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Gravity Modelling of Siirt Kentalan Region by Using Nomogram Method

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Abstract In this study, we have used a practical method to obtain the possible depth of a structure from gravity field anomalies of 2-D and 3-D bodies. The given geometrical model gravity anomalies have been calculated for several depths and structure sizes. Gravity anomalies of the rectangular prism for 2-D structures and the vertical cylinder for 3-D structures have been calculated for different structure sizes. The parameters which will be used in nomogram evaluation have been obtained by examining the depths and sizes of model structures with the assistance of critical point values obtained from these anomalies (g_{max}, $X_{1/2}$, $X_{3/4}$). The given nomograms could be easily used for the calculation of the possible structure depth and sizes for the acquired field gravity anomaly. In this study we have applied the method to the gravity anomaly map of Kentalan-Reşan region in Siirt, and the study results is in a good harmony with the previous studies.

Keywords Gravity Modelling, Nomogram Method

Introduction

Searching for the geometric shape of the underground structure that creates the anomaly in the evaluation of gravity anomalies forms the basis of modeling studies. As a result of comparing the theoretical curves of the structure of any shape with the sections obtained by measuring from the land, we can have information about the underground geological structure. There are many factors to model the underground geological structure well. The most important of these factors is the determination of many parameters such as density difference, upper and lower surface depth and width of the geological structure. The deeper the object to be modeled, the longer the wavelength of the anomaly it generates, and the anomaly is less affected by the geometry of the deep structures or the shape changes in the deep sections of the structure. Geological structures can be handled in gravity models in two and three dimensions. The gravity area of two-dimensional masses can be calculated using the gravity areas of three-dimensional masses. Since one dimension of the three-dimensional masses is put to the end, the gravity area of the whole mass is equivalent to the gravity area of the two-dimensional masses, since the gravity field in this dimension will remain constant. Modeling happens in two types in geophysics. Firstly, by using the geological structure model, the geometry of the structure that creates the anomaly is tried to be found. This is called flat modeling. The second is the reverse of this process; In other words, by using anomaly, the parameters of the geological model are tried to be found. This process is called reverse solution process. In the reverse solution, although there are endless solutions giving the same anomaly, there is only one anomaly depending on the parameters of the model given in flat modeling. In the modeling studies using nomogram, many authors have worked [1-8].

Methods

Calculation of the gravity anomaly of a two dimensional rectangular prism;

Potential expression of the dm mass element of any object at one point,

$$du = k_0 \frac{dm}{r},$$

$$du = k_0 \, \Delta g \frac{dxdydz}{r} \,, \tag{1}$$

Here it is the k_0 universal gravitational constant (6.67 10^{-8}cm^3/grsn^2), density contrast and potential expression of the total mass $r^2 = x^2 + y^2 + z^2$. In three-dimensional case, this expression,

$$U = k_0 \Delta g \int_x \int_y \int_z \frac{1}{r} dxdydz \,, \tag{2}$$

Moving from here, the gravity expression of such a mass along the z axis (in the vertical direction) [9],

$$g_z = \frac{du}{\delta z} = -k_0 \Delta g \int_x \int_y \int_z \frac{z}{r^3} dxdydz, \tag{3}$$

If we assume that the mass extends forever along the y axis (Formula-3), the formula given by

$$U = 2k_0 \Delta g \int_x \int_y \frac{z}{r^2} dxdz, \tag{4}$$

Taking advantage of this relation, gravity gravity of two-dimensional masses (Figure-1),

$$g = \frac{\delta u}{\delta z} = -2k_0 \Delta g \int_x \int_y \frac{z}{r^2} dxdz \tag{5}$$

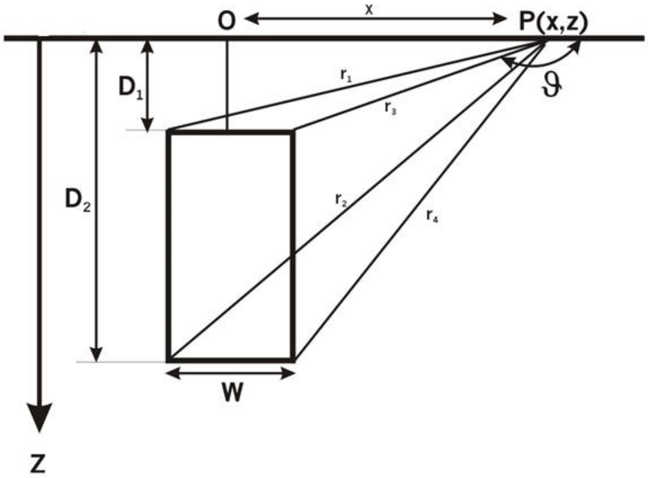

Figure 1: Demonstration of gravity anomaly of a prismatic structure

This equation is a general expression used to calculate gravity shots of two-dimensional structures. By using this formula, gravity shots of structures of any shape can be found. In this way, the gravity anomaly of a vertical dyke or prism model can be calculated by known magnetic correlations. The mathematical expression that gives gravity shooting of a vertical prism or dyke is as follows [10].

$$g = 2\Delta\rho k_0 \left[\begin{array}{l} \frac{x}{2}\log\left\{\frac{D_2^{\,2} + x^2 D_1^{\,2} + (x-W)^2}{D_1^{\,2} + x^2 D_2^{\,2} + (x-W)^2}\right\} + \frac{W}{2}\log\left\{\frac{D_2^{\,2} + (x-W)^2}{D_1^{\,2} + (x-W)^2}\right\} - D_2\left\{\tan^{-1}\left(\frac{x-W}{D_2}\right) - \tan^{-1}\left(\frac{x}{D_2}\right)\right\} \\ + D_1\left\{\tan^{-1}\left(\frac{x-W}{D_1}\right) - \tan^{-1}\frac{x}{D_1}\right\} \end{array} \right] \tag{6}$$

Calculation of the gravity expression of a three-dimensional vertical cylinder

The expression of gravity anomaly on the full axis of the vertical cylinder is derived from formula-1. Gravity anomaly expression at the P point of the vertical cylinder (Figure-2).

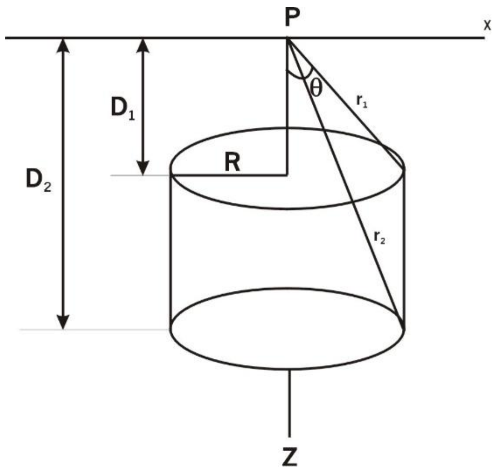

Figure 2: Representation of a three-dimensional vertical cylinder

$$dg = k_0 \Delta g \frac{dV}{r^2} \cos\alpha = k_0 \Delta g \frac{ZdV}{r^3} \tag{7}$$

Here, $dV = \rho\, d\phi\, d\rho\, dz$, $r = (p^2 + z^2)^{1/2}$.

$$g = k_0 \Delta g \int_0^{2\pi} \int_0^{R} \int_{D_1}^{D_2} \frac{Z\, \rho\, dp\, d\phi}{(\rho^2 + Z^2)^{3/2}},$$

$$g = 2\pi\, k_0 \Delta g \left\{ \left[(R^2 + D_1^2)^{1/2} - D_1\right] - \left[(R^2 + D_2^2)^{1/2} - D_2\right] \right\}, \tag{8}$$

$$r_1 = (R^2 + D_1^2)^{1/2} \text{ and } r_2 = (R^2 + D_2^2)^{1/2}$$

$$g = 2\pi\, k_0 \Delta g \left[D_2 - D_1 - r_2 + r_1\right], \tag{9}$$

The relation (9) gives the expression of gravity anomaly that it will form at some point on the cylinder axis. Anomaly expressions at other points on the X profile can be found by opening this expression to the series.

