or X direction and the local North or Y direction. Therefore,

$$x\frac{\partial g}{\partial x} + y\frac{\partial g}{\partial y} + z\frac{\partial g}{\partial z} + \eta = x_0\frac{\partial g}{\partial x} = y_0\frac{\partial g}{\partial y} = z_0\frac{\partial g}{\partial z} + \eta(\beta - g) \quad (2)$$

can be deduced.

In this formula (x, y, z) stand for the location of the source (x_0, y_0, z_0) for which the total gravity value will be determined while β represents the regional gravity value, η the distance-correlated fading rate of the anomaly and SI the structural index. SI is related to the geometry of the source and should be selected based on preliminary information. For instance, FitzGerald et al. (2004) suggest that in gravity studies SI can be set as $SI = -1$ for contacts, $SI = 0$ for faults with small step, $SI = 1$ for horizontal cylinders and $SI = 2$ for spheres.

Euler deconvolution is applied to newly acquired gravity data to image the subsurface structures thereby

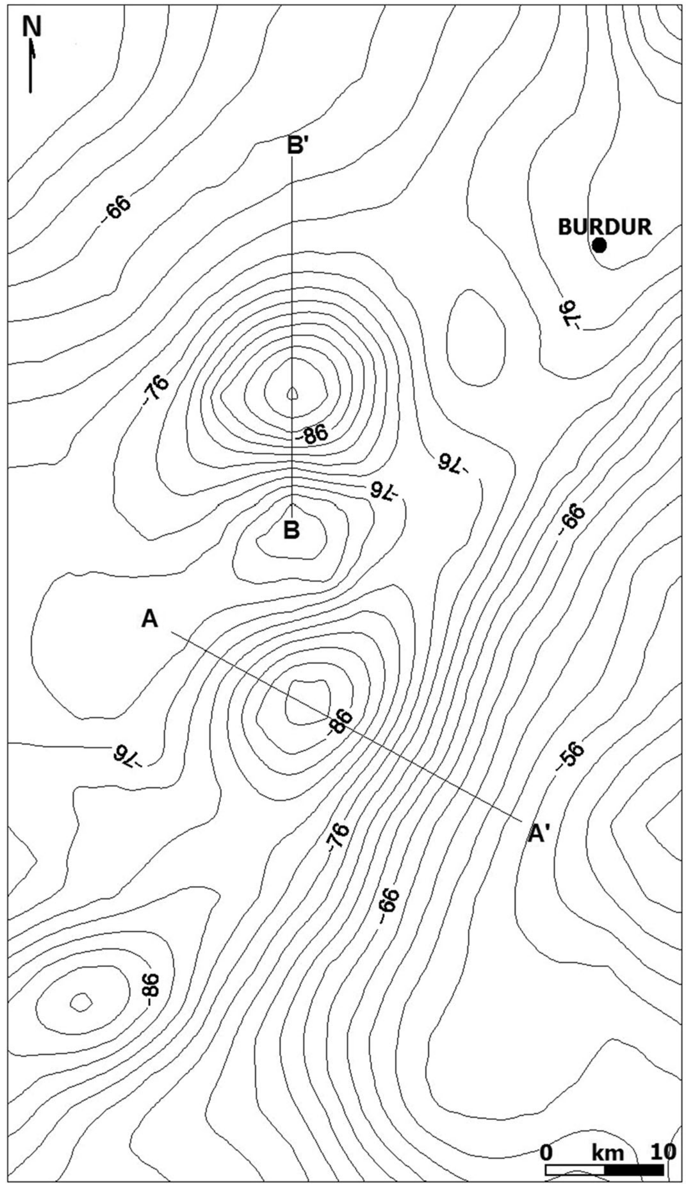

Fig. 2 Bouguer gravity map of Burdur (MTA)

aiding the geothermal exploration. The results were compared with the available geologic and geothermal information in order to get a relationship between structures and geothermal resources (Saibi et al. 2006).

In this study, the cross-sections A–A′ and B–B′ were taken from the Bouguer gravity map of Burdur where contour lines are closer together. The length of the cross-section A–A′ is 31.5 km while the length of the cross-section B–B′ is 30.6 km. Here, the cross-sections A–A′ represents the FBFZ. In addition, the cross-section B–B′ represents the local a graben system. The contour interval was carefully selected to fully reflect the anomaly values of the area. The Euler deconvolution (EULER 1.15 Version) freeware program form Cooper (2004) was applied to these data. Window sizes 7, 9, 11 and 13 were used in these calculations. Different structural index values were used due to the complex tectonic and geological nature of the study area. The deepest point along the resolution of the cross-section A–A′ had a depth value of 11 km and was located 11.5 km away from the beginning of the cross-section (Fig. 3). However, significant results could be obtained outside these calculations. That is, solutions are not meaningful to structural index values and other windows size. Due to scattered values meaningful solutions could be obtained.

