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Research Article

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Modeling of the Büyük Menderes Grabe using the Double Circle Method

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Abstract The given method can be applied to two-dimensional structures such as horsts and grabens, and is also suitable for structures in the form of a sloping dyke that extends to infinity. It is possible to provide some parameters such as depth, upper surface width, and slope angle by using the Double Circle Method, which is a geometric method by taking advantage of the gravity anomalies that these structures will create on the earth. In this study, the application of the Double Circle Method to the Büyük Menderes Graben is given. Büyük Menderes graben is located between Denizli and the Aegean Sea and is approximately 200 km long. The eastern end of the graben intersects with the Gediz graben around Pamukkale. The western end divides into two branches around Germencik. The northern branch continues to Kuşadası, and the southern branch turns SW and enters the Aegean Sea. A regional gravity anomaly map was derived by using the Bouger gravity anomaly map data obtained as a result of the gravimetric survey conducted in the region. The Double Circle Method was applied to the gravity anomalies obtained from various sections.

Keywords Double circle method, Büyük Menderes, Modeling

Introduction

Approaches that provide convenience and quickness in terms of time in the direct calculation of structures from gravity anomalies have an important place in gravity interference studies. The fact that the formulas given to find the gravity effects of structures with relatively simple shapes require long and tiring calculations, and the situation becomes more complicated for structures with irregular shapes, has led to the need to detect such structures in calculations to be made with appropriate approaches. In fact, since gravity anomalies are rarely known with a precision better than 3% in field studies, there is not much need for very high precision calculations. Direct calculation of geometric model structures with appropriate approaches was also done before [1]. Since gravity anomalies consist of different density differences of underground geological structures, an anomaly cannot be easily associated with the target structure. Therefore, to make a reliable interpretation depends on a good knowledge of underground geology and density differences. The densities of sedimentary rocks vary depending on some factors. For example, density increases exponentially with depth. Thus [2, 3, 4, 5, 6, 7]. In this study, the Double Circle Method, which is a direct interpretation method, was tried to be applied with a horizontal, thin (infinite) plate approach to the Büyük Menderes depression basin, which was claimed to be a graben by previous studies. That is, the upper surface width is greater than 2b or the middle depth from the surface. It has been observed that if h is small, results are obtained with minimum error.

Method

If the vertical section of the two-dimensional structure, horst and graben, is taken as a rectangle as shown in Figure 1, the gravity effect it will create at a point P on the surface is as follows:

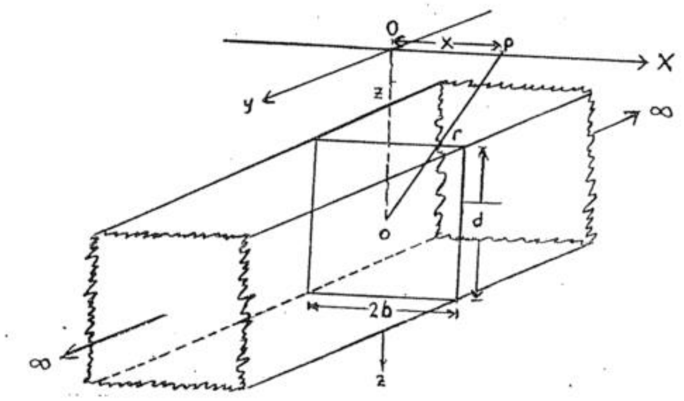

Figure 1: *Horizontal dyke extending to infinity on both sides [1].*

$$\Delta g(x) = 2k_0\delta \iint \frac{z}{r^2} dxdz \qquad (1)$$

It will happen. Here, if the surface S is 2b wide and d thick:

$$\Delta g(x) = 2k_0\delta \int_{x-b}^{x+b} \int_{z-d/2}^{z+d/2} \frac{z}{x^2+z^2} dxdz \qquad (2)$$

Clearly the effect of gravity;

$$\Delta g(x) = 2k_0\delta\{ \frac{1}{2}(x+b)\ln\frac{(x+b)^2+(z+d/2)^2}{(x+b)^2+(z-d/2)^2} - \frac{1}{2}(x+b)\frac{\ln(x-b)^2+(z+d/2)^2}{\ln(x-b)^2+(z-d/2)^2}$$

$$+\ z+d/2[\tan^{-1}\frac{x+b}{z+d/2} - \tan^{-1}\frac{x-b}{z+d/2}] - (z-\frac{d}{2})[\tan^{-1}\frac{x+b}{z-d/2} - \tan^{-1}\frac{x-b}{z-d/2}]$$

}

We can write it as.