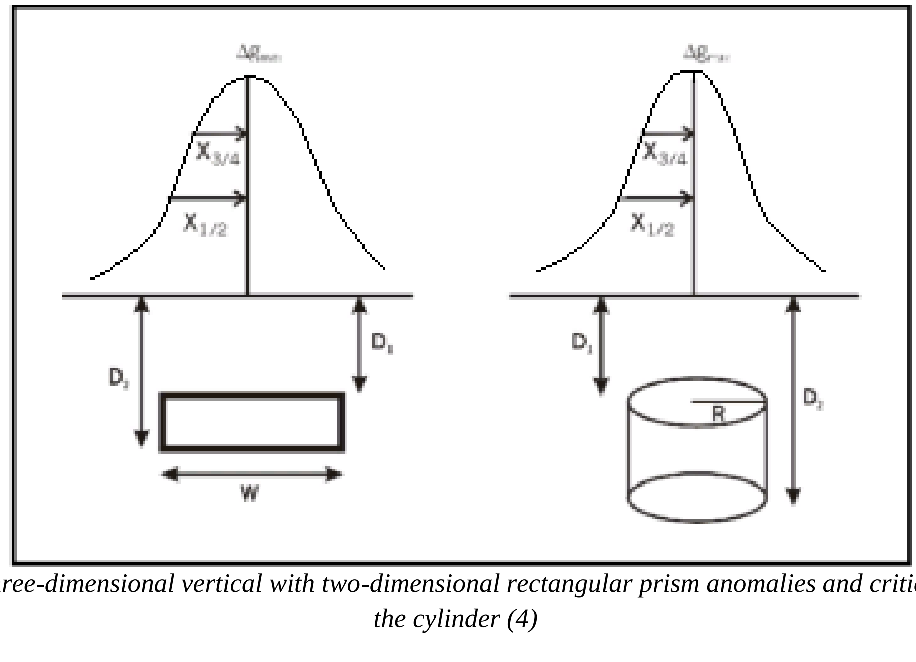

Figure 3: Three-dimensional vertical with two-dimensional rectangular prism anomalies and critical points of the cylinder (4)

Three-dimensional vertical cylinder with two-dimensional rectangular prism; g_{max}, $x_{3/4}$, $x_{1/2}$, values on the anomalies of the models and the ratios of the top surface depth D1 of the models, equations are written [4].

$$F = X_{3/4} / X_{1/2},$$
$$M = \Delta g_{max} / X_{(1/2)} \Delta\rho \qquad \text{(mgal/km)},$$
$$N = D_1 / X_{(1/2)}$$

Here is $\Delta\rho$ the Density Difference. The F parameter is given as the ratio of the distance x¾, which expresses the value of g max, to the distance x½, which expresses the value of $g_{max/2}$. Secondly, the selected parameter M is taken as the product of the g_{max} value, the density difference of the structure and the distance of x½, which corresponds to the $g_{max/2}$value.The third selected parameter N was taken as the ratio of the upper surface depth of the structure to the anomaly half-value gap $x_{1/2}$and was called the depth factor in the study.

These parameters, selected for two-dimensional rectangular prism and three-dimensional vertical models, have been observed to show a change on models with different depths and dimensions. As a result of their proper change, these parameters are shown as a function of the D1/D2 and W/D2 aspect ratios for the two-dimensional rectangular prism in Figure-4 and Figure-5, and as a function of the D1/D2 and R/D2 dimensional ratios for the three-dimensional vertical cylinder. It is given in Figure-6 and Figure-7 for three-dimensional situation. Due to the behavior of the values of the parameters for the three-dimensional state, it was considered more appropriate to draw on the logarithmic scale.

The main purpose of the study is to find possible building depth for two and three-dimensional structures. The "N" parameter, called the depth factor, "F" and "M" parameters obtained from the anomalies are given in Figure-8 and Figure-9. With the help of these nomograms given for both two and three dimensional structures, the possible depth of construction will be found by multiplying the "N" depth factor by the anomaly half-value gap x½. With the help of the given nomograms, the possible building depth is found with the help of D1.

In the nomograms given, the change of the density contrast of the medium plays a role primarily in the "M" and "F" parameters and accordingly the "N" parameter. For this reason, a good estimation of the density contrast of the structure is an important factor when changing from the values to be obtained over the anomaly to the determination of the parameters. If only possible depth of structure is desired, nomograms in Figure-8 will be enough for three-dimensional structures.

Using Nomograms in Calculation of Possible Structure Depth

The calculation method is the same for two-dimensional rectangular prism and three-dimensional vertical prism shapes. For two- and three-dimensional structures, "F" and "M" ratios should be obtained directly from anomaly profiles. Then the "N" depth factor ($N=D_1/x_{½}$) corresponding to this ratio and which will play an important role for the environment is obtained. N value is determined with the help of nomograms. Possible structure depth from the "N" value found in the nomograms given in Figure-8 for two-dimensional structures and Figure-9 for three-dimensional structures is obtained by multiplying the N value by the half value gap (x½) obtained from the anomaly. Other dimensions of the building are found based on the possible building depth "D1". D_1/D_2 and W/D_2 dimension ratios are found with the nomograms given in Figure-4 and Figure-5, among the parameters "F" and "M", which were calculated on anomaly previously. D_1/D_2 ratio is determined from the W/D_2 ratio found. Among the values found, the base depth "D_2" and the width parameter "W" belonging to the structure are found. Radius "R" value is used instead of width for three dimensional structures.

Thus, in gravity modeling studies, if two-dimensional structures, two-dimensional rectangular prisms are taken as vertical cylinders, the possible structure depth and structure dimensions can be easily made with the help of nomograms.

