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REDUCTION OF POTENTIAL FIELD DATA MEASURED ON IRREGULAR SURFACES TO A HORIZONTAL PLANE

Düzensiz Yüzeylerde Ölçülmüş Potansiyel Saha Verilerinin Yatay Düzleme İndirgenmesi

İbrahim KARA*

ABSTRACT

The standard reductions applied on gravity and magnetic data measured on an irregular surface do not reduce the effect of masses under the ground to a known horizontal surface. However, the topography is considered as a flat surface in the interpretation techniques developed for the potential field data. If the effect of the mass under the ground is not reduced to a horizontal surface, the result of the interpretation becomes wrong. In this work, a method was developed for the reduction of potential field data measured on an irregular topography. The concept of this method is based on the equivalent source technique. The method was successfully applied to three synthetic case studies.

ÖZET

Düzensiz bir yüzeyde ölçülen gravite ve manyetik verilere uygulanan standart indirgemeler yeraltındaki bozucu kütlenin etkisini bilinen bir yatay yüzeye indirgemezler. Fakat, potansiyel veriler için geliştirilen yorum tekniklerinde topoğrafya düz bir yüzey olarak kabul edilir. Eğer yer altındaki kütlenin etkisi yatay bir yüzeye indirgenmezse yorumun neticesi hatalı olacaktır. Bu çalışmada düzensiz bir topoğrafyada ölçülmüş potansiyel saha verilerinin indirgenmesi için bir yöntem geliştirilmiştir. Yöntemin esası eşdeğer kaynak tekniğine dayanır. Yöntem üç adet yapay çalışmaya başarıyla uygulanmıştır.

INTRODUCTION

The potential field data are generally obtained on irregular surfaces. The standard reduction techniques do not reduce the effect of anomalies due to subsurface mass. However, most of the interpretation techniques require the values measured on the horizontal surface. Therefore, it is necessary to reduce the observed values measured on rugged topography to an arbitrary horizontal surface.

Previous workers have proposed many methods on this topic. Strakhov and Devitsyn (1965) solved the integral equation relating surface and plane fields using the method of successive approximation in the space domain. Tsirulskiy (1968) made the comparison among various methods using second kind Fredholm equation. Bhattacharyya and Chan (1977), obtained an equivalent source solving second kind Fredholm Integral. Dampney (1969) obtained the values on an horizontal surface from Bouguer anomaly on an irregular surface solving a linear equation system. Henderson and Cordell (1971) expressed the observation values by Finite Fourier Series for this reduction analysis and they obtained the coefficients of the series with matrix inversion. Syberg (1972) examined the topic of potential field continuation between general surfaces in terms of generalized operators. Emilia (1973) has obtained magnetic anomalies for different horizontal levels by using line dipoles as equivalent source distribution. However, he did not consider topographic irregularities considered in the present study. Pilkinkton and Urguhart (1990) made the

* İ.U. Engineering Faculty, Department of Geophysical Engineering, 34850, Avcılar, İSTANBUL.

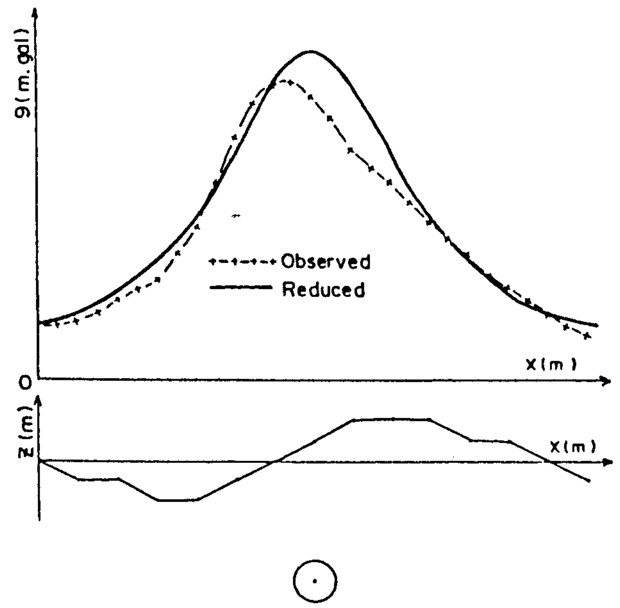

Fig. 1. The anomalies on the irregular surface and the horizontal plane of the disturb body.