Dolmaz et al. (2003) calculated the depth of this point to be 10.74 km using the power spectrum method.

Figure 4 contains the Euler deconvolution resolutions of the cross-section B–B′. The depth value at the 12th kilometer of this cross-section was calculated to be approximately 12.5 km. Dolmaz et al. (2003) calculated the depth of this point to be 13.21 km using the power spectrum method.

5 Conclusions and discussions

The contact of significant depth extent does not give rise to a homogeneous gravity field and the Euler method is therefore at best an approximation in that case. The two Hilbert equation case is more stable in this situation. Geologically, plausible results are obtained with real data. Discrimination of solutions using depth error estimates is not recommended.

In this study, the depth calculations of two cross-sections taken from the Bouguer gravity map of Burdur and its surroundings were made using the Euler deconvolution technique. These cross-sections were selected from areas where the contour lines were the closest together. The calculations showed that the maximum depth value along the cross-section A–A′ was 11 km while it was approximately 12.5 km for the cross-section B–B′. When these Euler deconvolution resolutions were compared with the power spectrum resolutions of Dolmaz et al. (2003), who made their calculations using the same cross-sections, it was revealed that the depth value for the cross-section A–A′ was about 250 m deeper and the value for the cross-section B–B′ was about 750 m shallower.

The results from this work show the importance of using Euler deconvolution in the analysis of gravity data. It also provides new insights into the structure of the study area. The structural map is a very useful document in the planning of basement research to be undertaken in the study area. Euler method cannot be expected solutions in complex geological and tectonic area. Because there are so many parameters that affect the process.

Models of the areas covering the cross-sections were also built. The fairly high depth values that were

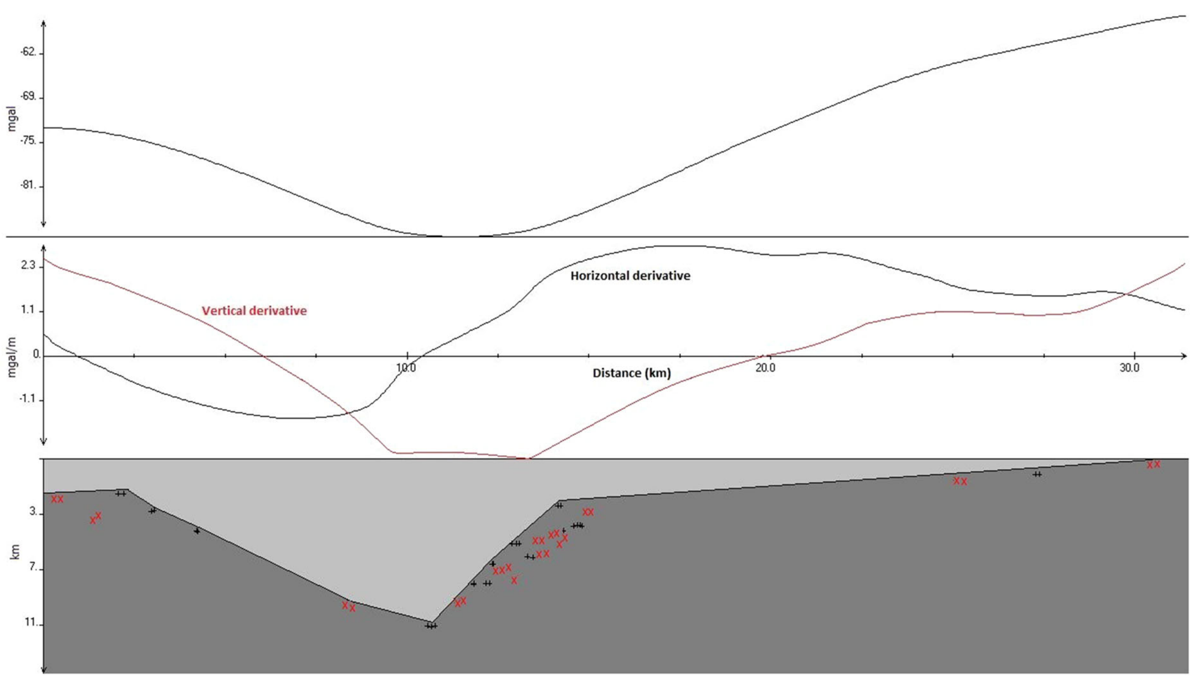

Fig. 3 Depth resolutions of the A–A′ profile calculated using Euler deconvolution and the model that was created