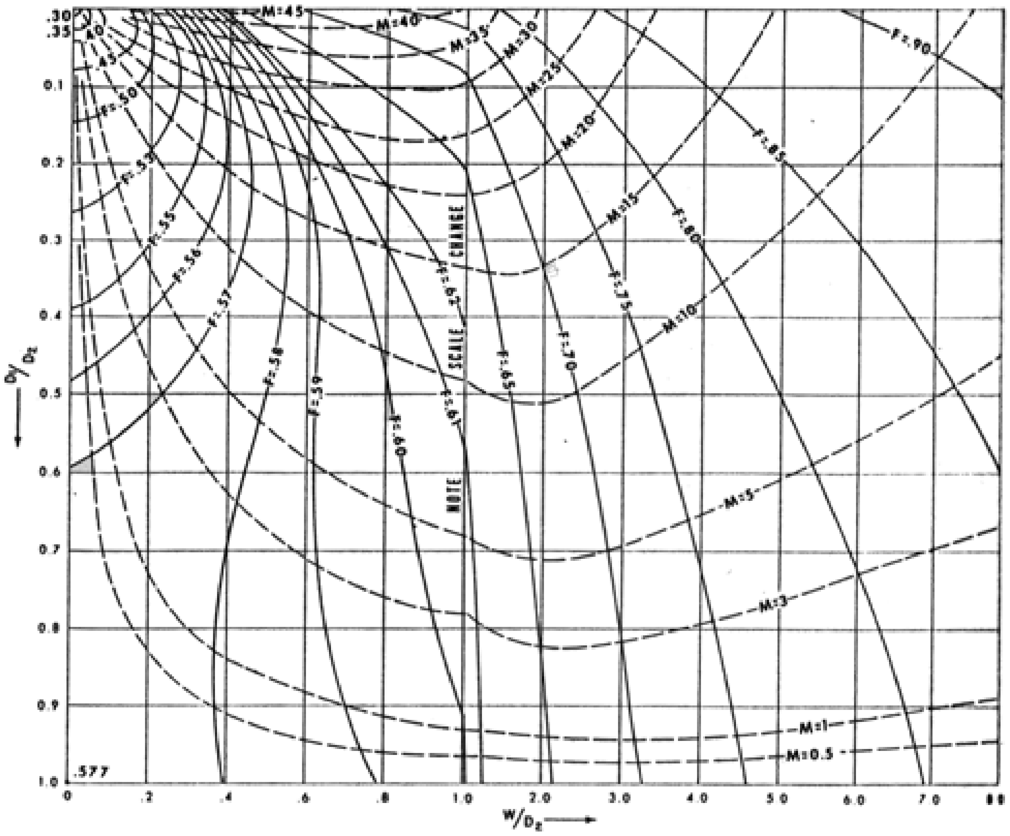

Figure 4: Representation of F and M parameters as a function of D_1/D_2 and W/D_2 for two dimensional rectangular prism [4]

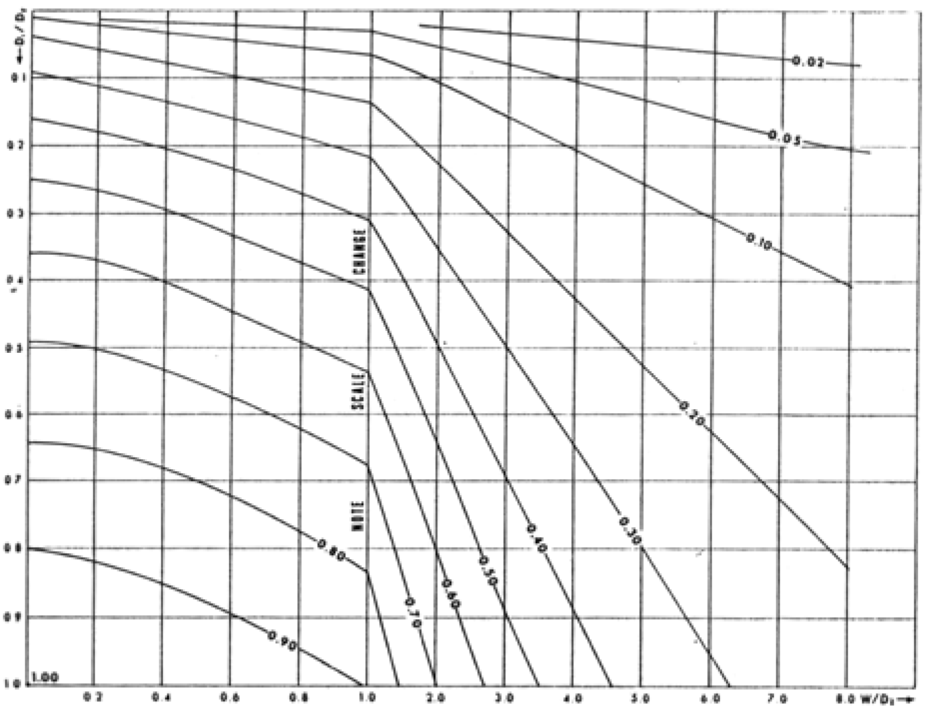

Figure 5: D_1/D_2 for the two-dimensional rectangular prism of parameter N and Representation of W/D_2 as a function [4]

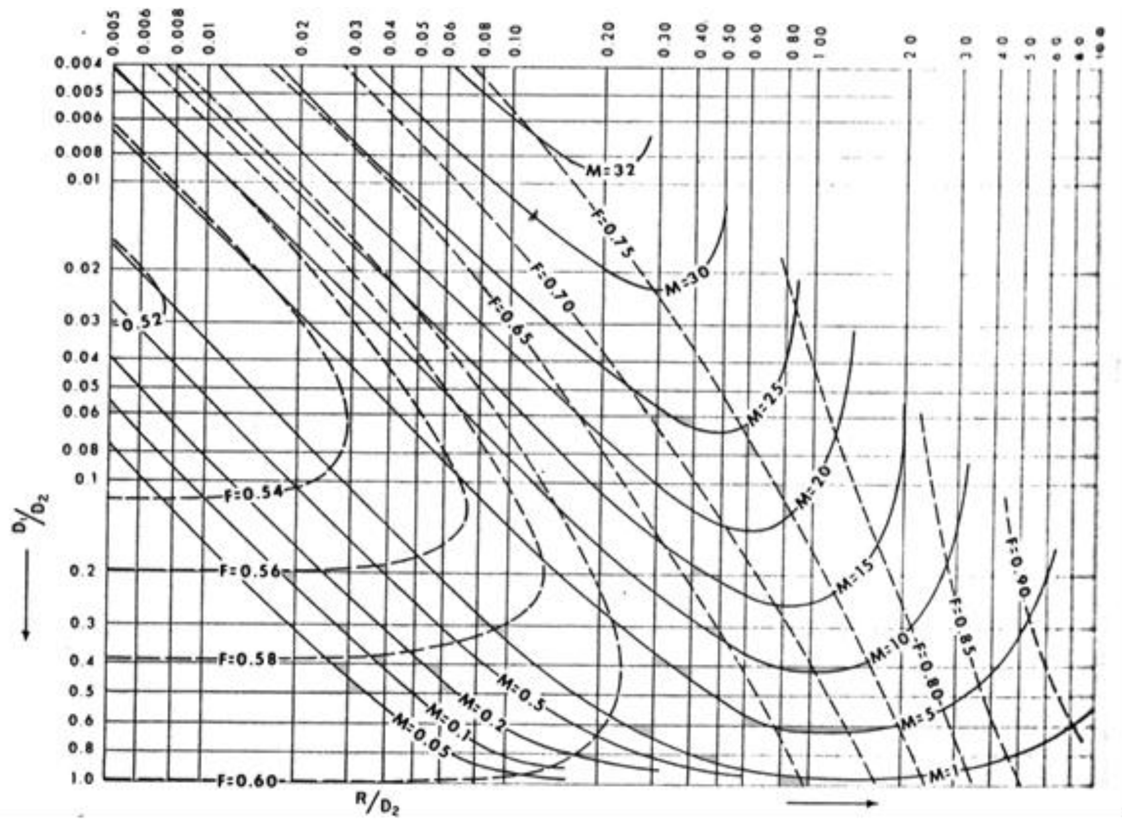

Figure 6: For vertical cylinder of F and M parameters, D_1/D_2 and R/D_2 representation as a function [4]

