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NOMOGRAMS FOR INTERPRETING GRAVITY ANOMALIES ABOVE A FINITE HORIZONTAL CYLINDER

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ABSTRACT

The present study gives a new method for solving the inverse problem of the gravitational anomalies related to a finite horizontal cylinder, by the use of the downward continuation method. Master curves have been obtained for this purpose, besides a detailed explaination of calculating the different parameters of such a causative body. The accuracy of the methods has been also demonstrated with a synthetic model, together with calculated error curves to obtain the corrected depth and length for any cylinder. An interpreted example of a real anomaly in the Western Desert of Egypt has been given using this procedure.

INTRODUCTION

This work is a continuation of that reported in a previsous paper by El Hussaini, 1978, dealing with the distinction between the gravitational anomalies due to infinite cylindrical bodies, using the downward continuation method. Employing the same technique, the present work is concerned with giving a suitable solution for gravity anomalies that are caused by finite horizontal cylinders. It is derived mathematically and can be easily used for determining the depth to the cylinder axis, length, the mass per unit length and the radius for a known density contrast. The importance of this study is attributed to its utility in interpreting linear deposits, such as vein type deposits, anticlinal and synclinal folds.

METHODS AND MATERIALS

The gravitational effect of a horizontal cylinder extending from +y to −y with center buried at depth z parallel to the y axis, at a point P (x,o,o) is given by the following relation (Dobrin, 1976):

$$g_{x,o,o} = 2f \quad x/(z^2+z^2).\ y/(x^2+y^2+z^2)^{1/2} \tag{1}$$

where,

f is the universal gravitational constant.

λ is the mass per unit length.

assuming that the gravity measurements are made at the horizontal surface along the x-axis perpendicular to the base line.

For solving the inverse problem in our case, it would be necessary to consider that the cylinder has infinite extension along the y-axis (Sazhina, 1971 and Dobrin, 1976). This assumption would simplify the formula, but it is completely different from the real configuration. So, here we are interested to get an adequate solution for formula (1) without any approximation.

The gravitational effect vertically above the cylinder is derived from relation (1) by letting x = o:

$$g_{o,o,o} = 2f\lambda\, y/z(y^2+z^2)^{1/2} \qquad (2)$$

At a depth h below the surface the gravitational effect is given by:—

$$g_{o,o,h} = 2f\lambda y/(z-h)(y^2+(z-h)^2)^{1/2} \qquad (3)$$

From (2) and (3), it can be deduced that:-

$$g_{o,o,o}/g_{o,o,h} = (1-h/z)((y/z)^2+(1-h/z)^2)^{1/2}(1+(y/z)^2)^{-1/2} \qquad (4)$$

Considering that y = Az and h=Bz, where both A and B are greater than zero, relation (4) becomes:

$$G_{o,o,o}/g_{o,o,h} = (1-B)((A^2+(1-B)^2/(1-A^2))^{1/2} \qquad (5)$$

Master curves are prepared for various values of y as a function of z on semi-logarithmic paper as shown in Fig. (1).

RESULTS AND DISCUSSION

In order to calculate the different parameters of the anomalous mass such as the depth to its center, its length and the mass of unit length one follows the following steps:

1. The maximum gravity value $g_{o,o,o}$ is determined for the selected anomaly on the Bouguer map, which should be as elongated and symmetrical as possible.

2. Values of $g_{o,o,h}$ are computed by downward continuation to desired levels, utilizing any known formula such as Peter (1949) and Roy (1966). Then, the ratio $g_{o,o,o}/g_{o,o,h}$ is deduced for every choosen level.