Şekil 1. Yeraltındaki bozucu kütlenin düzensiz topoğrafyadaki ve yatay düzlemdeki anomalileri.

reduction of tpe equivalent source distribution of the observation values that come from underground model by calculating the observation surface in mirror symmetry. Xia et al. (1993) used the concept of equivalent source in wave number domain in order to correct the irregularities caused by rugged topography in potential field data. There are many other authors who worked in this subject.

In this work, the horizontal infinite cylinders were used as equivalent sources in order to reduce the observation values measured on an irregular topographic field to a flat surface.

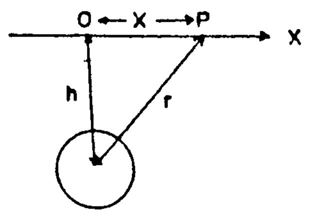

Fig. 2. The demonstration of 2-dimensional body under the ground with horizontal cylinders of n numbers.

Şekil 2. Yeraltındaki iki boyutlu kütlenin n adet yatay silindir ile gösterimi.

THEORY

The anomaly of an anomalous mass under the ground in a region of high topographic relief is shown as dotted line in Fig.1. The probability of making error in its interpretation is rather high. It is necessary to reduce the observation points measured on rugged topography to a horizontal surface in order to eliminate this error.

In order to realize this, there must be n numbers of small horizontal infinite cylindrical bodies at the same depth which will verify the same anomaly realized by the anomalous body on the rugged topography (Fig. 2).

At first, let us define a horizontal infinite cylinder. The anomaly equation of an infinite cylinder in Fig. 3 is

$$g=2\gamma m_l\, h/(x^2+h^2) \qquad (1)$$

where γ is the gravity constant, m_l is the cylinder mass per unit lenght, x is the distance of a measurement point to the origin and h is the depth of the cylinder.

If $M=2\gamma m_l$ and $A=h/(x^2+h^2)$ are assumed, equation 1 takes the form of

$$g=M\,.\,A \qquad (1a)$$

where A is called the geometric factor. However, from Fig. 2 we have h=H+Z.

Then A takes the form of

$$A=(H+Z)/[(x^2+(H+Z)^2] \,, \qquad (1b)$$

where Z is the elevation difference between the observation point and the reduction surface and H is the depth of the cylinders from the horizontal surface.

The anomaly values at each observation point were obtained summing effects of all M,

$$g_B(I) = \sum_{j=1}^{N} M(J).A(I,J) \qquad (2)$$

where, I=1,2,3,......n and g_B are observation values. If A is expressed in the form of index notation, then we have

$$A(I\,,J)=[H+Z(I)]/\{[Dx\,.(I-J)]^2+(H+Z(I)]^2\}\ .$$

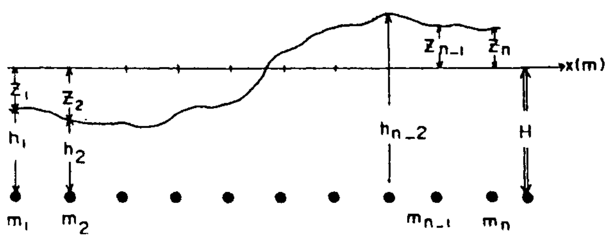

Fig. 3. The geometry of a horizontal infinite cylinder.

Şekil 3. Yatay sonsuz silindirin geometrisi.

Here, Dx is the distance between observation points. The expression of (2) can be written in matrix form as

M(1).A(1,1)+M(2).A(1,2+.....+M(n).A(1,n) = g(1)
M(1).A(2,1)+M(2).A(2,2+.....+M(n).A(2,n) = g(2)
. . . .
. . . .
M(1).A(n,1)+M(2).A(n,2+.....+M(n).A(n,n) = g(n) .