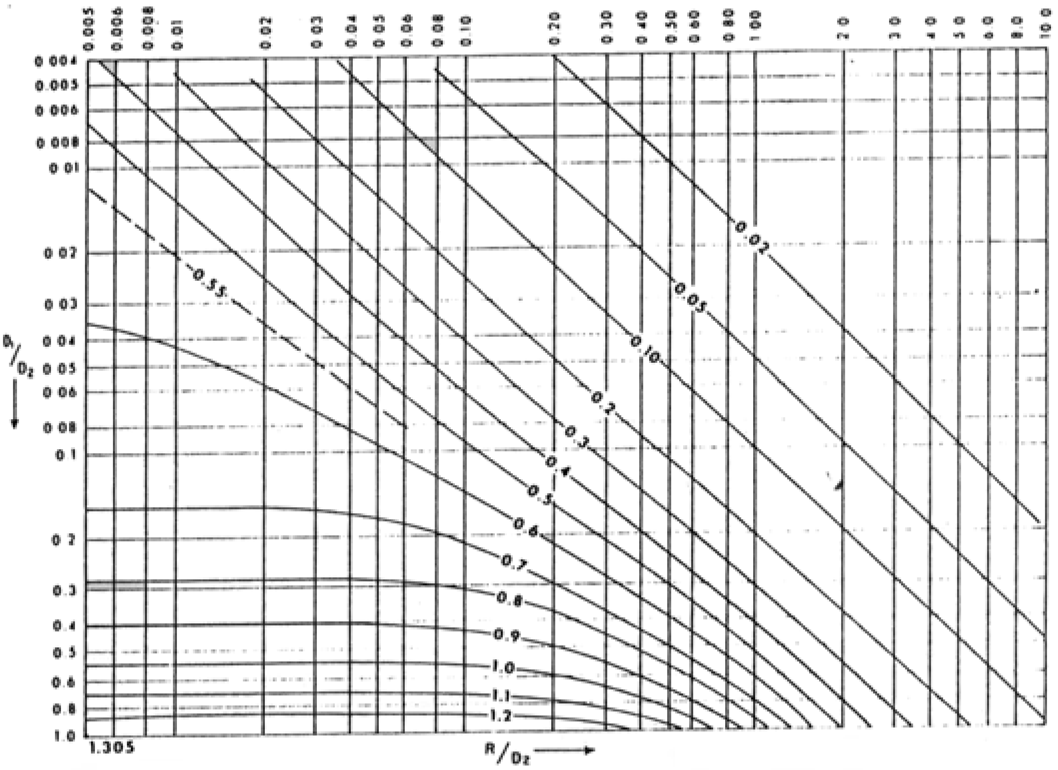

Figure 7: Function of D parameter D_1/D_2 and R/D_2 for vertical cylinder representation as [4]

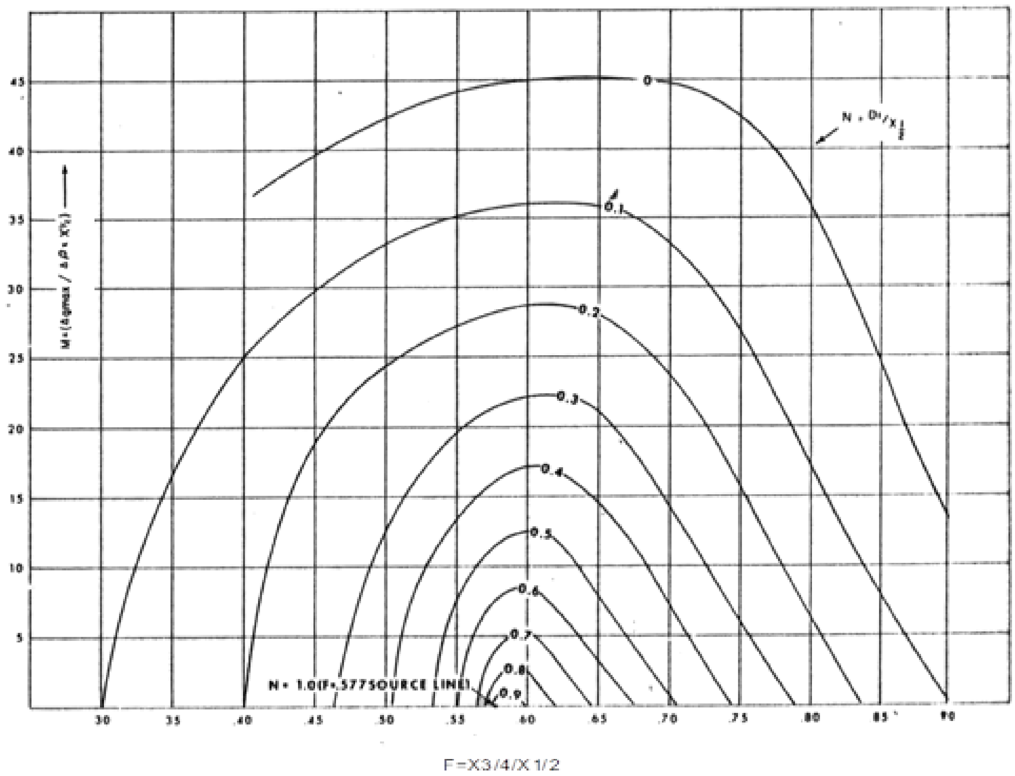

Figure 8: For the two-dimensional rectangular prism of the parameter N, the parameters of F and M representation as a function [4]

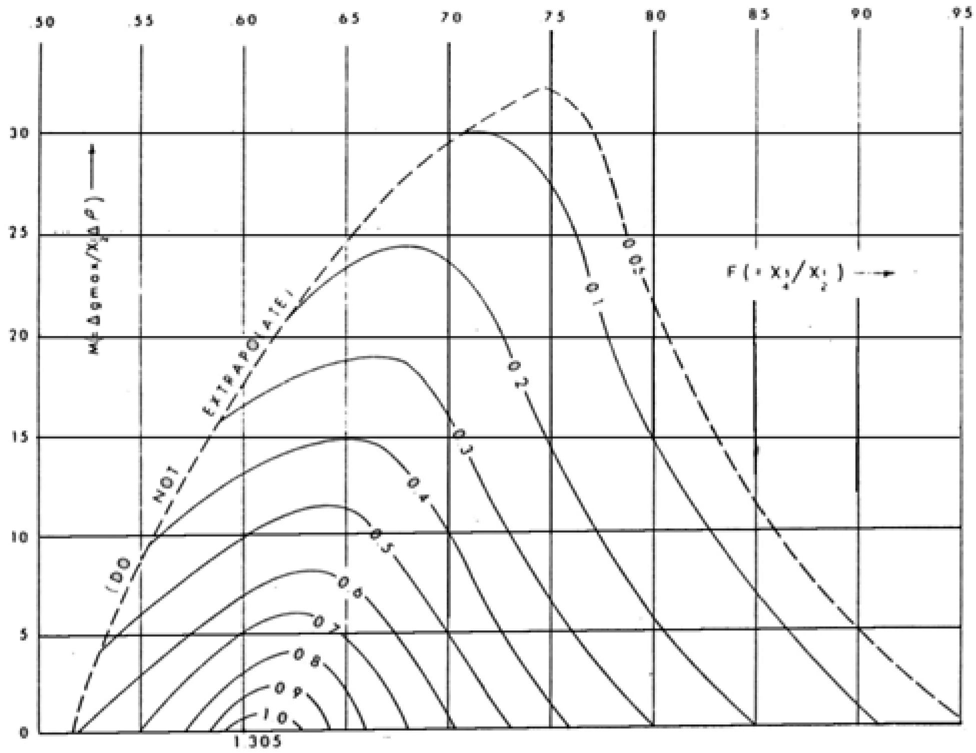

Figure 9: As a function of parameters F and M for the vertical cylinder of parameter N representation [4]