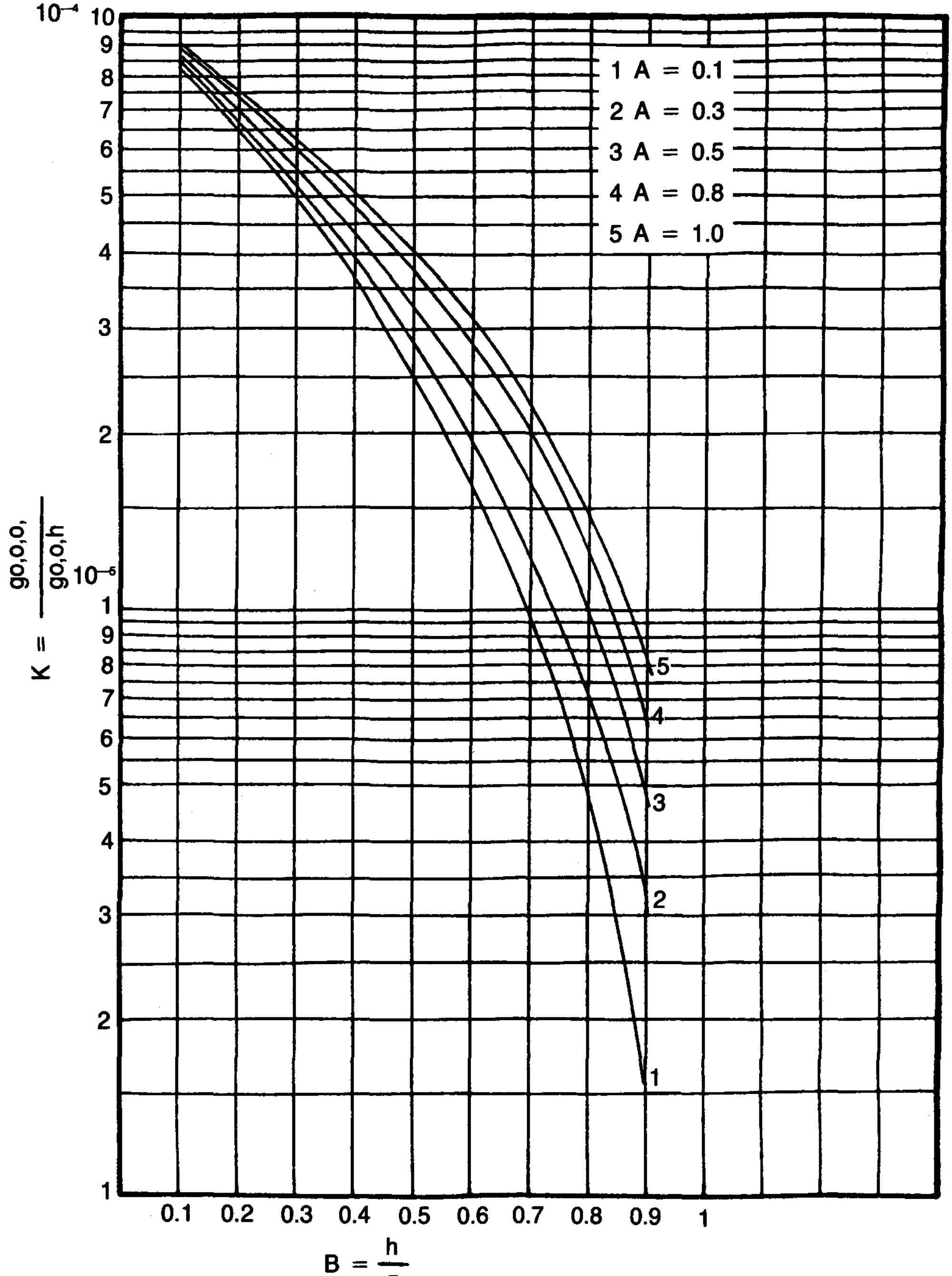

Figure 1a. Master curves for computing y,z and R for finite horizontal cylinder from gravity data (≤1).