The values of M are obtained from the solution of this equation set.

The anomaly values which will exist on the accepted horizontal surface, will be known by the total effects of cylindrical masses at each the observation point. Hence we can write

$g_R(I) = \Sigma M(J).A_R(I,J)$ (3)

where, g_R is the anomaly values reduced to the horizontal surface and A_R is the geometric factor with respect to the horizontal surface.

In particular, A_R can be expressed as

$A_R(I, J) = H / \{[Dx . (I-J)]^2+H^2\}$ (4)

This can be written in matrix form as

$M(1).A_R(1,1)+M(2).A_R(1,2)+.....+M(n).A_R(1,n)= g_R(1)$
$M(1).A_R(2,1)+M(2).A_R(2,2)+.....+M(n).A_R(2,n)= g_R(2)$
. . . .
. . . .
$M(1).A_R(n,1)+M(2).A_R(n,2)+.....+M(n).A_R(n,n)= g_R(n)$

Hence the reduced values on the accepted surface are obtained.

NUMERICAL EXAMPLES

The method mentioned above was applied to the gravity anomaly of a buried cylinder in (Fig . 4) . As seen from the figure, the gravity values calculated theoretically on the horizontal surface are almost similar to the values calculated by this method. All of the numerical values obtained by this method are shown in Table 1.

This method was applied to the gravity anomaly of an irregular cross-sectional surface (Fig. 5). The theoretical anomaly obtained by this method are in good agreement with Bouguer anomaly as seen in Figure 5.

In Fig. 6, when the method was applied to the vertical magnetic anomaly of the irregular cross-sectional mass in Fig. 5, a reasonable result was obtained.

Table 1. The Bouguer anomaly of the buried cylinder in rugged topography and the values of reduced gravity anomaly.

Çizelge 1. Düzensiz topografyadaki gömülü silindirin Bouguer anomali ve indirgenmiş anomali değerleri.

x(m)	Z(m)	Bouguer g(x,z) m-gal	Real g(x,0) m-gal	Calculated g(x,o) m-gal
0	10	0.0261	0.0231	0.0230
20	10	0.0315	0.0279	0.0280
40	6	0.0369	0.0344	0.0344
60	-6	0.0402	0.0434	0.0433
80	-15	0.0459	0.0559	0.0559
100	-20	0.0578	0.0740	0.0740
120	-24	0.0784	0.1006	0.1006
140	-23	0.1248	0.1397	0.1397
160	-20	0.2095	0.1934	0.1935
180	-10	0.2890	0.2515	0.2514
200	10	0.2395	0.2794	0.2794
220	18	0.2017	0.2515	0.2516
240	25	0.1615	0.1934	0.1932
260	30	0.1290	0.1397	0.1402
280	33	0.1036	0.1006	0.1003
300	28	0.0831	0.0740	0.0736
320	0	0.0559	0.0559	0.0559
340	-8	0.0391	0.0434	0.0434
360	-14	0.0278	0.0344	0.0345
380	-18	0.0206	0.0279	0.0280
400	-20	0.0161	0.0231	0.0232

RESULTS

As well-known, that the direct interpretation of potential field data measured on a rugged topography is wrong. For this purpose, these data must be reduced on a horizontal surface. In this work a method that will provide such a reduction has been proposed . Although the method is fast and accurate, the sampling interval of the data must be selected compatibly. The sampling interval must not be chosen less than half of the maximum elevation difference to the reduction surface. The value of H must not take the values near the depth of the anomalous mass.

In this work the reduction has been chosen for only one-dimensional cases. As an equivalent source, a solution for 2 dimensional case can easily be done by substituting spheres instead of cylinders.