Application of Nomograms to Synthetic Data

In order to prove the validity of the method, 4 different model studies were conducted. First, the top surface depth D_1= 50 m, the bottom surface depth D_2= 100 m., and the building width W= 60 m. A two-dimensional rectangular prism model is discussed. In order to calculate the possible depth and dimensions of the model structure from the gravity anomaly of the two-dimensional rectangular prism given in Figure-10, we first need to find the x ½ and x ¾ values from the anomaly.

g_{max}	$x_{3/4}$	$x_{1/2}$	Density contrast
0.522 mgal	47 m.	80 m	1 gr/cm^3

F = 47/80 = 0.587 (unit), M = 0.587/0.08 =6.5 (unit) N= 0.63 (nomogram),
D_1/D_2 = 0.5 (nomogram), D_1 = 0.63*0.08 = 0.0504 km. = 50.4 m. 50.4/D_2 = 0.5 D_2=100.8 m.
W/D_2 = 0.6 (nomogram) W=100.8*0.6 = 60.48 m. It is found as.

F	M	N	D_1/D_2	D_1	D_2	W/D_2	W
0.587unit	6.5unit	0.63	0.5	50.4m.	100.8m.	0.6	60.48m.

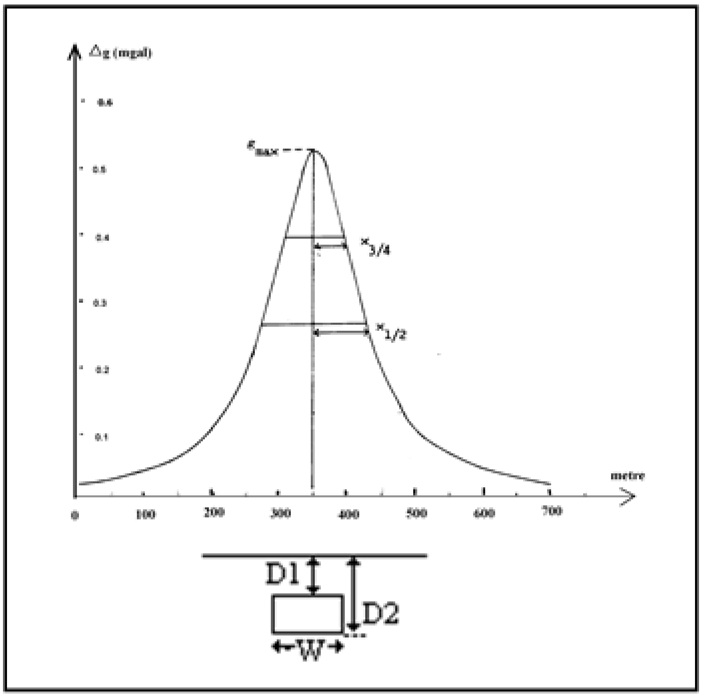

Figure 10: Gravity anomaly of two dimensional rectangular prism

As the second model, upper surface depth D1 = 25 m., Lower surface depth D2 = 125 m., Building width W = 60 m. and a two-dimensional beveled and finite prism with a slope angle of 450. This model has been chosen in order to show the validity of the calculations to be made with the rectangular prism approach if the obtained gravity anomaly is not symmetrical along the profile. In order to find the possible structure depth and dimensions of the structure from a two-dimensional inclined and finite prism gravity anomaly given in Figure-11, respectively,(Since the anomalies of x ½ and x ¾ values are not symmetrical, the anomaly is taken from the left and right according to the max axis).

g_{max}	$x_{3/4}$	$x_{1/2}$	Density contrast
1.05 mgal	45 m.	80 m	1 gr/cm^3

F = 45/80 = 0.56, M = 1.05/0.08 = 13.12, N = 0.4 (nomogram), D_1/D_2 = 0.24 (nomogram), D_1 = 0.4* 80 = 0.032 km. = 32 m. 32/D_2 = 0.24 D_2=133 m. W/D_2 = 0.5 (nomogram) W=133*0.5 = 66.5 m.
It is found as.

F	M	N	D_1/D_2	D_1	D_2	W/D_2	W
0.56unit	13.12unit	0.4	0.24	32m.	133m.	0.5	66.5m.

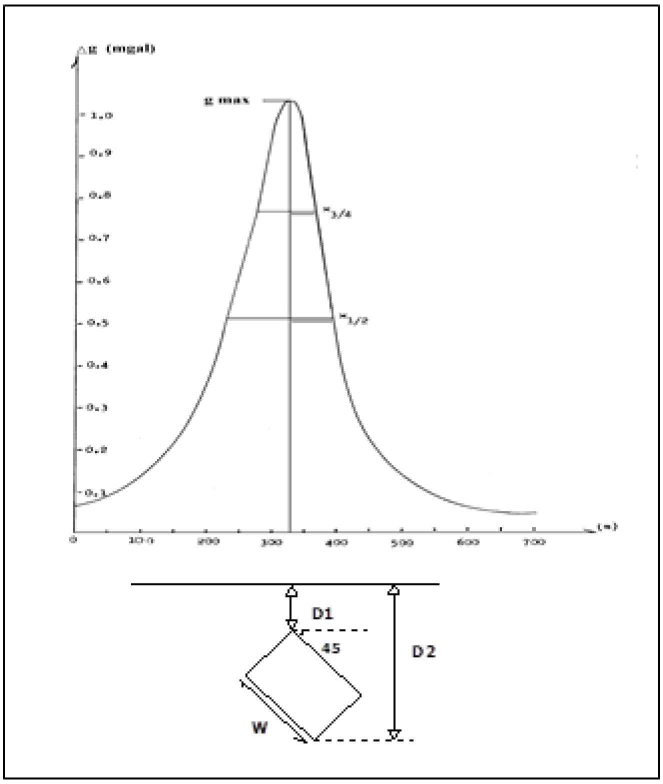

Figure 11: Gravity anomaly of a two-dimensional inclined dyke (Calculated by the Talwani method)

As the third model, upper surface depth D_1= 50 m., Lower surface depth D_2= 70 m. and the building width W= 286 m. Two-dimensional rectangular prism is discussed. In order to find the possible structure depth and dimensions of the structure from the gravity anomaly of the two-dimensional rectangular prism given in Figure-12, respectively,

g_{max}	$x_{3/4}$	$x_{1/2}$	Density contrast
0.668 mgal	120m.	160m	1 gr/cm^3

F = 120/160 = 0.75, M = 0.688/0.16 = 4.12, N = 0.32 (nomogram),

D_1/D_2 = 0.7 (nomogram), D_1 = 0.32* 160 = 51.2 m. 51.2/D_2 = 0.7 D_2= 73.14 m.