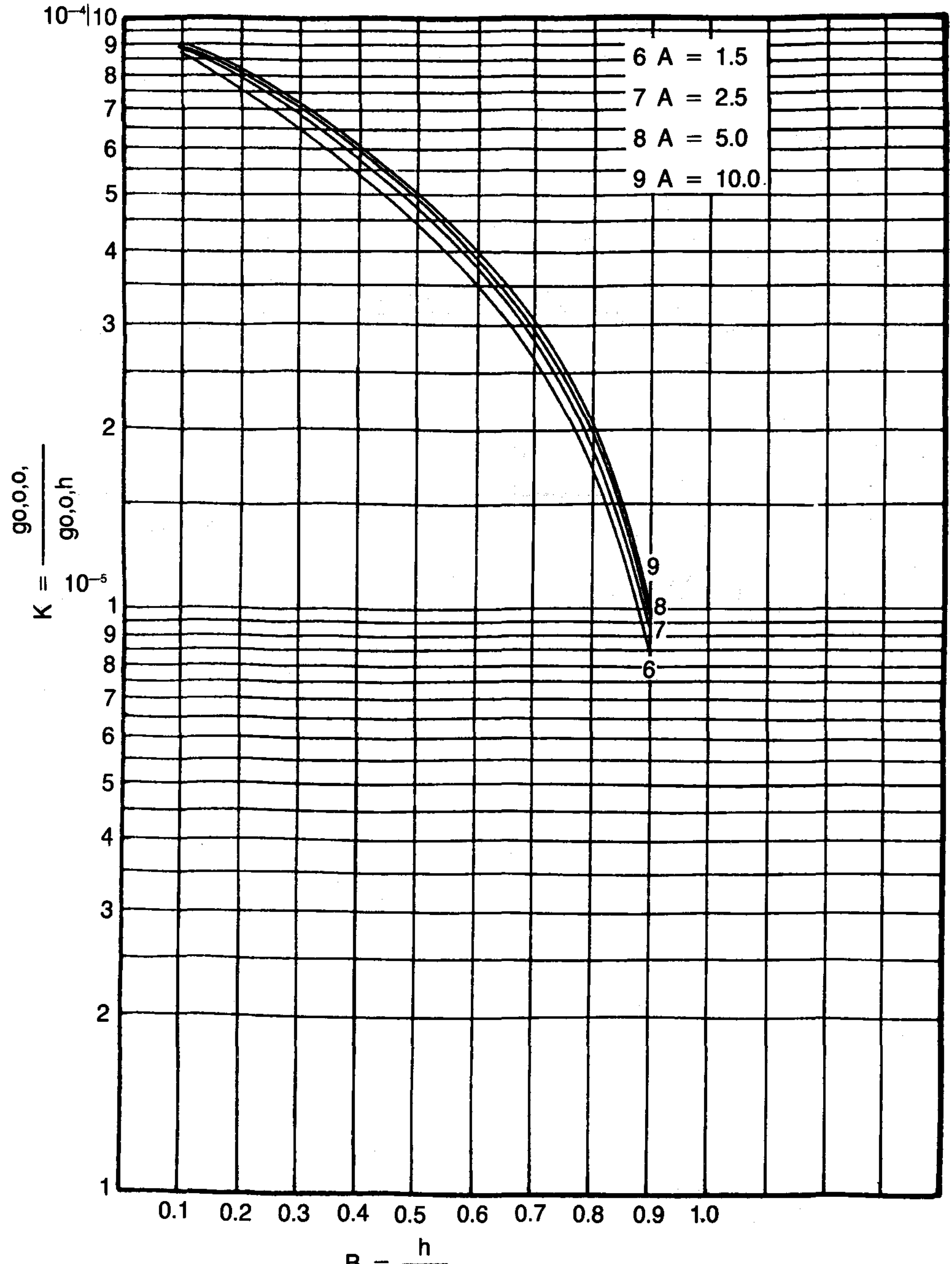

Figure 1b. Master curves for computing y, z and R for finite horizontal cylinder from graviy data (A>1)

3. Horizontal lines are drawn for every value of $g_{o,o,o}/g_{o,o,h}$ on Master curves (Fig. 1) and the corresponding values of A and B are directly obtained. The theoretical relation between these two parameters is shown in Fig. (2) for three hypothetical values of $K = g_{o,o,o}/g_{o,o,h}$. Therefore it becomes easy to conform sets of different depths z with their corresponding y's by the known values of h.