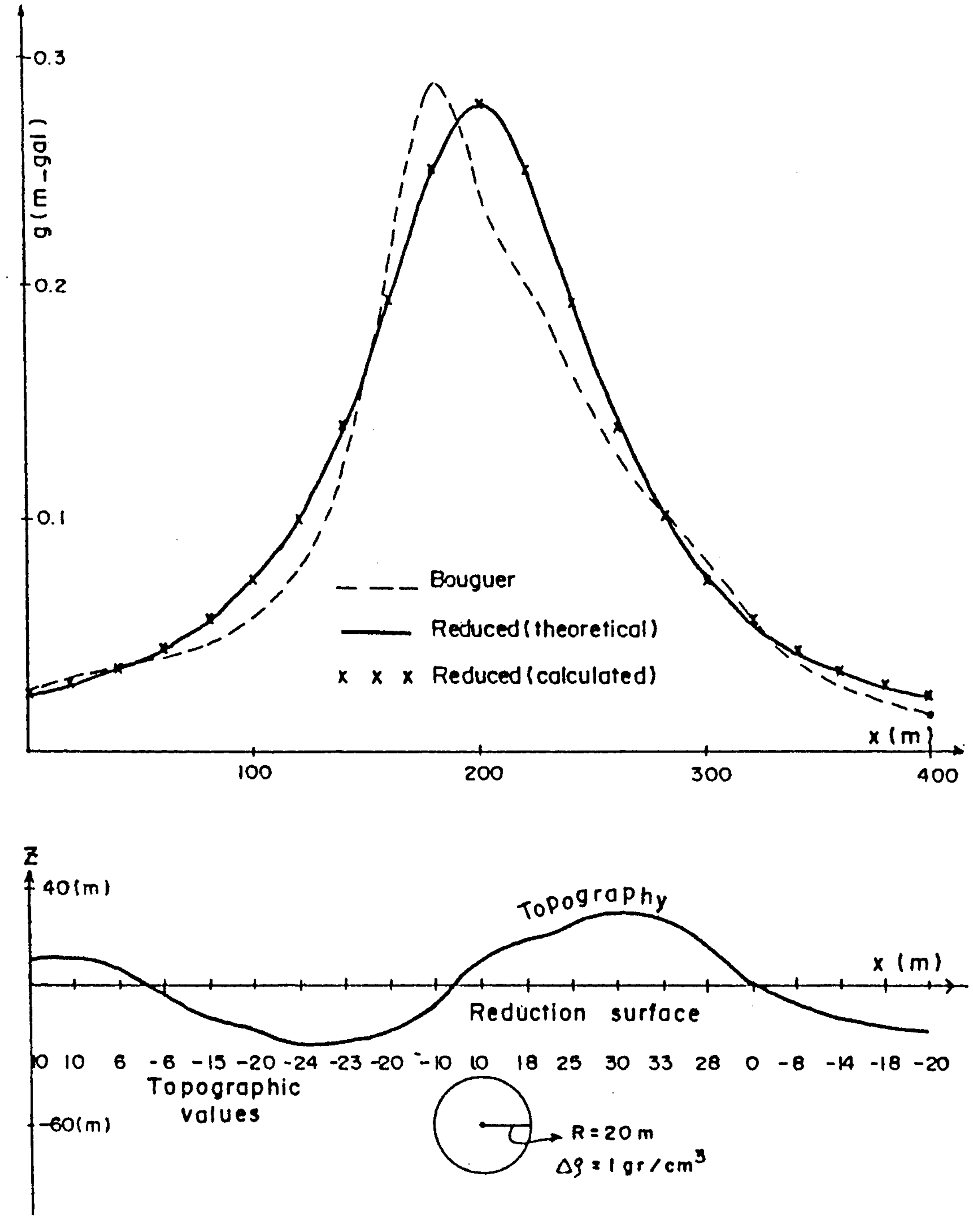

Fig. 4. The buried cylinder under the rugged topography and its Bouguer and reduced anomalies.
Şekil 4. Düzensiz topoğrafya altındaki gömülü silindir ve bunun Bouguer ve indirgenmiş anomalileri.