If we accept the upper surface depth of the prism in Figure 1 as t, the lower surface depth as T, and the distances from the corners to point P as r1, r2, r3, r4, we can write the gravity effect $\Delta g(x)$ as follows, which will be easier to calculate.

$$r_1^2 = (x+b)^2 + (z-d/2)^2 \qquad r_3^2 = (x-b)^2 + (z+d/2)^2$$

$$r_2^2 = (x-b)^2 + (z-d/2)^2 \qquad r_4^2 = (x+b)^2 + (z+d/2)^2$$

$$\theta_1 = \tan^{-1}\frac{x+b}{z-d/2} \qquad \theta_3 = \tan^{-1}\frac{x-b}{z+d/2}$$

$$\theta_2 = \tan^{-1}\frac{x+b}{z-d/2} \qquad \theta_4 = \tan^{-1}\frac{x+b}{z+d/2}$$

If we substitute these into the previous $\Delta g(x)$ formula,

$$\Delta g(x) = 2k_0\delta \left\{ \frac{1}{2}(x+b)\ln\frac{r_4^2}{r_1^2} - \frac{1}{2}(x-b)\ln\frac{r_3^2}{r_2^2} + (z+d/2)(\theta_4-\theta_3) - (z-d/2)(\theta_1-\theta_2) \right\}$$

$$\Delta g(x) = 2k_0\delta \left\{ T(\theta_4-\theta_3) - t(\theta_1-\theta_2) + (x+b)\ln\frac{r_4}{r_1} - (x-b)\ln\frac{r_3}{r_2} \right\} \quad (3)$$

If a horizontal thin plate passing through the middle of this structure is taken instead of a two-dimensional structure with a rectangular vertical section, the gravity anomaly that this horizontal thin plate will create at a point P on the surface is found by the following expression.

$$\Delta g(x) = 2\pi k_0 \mu_G \left(\frac{1}{\pi}\tan^{-1}\frac{X_A}{h} - \frac{1}{\pi}\tan^{-1}\frac{X_B}{h}\right) \quad (4)$$

μ_G : surface density

ϕ : ϕ_A-ϕ_B point of view, $\phi = \phi^o \frac{\pi}{180^o}$

X_A= X+b ve X_B = X-b , h = deph d = structure thickness

2b = structure width, $\Delta g = (\delta_2-\delta_1)$ intensity contrast, $\Delta g_{max} = 4\pi k_0 \mu_G \tan^{-1}\frac{b}{h}$

For surface density :

$\mu_G = -(\delta_2-\delta_1)d = \Delta g d$ we can write. (5)

If the underground structure is in the form of a sloping dyke that extends to infinity, then in order to find the gravity effect $\Delta g(x)$, the upper surface of the dyke is considered a loaded surface and here the horizontal plate approach is used to determine it.

$$\Delta g(x) = -2k_0 \Delta g \sin\alpha[\sin\alpha \ln\frac{R}{r} - \cos\alpha(\phi-\theta)] \quad (6)$$

$$\Delta g(x) = -2k_0 \Delta g \sin\alpha[\sin\alpha \ln\frac{\sqrt{(x+b)^2+h^2}}{\sqrt{(x-b)^2+h^2}} - \cos\alpha(\tan^{-1}\frac{h}{x+b} - \tan^{-1}\frac{h}{x-b})]$$

Eğrilik : $H(x) = -2k_0 \Delta g \sin\alpha[\cos\alpha \ln\frac{R}{r} + \sin\alpha(\phi-\theta)]$

Burada : $S(x) = H(x) - \Delta g(x)\cot\alpha = -2k_0 \Delta g(\phi-\theta)$

Geology of the Application Area

The study area is located within the Menderes Massif in Western Anatolia. The "Menderes Massif", which covers a large area in Western Anatolia, presents an egg-shaped appearance in NE-SW direction. Approximately E-W trending Büyük Menderes, Küçük Menderes, Gediz and Simav Grabens divide the massif into 4 main massifs. The NW edge of the massif is limited to the ophiolite rock group of the Izmir-Ankara zone, and the southern edge is limited to the Taurus belt. While its western extension is observed in the Cyclades islands in the Aegean Sea, it breaks apart in the east and disappears under the Neogene cover.