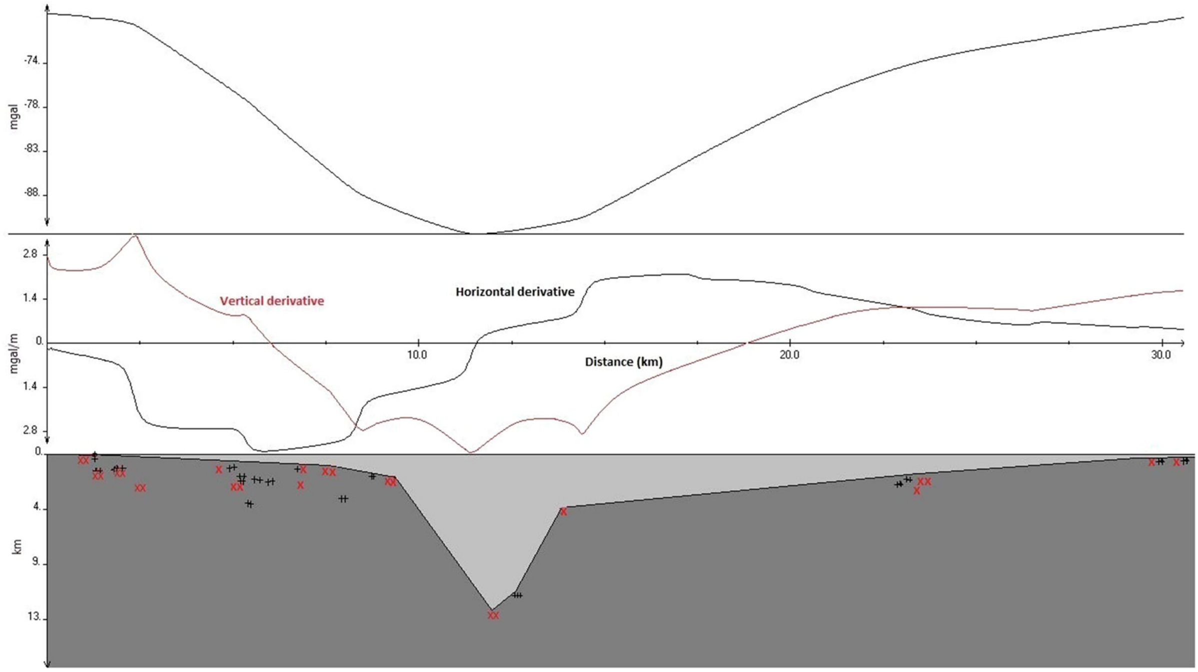

Fig. 4 Depth resolutions of the B–B′ profile calculated using Euler deconvolution and the model that was created

calculated can be explained by a possible deformation that took place in the region. Koçyiğit (1984) suggests that the block faulting in and around Burdur Lake is caused by intraplate extension and that the faults in the region are still active. When the regions geological and tectonic characteristics are also taken into consideration, it is understood that these depth values correspond to normal faults. The contact points between the Quaternary unit and the Neogene unit observed around Burdur Lake are clearly differentiated over the maximum values of the horizontal gradient.

Acknowledgments The authors are grateful to the General Directorate of Mineral Research and Exploration for their kind permission to use the gravity and geological maps from Turkey.

References

Alçiçek CM, Ten Veen HJ, Özkul M (2006) Neotectonic development of the Çameli Basin, southwestern Anatolia, Turkey. Geol Soc Lond 260:591–611

Bering D (1971) Lithostratigraphie, Entwicklung and Seegeschichte des neogenen und quartâren intramontanen Becken der pisidischen Seenregion (Südanatolien). Beihefte zum Geologischen Jahrbuch, 101. Eren Publications, Hannover

Bozcu M, Yağmurlu F, Şentürk M (2007) Some neotectonic and paleosismological features of the Fethiye–Burdur fault zone, SW Anatolia. CGET. J Geol Eng 31(1):25–48

Cooper GRJ (2002) An improved algorithm for the Euler deconvolution of potential field data. Lead Edge 21(12):1197–1198

Cooper GRJ (2004). Euler 1.15. Euler deconvolution freeware program. School of Geosciences University of the Witwatersrand