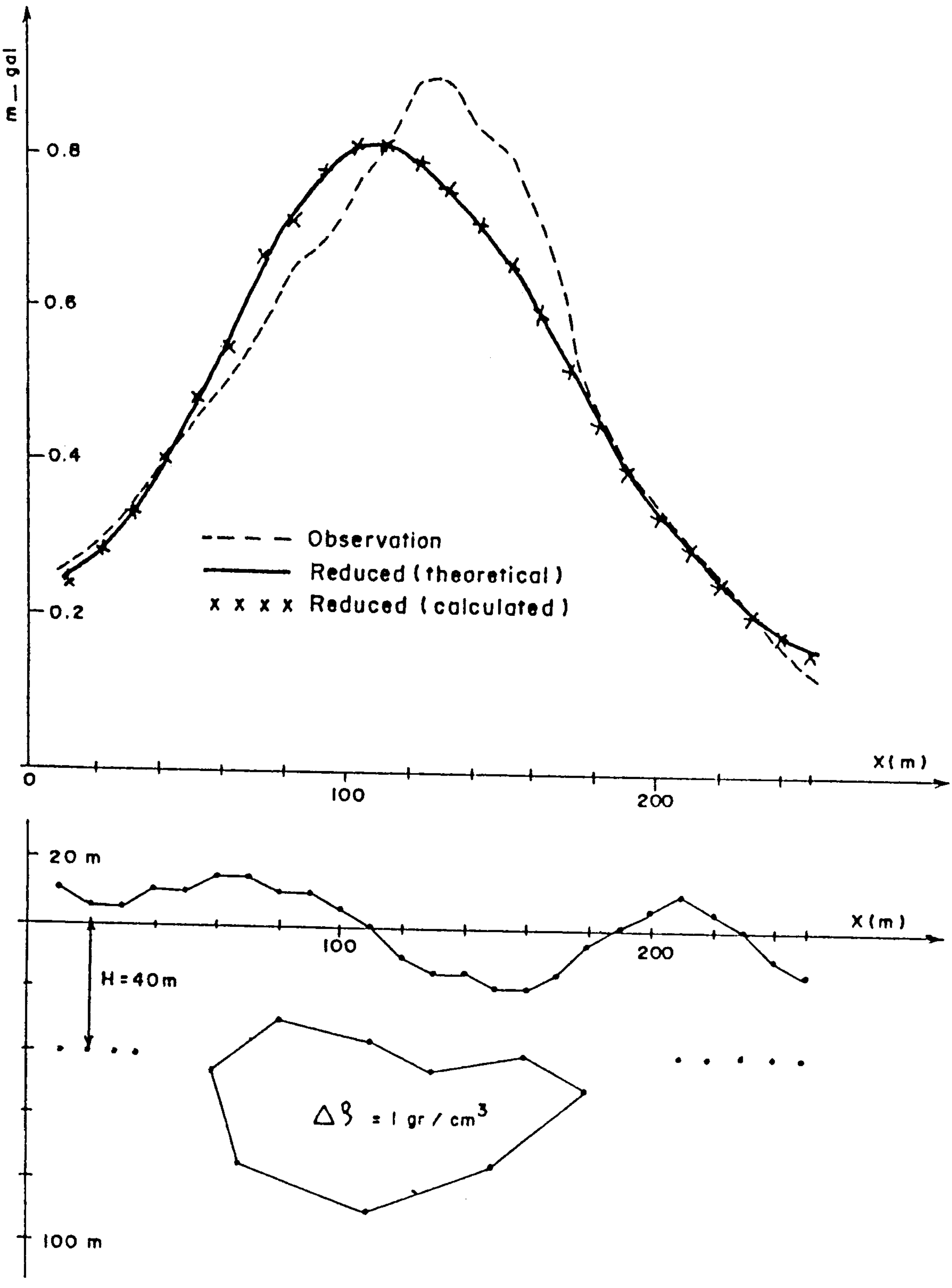

Fig. 5. The buried mass with random shape under the rugged topography and its Bouguer and reduced anomalies.
Şekil 5. Şekil 5. Düzensiz topoğrafya altındaki gelişigüzel şekilli gömülü kütle ve bunun Bouguer ve indirgenmiş anomalileri.