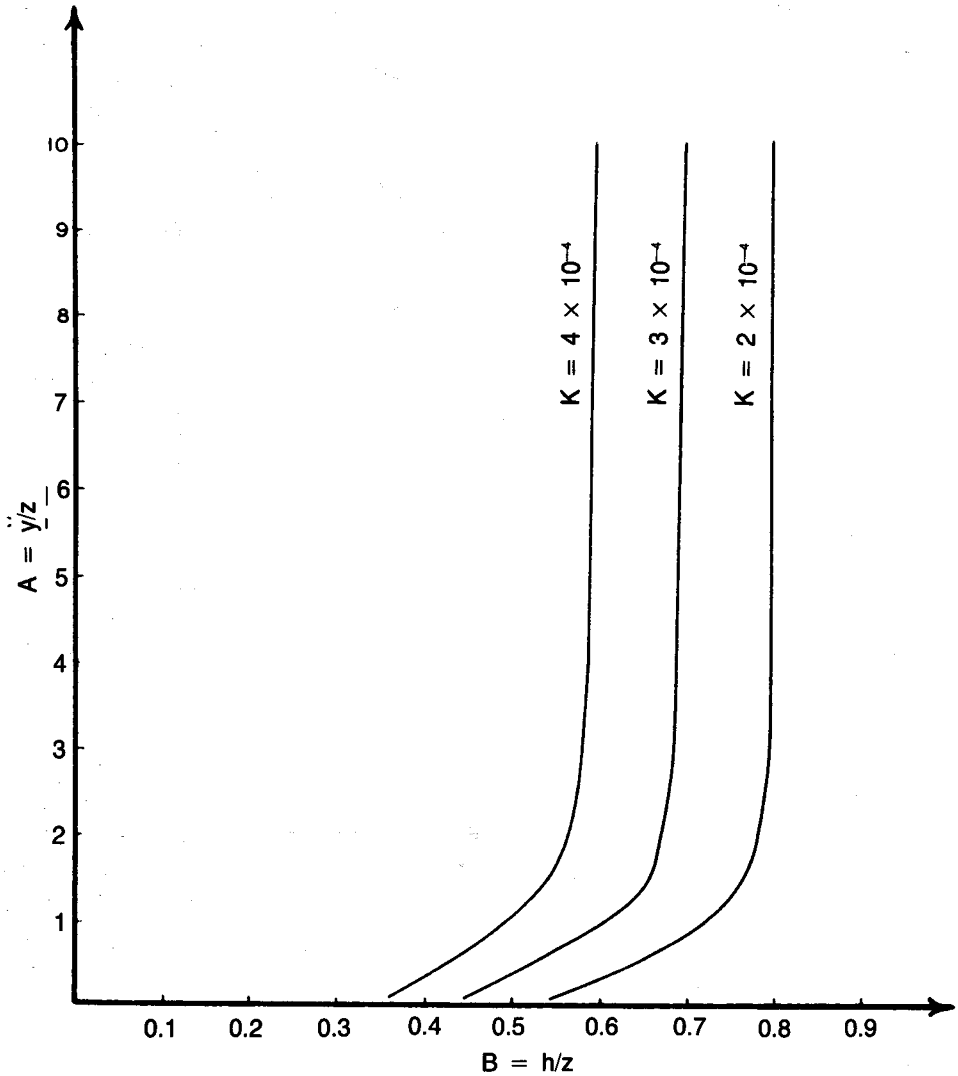

Figure 2. Theoretical relation between A and B for three hypothetical values of K.

4. The relation between y and z is plotted as shown for the given example in Fig. (6). The general trend of these curves are the same at different levels below the surface, firstly, the depth is inversely proportional to the length, and suddenly it becomes constant at a certain value of z which represents the summation of the depth to the center and the choosen h. This value of z can be assumed as a critical depth at which the variation of y is not significant.

5. The characteristic value of A indicating the unique depth to the center and the half length of the cylinder as calculated from the slope of the tangent of the curved at the inflection point.

6. From the assumption, that $y = Az$, the length of the cylinder is obtained. Substituting in equation (1) the mass per unit length can be also deduced.

It is clear from the previous explaination that the parameters can be calculated from one y-z curve. For more accurate results, it is better to apply the method on a number of curves and to take the mean value.