W/D_2 = 4 (nomogram) W= 73.14*4 = 292.5 m. It is found as.

F	M	N	D_1/D_2	D_1	D_2	W/D_2	W
0.75unit	4.12unit	0.32	0.7	51.2m.	73.14m.	4	292.5m.

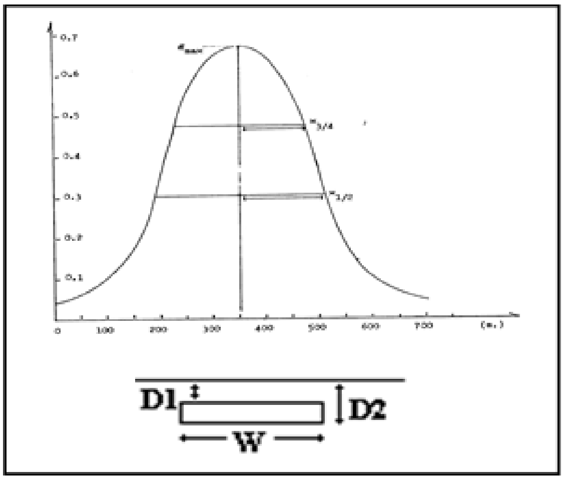

Figure 12: Gravity anomaly of a large two-dimensional prism

Fourth, the three dimensional vertical cylinder is given as an example. Upper surface depth D_1= 50 m., Lower surface depth D_2= 100 m. and radius R= 60 m. In order to find the possible building depth and dimensions of the structure from the gravity anomaly of the model building,

g_{max}	$x_{3/4}$	$x_{1/2}$	Density contrast
0.386 mgal	50m.	75m	1 gr/cm^3

F = 50/75 = 0.66, M = 0.368/0.075 = 4.9 N = 0.68 (nomogram),
D_1/D_2 = 0.5 (nomogram), D_1 = 0.68* 75 = 51 m. 51/D_2 = 0.5 D_2= 102 m.
R/D_2 = 0.5 (nomogram) R = 102*0.5 = 51 m. It is found as.

F	M	N	D_1/D_2	D_1	D_2	R/D_2	R
0.66unit	4.9unit	0.68	0.5	51m.	102m.	0.5	51m.

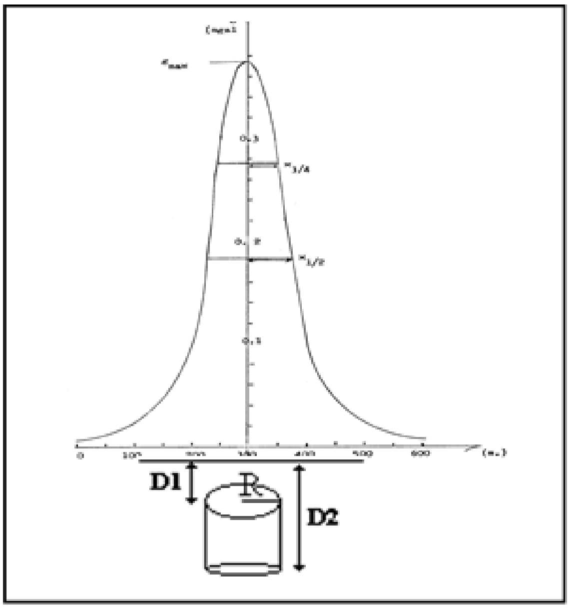

Figure 13: Gravity anomaly of three dimensional vertical cylinder

Application of the Method to the Kentalan-Reşan Field Gravity Anomaly Map

Bouguer anomaly map of Kentalan area located in Southeast Anatolia Region, South-Southeast of Siirt province was used as application area. When the Bouguer anomaly map is examined, it is considered for application since it shows a structure suitable for gravity anomalies such as faults, synclines, anticlines, and provides good compatibility with geological findings.

Geology of the Application Area

Stratigraphy

The deposited materials in the application area on the Southeastern Anatolian fault zone belong to the formations that partially cover the Diyarbakır-Cizre pit and partly the Arab platform transgressive (Figure-14).

First time

Cambrian and older formations: These formations seen around Mardin-Derik were found in the field of application.

Second time

It covers larger areas compared to the previous times. This time forms the basis of the geological structure structure including our application area in the Mardin block and its northern regions. In the field of application, they have been exposed to Jurassic-Cretaceous limestones, Upper Kreastese marls and clays, and the Kentalan and Espendika basins.

Cretaceous: It is a very thick limestone series that is outcropped with pivot elevations in the edge extensions. It was found between 432-1407 meters in Kentalan soundings. They are generally in the form of a dolamitic body.

Upper Cretaceous-Paleocene (Germav Formation): Massive mesozoic limestones in Southeastern Anatolia are covered with a clayey and gray soft formation that turns into gray, greenish gray, thick marly layers. This cover of the Upper Cretaceous and Lower Paleocene covers the basement layers and massive limestones of the Germav formation, sometimes with concordant, sometimes discordant. 850 m of Germav formation. 300 m in thickness. It belongs to the lower paleocene. 450 m from Kentalanda. Some of them are afflicted. 850 m. It was found in thickness.

Mardin Formation: This formation in marl gre and shales on the Upper Cretaceous-Paleocene massive limestones is encountered in the application area.

Becirman Limestone: This formation, which covers the Germav formation and whose age varies between Donien and Lower Paleocene, is 10-110 m. thick white and locally dolamitic limestone zone.

Third Time

Lower Eocene-Paleocene (Gercüş Formation): It is a classical series consisting of limestone and frequent gypsum-shale shales, generally starting with reddish greens around Kentalan, Reşan and Ispendika. Its average thickness is 270-330 m. d. This formation, which is easy to recognize with its facies and color in the southeast, is also called “Red Layers”.

Middle Eocene (Midyat Formation): Since the most characteristic formation of the eocene limestone, which has a wide transgression field in Southeastern Anatolia, these limestones are called Midyat Formation. This formation shows two different facies.

Neogene: This formation, whose lower parts are partially marine and the upper parts are in terrestrial facies, covers large areas in the application area. The lower parts belong to Miocene and the upper levels can be included in Pliocene and Quaternary.

Lower Miocene: The Miocene series begins with a light red colored Burdigalian plinth convention on Eocene limestones. 250 m from Burdugailen at the ends of the Kentalan anticline. gray, compact, gypsiferous marly levels in thickness and tuffaceous chalk limestones at the top occur.

Upper Miocene: The fine gre layers that fill the depressions in the side stretches, silt and clay alternation, and the gray layers with salt gypsum belong to the Post-Helveti. It is lithologically typical Molas limestone. These series, which generally have sea and lagoon characteristics, are 800 m. they are in thickness

Pilo-Quaternary: This series, consisting of coarse gre and hetorogen congresses, is common in the depression in the east of Diyarbakır and in a wide area in the north of Bismil. Usually these series are 250 m. The province has a visible thickness and the thin and rough meterials of the mountain sinks filled the depressions with the fluviatile regime.