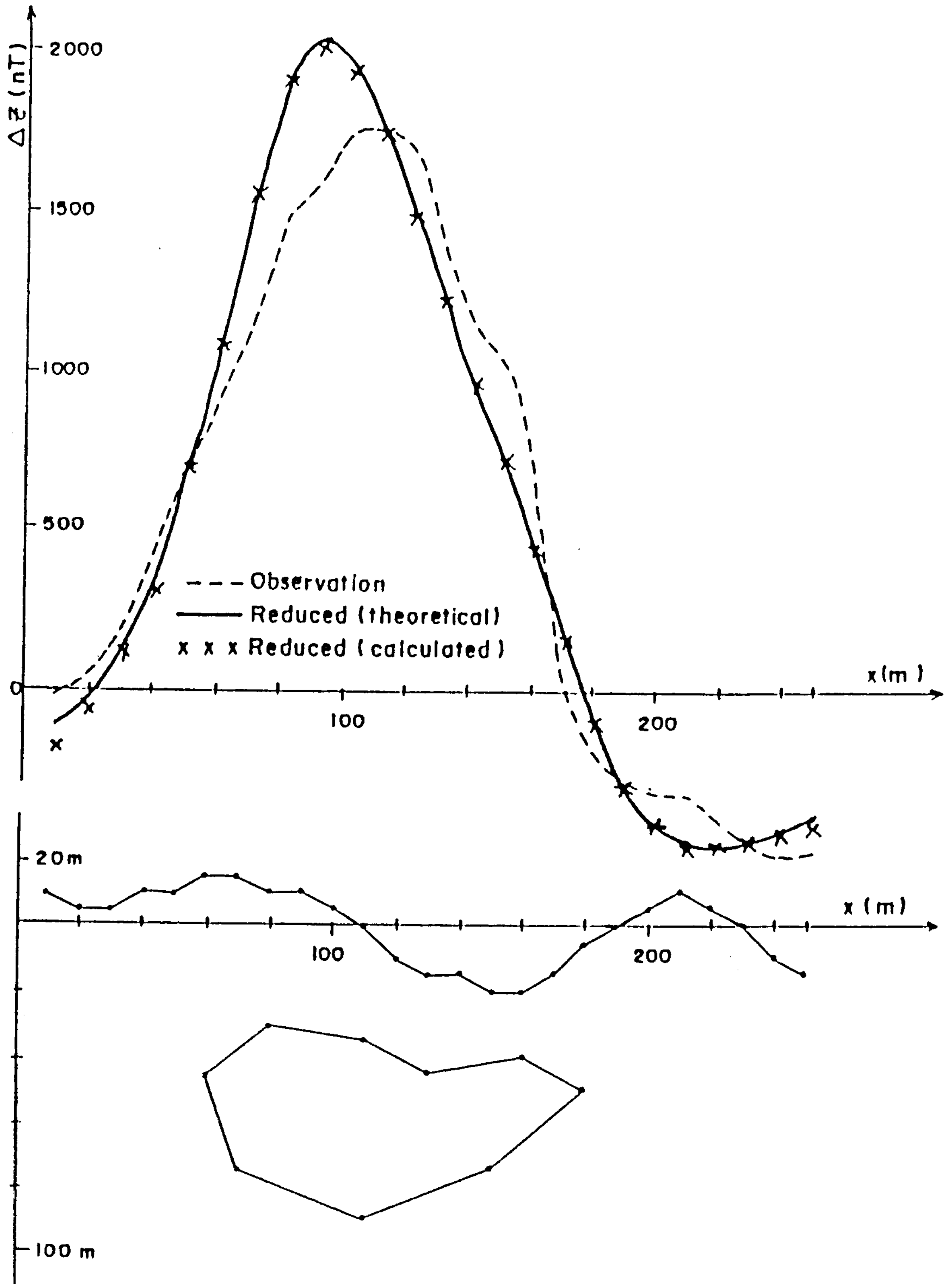

Fig. 6. The buried mass with random shape under the rugged topography and its vertical magnetic (ΔZ) and reduced anomalies.

Şekil 6. Düzensiz topoğrafya altındaki gelişigüzel şekilli gömülü kütle ve bunun düşey manyetik (ΔZ) ve indirgenmiş anomalileri.

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