The base of the Menderes Massif consists of auger, grabitic and banded gneisses and a gneiss unit made of migmatite. Consistently, this unit superimposes the leptide unit. It prevents schists with a contact that gives the impression of being compatible with the leptides. The schists are harmoniously covered by marbles derived from platform-type limestones. In the upper levels of the massif, there are Paleocene aged red marbles with plaques. The lithological sequence completes the postmetamorphic intruded granodioritic and gabbroic pluton stocks Figure (2).

The basis of the study area consists of phyllite-type Paleozoic schists and marbles belonging to the cover units of the Menderes Massif. It was deposited with an angular unconformity on the Quaternary alluvium massif in the Büyük Menderes Plain. The grabenization regime, in which the Menderes Massif and Tertiary sediments were affected in several phases, was formed as a result of the tectonic activity of the region. The core part of the massif consists of gneiss and schists in high-grade amphibolite facies [8]. Stated that the general stratigraphic sequence of the massif begins with Precambrian gneisses and continues upwards with lower Paleozoic mica schists, Permo-Carboniferous metaquatsite, black phyllite and dark recrystallized limestones. These are overlain by Mesosoic thick-layered, recrystallized neritic limestones.

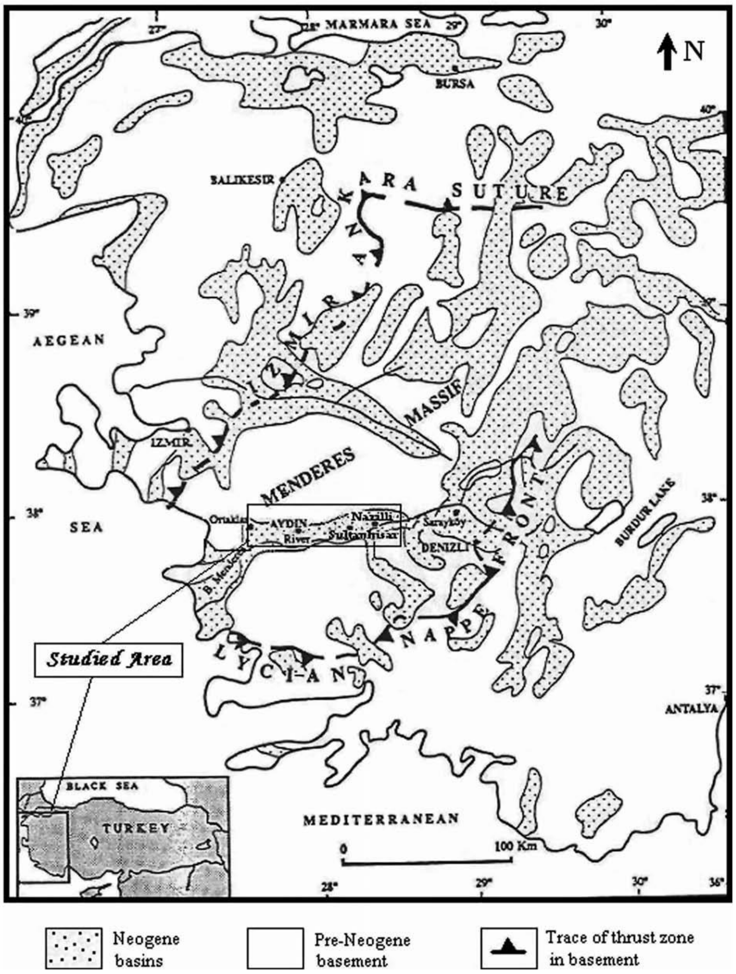

Figure 2: Geological map of the study area [9]

Results of the Double Circle Method in the Field of Application

The Bouguer anomaly map obtained in the Büyük Menderes region (Figure 3) has a land density of approximately 2.4 gr/cm^3. The Bouguer anomaly map was digitized on a 2 km grid along the x and y axes. The contour interval was made every 5 mgal. The A-B section was taken from the Bouguer anomaly map and the double circle method was applied to this section. The anomaly obtained from the A-B section is given in Figure 4. Before the anomaly values, the x1/2 and x1/4 half-value gaps were calculated. The double circle method was calculated geometrically. First, a compass is opened as much as the half-value value of the anomaly and a circle is drawn. A plus sign is made from the center of this circle. This time, our compass is marked from the right and left starting from the one-fourth value center point. This time, a one-fourth value half circle is drawn from the upper point of the circle. The intersection of the two circles found gives the width of the AB side graben. The angle drawn from the edges of the AB line to the center of the circle gives us theta angle. Theta angle gives the surface density and the average depth of the graben with the help of the formulas given in formula 4.