Old Alluviums (Terraces): 50 m from today's level. They are typical terrace ruins that are located high up and around the Botan Stream bed in the area. It is located on the Miocene in a tabular way. These terraces covering the whole region are the most important examples of vertical elevations after the Quaterner's last basalt currents.

New Alluviums: Alluvial plains along the plains in the area where the application area is located, and piles of gravel and thick sand in river lengths have formed in new times and filled the depressions.

Tectonic

Tectonism of the field of application is quite wide and covers different formations over time. For this reason, in order to obtain an examination and information, tectonic map in Figure-15 and geological structure section in Figure-16 are given [10].

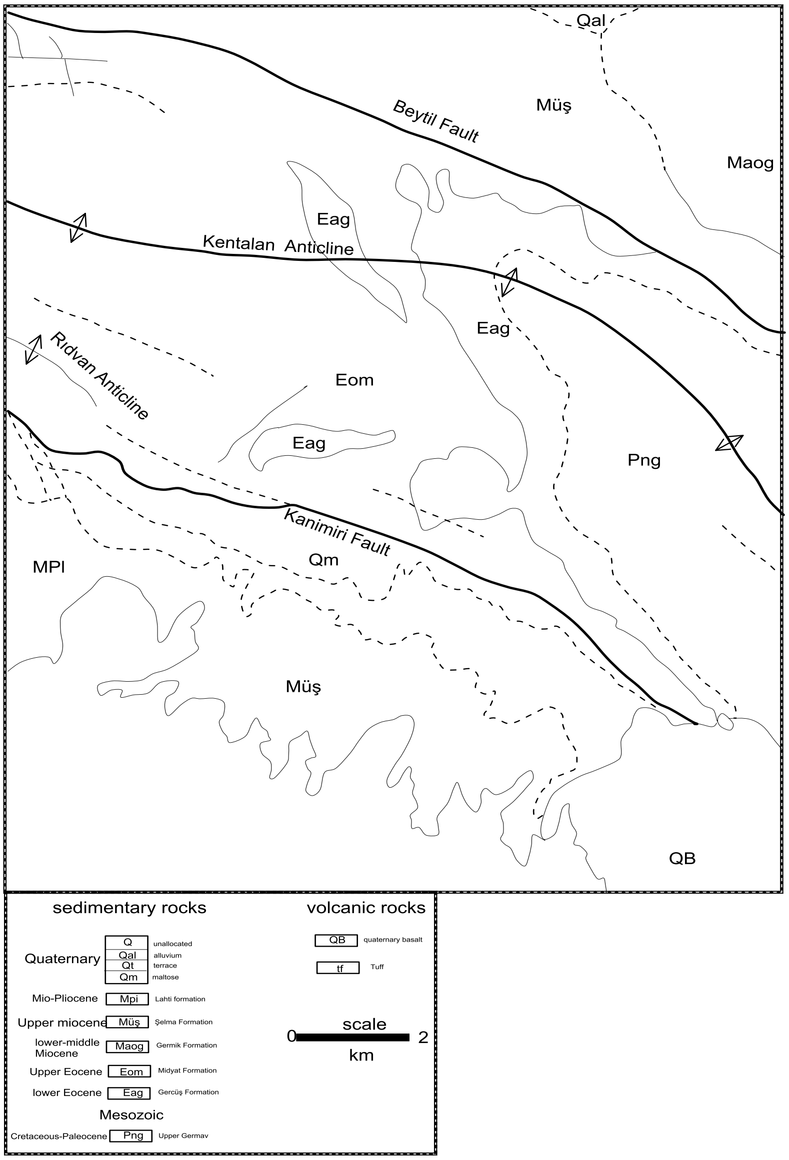

Figure 14: Kentalan-Reşan geology map

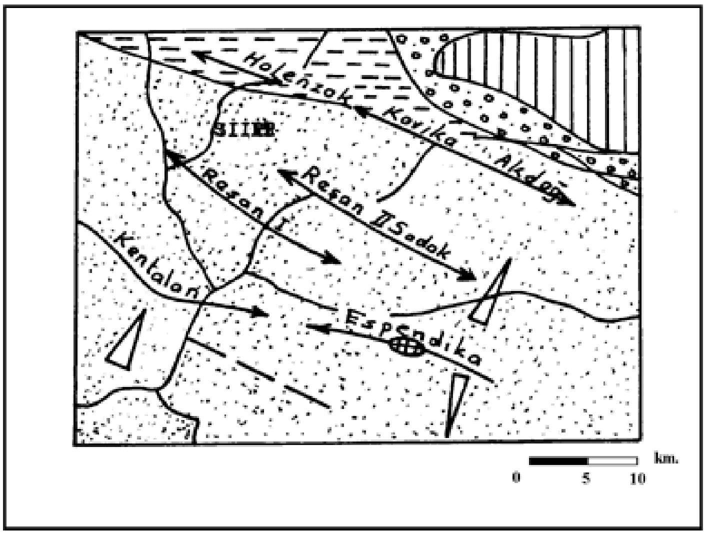

Figure 15: Tectonic map of the Kentalan-Reşan region

Field Application

The residual anomaly map (Figure-18) was obtained from the Bouguer anomaly map (Figure-17) of the Kentalan-Reşan area, which was taken as the application site. A-A 'and B-B' sections were taken from the residual anomaly map obtained (Figure-19). The methods presented in the study were applied on these field sections. The profiles taken for the application area are limited to the Kanimiri and Espendika faults in the south and the Beytil fault in the north. The part of these faults that form the rising blocks and are said to constitute the Kentalan anticline in the middle is represented by a two-dimensional rectangular prism. [12] It is about 6 km for the rising fault block by making use of the studies carried out in the north west of Kentalan-Reşan field. length, depth and thickness sizes were used.