Corner B, Wilsher WA (1989). Structure of the Witwatersrand basin derived from interpretation of the aeromagnetic and gravity data. In: Garland GD (ed) Proceedings of exploration ‘87, third decennial international conference on geophysical and geochemical exploration for minerals and groundwater: Ontario Geol. Survey, Special 3, pp 532–546

Dolmaz N, Hisarlı ZM, Orbay N (2003) Interpretation of the Burdur basin using Bouguer gravity data, Istanbul University, Faculty of Engineering. Earth Sci J 16(1):23–32

Durrheim RJ, Cooper GRJ (1998) EULDEP: a program for the Euler deconvolution of magnetic and gravity data. Comput Geosci 24(6):545–550

Fairhead JD, Bennet KJ, Gordon RH, Huang D (1994) Euler: beyond the ‘Black Box’, 64th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, pp 422–424

FitzGerald D, Reid A, McInerney P (2004) New discrimination techniques for Euler deconvolution. Comput Geosci 30:461–469

Huang D, Gubbins D, Clark RA, Whaler KA (1995) Combined study of Euler’s homogeneity equation for gravity and magnetic field. In 57th Conference and Tech. Exhib., Euro. Assoc. Expl. Geophysics, Extended Abstracts, p 144

Keskinsezer A (1997). Shallow crust of the region between the Gulf of İzmit and Sapanca Lake, Kocaeli University, Institute of Physical Sciences, Ph.D. Dissertation, İzmit

Klingele EE, Marson I, Kahle HG (1991) Automatic interpretation of gravity gradiometric data in two dimensions: vertical gradients. Geophys Prospec 39:407–434

Koçyiğit A (1984) New intraplate tectonic development in and around southwest Turkey. Geol Bull Turkey 27:1–16

Koçyiğit A, Deveci Ş (2007) A N-S-trending active extensional structure, the Şuhut (Afyon) graben: commencement age of the extensional neotectonic period in the Isparta Angle, SW Turkey. Turkish J Earth Sci 16:391–416

Marson I, Klingele EE (1993) Advantages of using the vertical gradient of gravity for 3-D interpretation. Geophysics 58: 1588–1595

MTA (1989) Bouguer gravity map of Burdur Region. General Directorate of Mineral Research and Exploration, Ankara, Turkey

Mushayandebvu MF, van Driel P, Reid AB, Fairhead JD (2001) Magnetic source parameters of two-dimensional structures using extended Euler deconvolution. Geophysics 66:814–823

Nabighian MN, Hansen RO (2001) Unification of Euler and Werner deconvolution in three dimensions via the generalised Hilbert transform. Geophysics 66:1805–1810

Över S, Özden S, Pınar A, Yılmaz H, Ünlügenç UC, Kamacı Z (2010) Late cenozoic stress field in the Cameli Basin, SW Turkey. Tectonophysics 492(1–4):60–72

Price SP (1989) Sedimentation and neotectonics of the Burdur Regioon, SW Turkey, Ph.D. Thesis, University of Leicester, UK

Price SP, Scott B (1994) Fault block rotations at the edge of a zone of continental extensions; south-west Turkey. J Struct Geol 16:381–392

Reid AB, Allsop JM, Granser H, Millet AJ, Somerton IW (1990) Magnetic interpretation in three dimensions using Euler deconvolution. Geophysics 55:80–91

Saibi H, Nishijima N, Aboud E, Ehara S (2006) Euler deconvolution of gravity data in Geothermal reconnaissance; the Obama geothermal area, Japan. Butsuri Tansa 59(3):275–282

Taymaz T, Price S (1992) The May 12 Burdur earthquake sequence, SW. Turkey: a synthesis of seismological and geological observations. Geophys J Int 108:589–603

Temiz H, Poisson A, Andireux J, Barka A (1997) Kinematics of the Plio-Quaternary Burdur–Dinar cross-fault system in SW Anatolia (Turkey). Ann Tecton XI 1–2:102–113

Thompson DT (1982) Euldph. A new technique for making computer assisted depth estimates from magnetic data. Geophysics 47(1):31–37

Verheart G, Dominique ST, Vandyske S, Sintubin M, Muchez P (2006) Different stress states in the Burdur–Isparta region (SW Turkey) since Late Miocene times: a reflection of a transient stress regime. J Struct Geol 28:1067–1083

Wilsher WA (1987). A structural interpretation of the Witwatersrand basin through the application of the automated depth algorithms to both gravity and aeromagnetic data, M.Sc. thesis, University of Witwatersrand