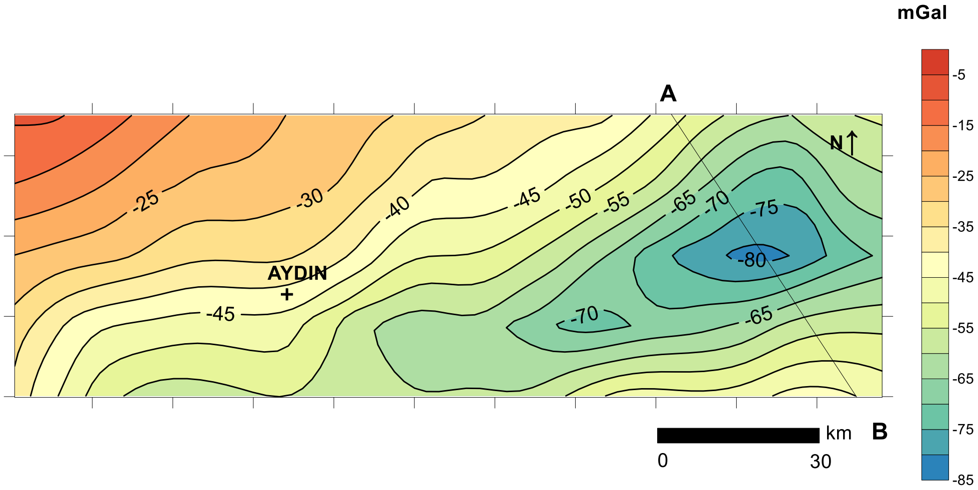

Figure 3: *Buyuk Menderes Bouguer anomaly map*

Conclusion

The Büyük Menderes graben was attempted to be modeled by applying the double circle method to the AB section taken from the Bouguer gravity anomaly map. As a result of the calculations, the average depth, width and surface density of the graben were calculated Figure 4.

Top surface width: b = 9.33 km

2b= 18.66 km

Surface density (μ):

$\phi/2 = 70^0$; $\tan\phi/2 = 2.74$

$\mu = 82*10^{-3}$ gal/2*6.67*10^{-8}*2.44

Depth (h) = $\dfrac{b}{\tan\phi/2}$ =9.33/2.74 = 3.41 km.

$\mu = 248850.98$ gr/cm^3

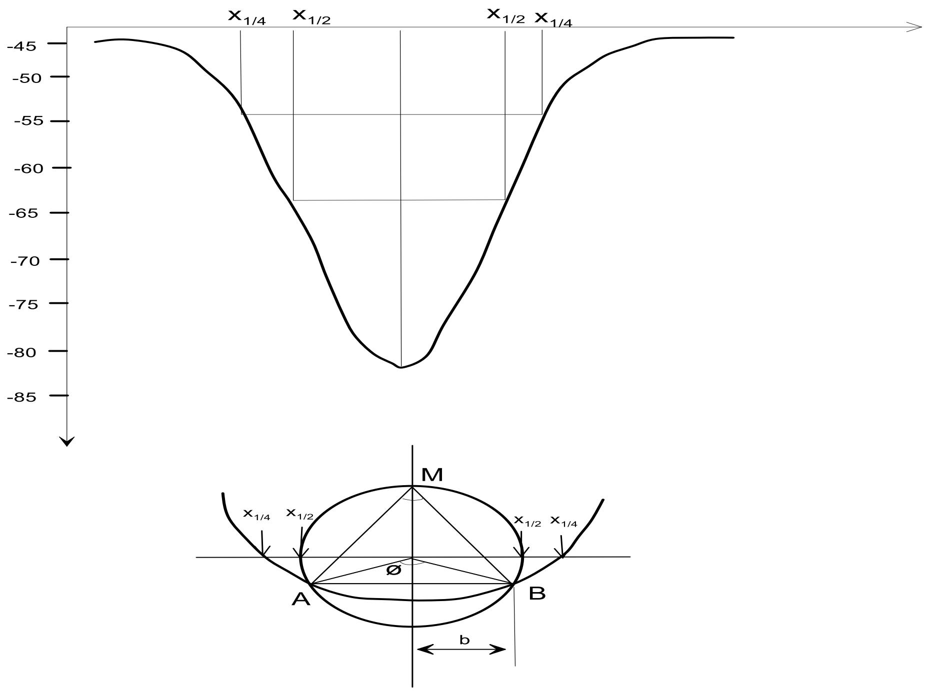

Figure 4: *AB' section taken from the Büyük Menderes Bouguer anomaly map and calculation of the double circle method*

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