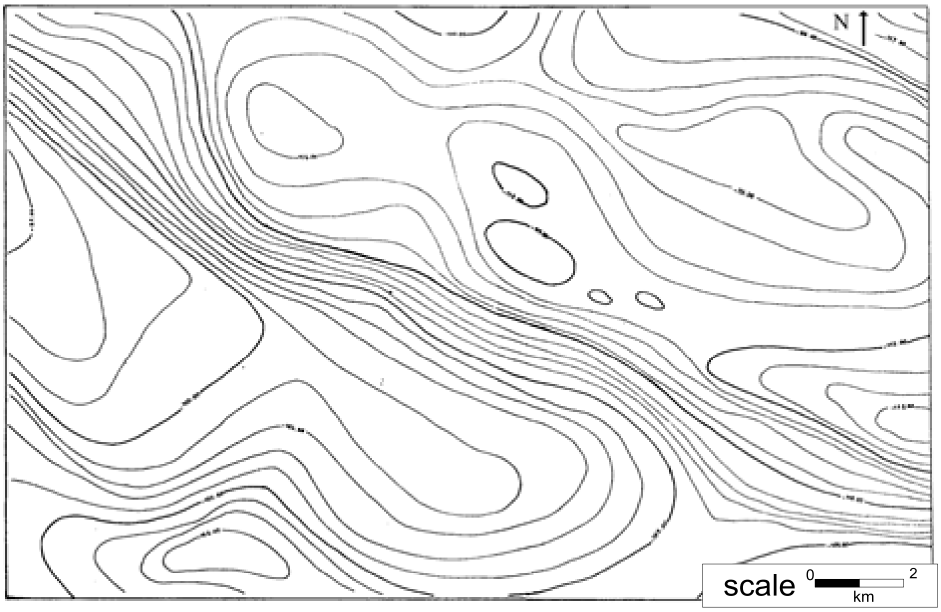

Figure 17: Kentalan-Reşan Bouguer Anomaly map

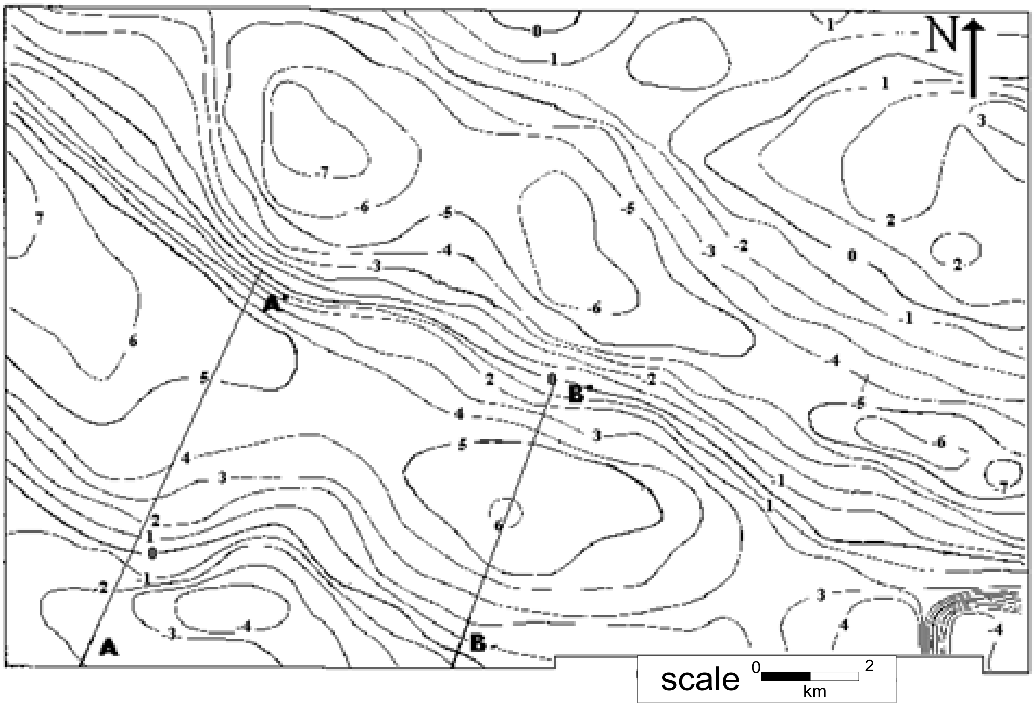

Figure 18: Kentalan-Reşan Regional Anomaly map

A-A' profili ile B-B' profilinden elde edilen neticeler sırasıyla,

A-A' profili:

g_{max}= 5.2 mgal, 2x ¾ =4 km., 2x ½ = 5.2 km.

F = 0.77 M= 5.2/2.6*0.4 = 5 unit. N=0.22 unit.

D_1= 0.22*2.6 = 0.572 km.

D_1/D_2= 0.4 D_2= 0.4*0.572 = 1.430 km.

W/D_2 = 4.7 W= 4.7* 1.430 = 6.7 km.

B-B' profili:

g_{max}= 6.0 mgal, 2x ¾ = 3.1 km., 2x ½ = 4.2 km.

F = 0.74 M= 6.0/2.1*0.4 = 7.14 unit. N=0.30 unit.

D_1= 0.30*2.1 = 0.630 km.

D_1/D_2= 0.4 D_2= 0.4*0.63 = 1.575 km.

W/D_2 = 4 W= 4* 1.575 = 6.3 km.

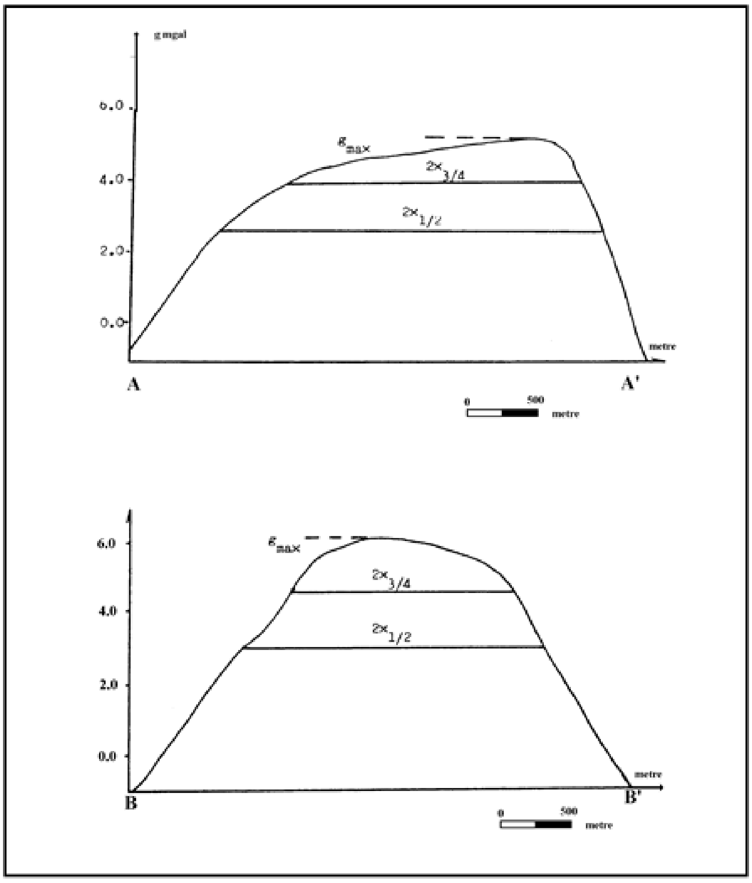

Figure 19: Gravity anomalies of A-A 'and B-B' profiles

Result

In this study, a method is provided to determine the dimensions of the underground structure that will determine the possible depth of the building and its shape. This presented method can be easily applied to both two and three dimensional structures. The important aspect of the method is that the structures can be applied directly to gravity anomalies. Long and parallel closure gravity anomalies obtained in the field are considered as two-dimensional rectangular prism and circular symmetrical gravity anomalies are considered as the field anomalies of the vertical cylinder and the required sizes of the structure are calculated.

The evaluation of two-dimensional field anomalies in the field application of the given method shows that the method yielded a healthy result when it was close to the values about the structure obtained in different ways. It also plays a role in explaining the structural character of the site. If we evaluate the result obtained in practice as a self, we can say that the geological information obtained results in accordance with gravity studies.

As a result, as can be seen in both profile calculations taken on the Kentalan-Reşan Bouguer Anomaly map, the possible depth of the building obtained on the site is 600 m. It was determined that the width of the building was 6.5 km. These results have been observed to be very close to the values obtained for the Beytil fault.

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