The accuracy of the method:

A group of theoretical models have been assumed for various depth and lengths with constant radius and unit density contrast. Fig. (3-a, b, c and d) shows the different gravity profiles that have been obtained for typothetical values of z and y at different levels below the surface. The outlined method has been applied for every case and the calculated depth and length of the cylinder are compared with the hypothetical values. The errors of z and y are calculated and given in Table (1) and plotted in Fig. (4).

From this table and the related figure it is noticed that:

1. The calculated values of z by the new method are less than the real ones for all cases. This is can be named as negative error. On the other hand some of the errors by of y are positive (i.e. the calculated values are greater than the real) and others are negative.
2. The error of z ranges between 30 and 65% reaching its minimum value when y is much greater than z.
3. The error of y is zero when $y \simeq 1.7$ z and reaches its maximum when y equals a fraction of z. The error gradient is small for high values of y/z.

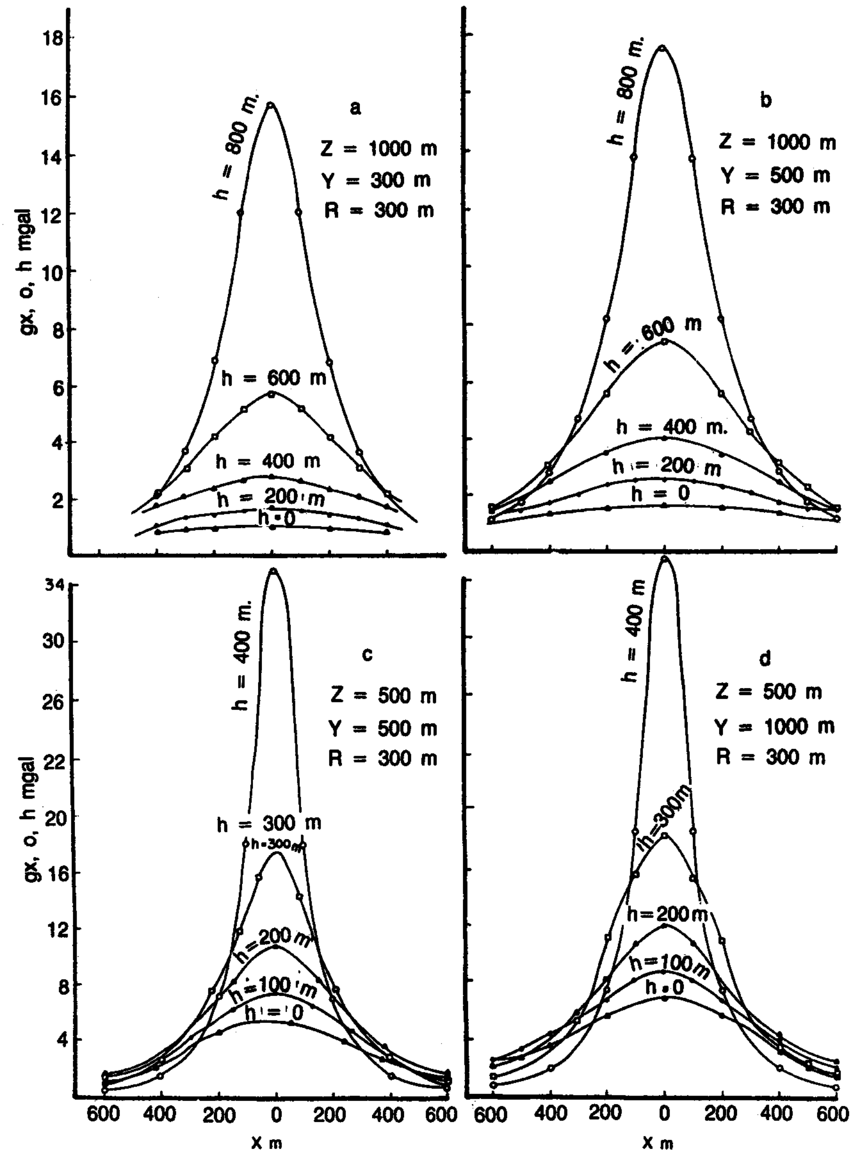

Figure 3-a,b,c and d. Different gravity profiles for hypothetical values of z and y at different assumed levels h below the surface.

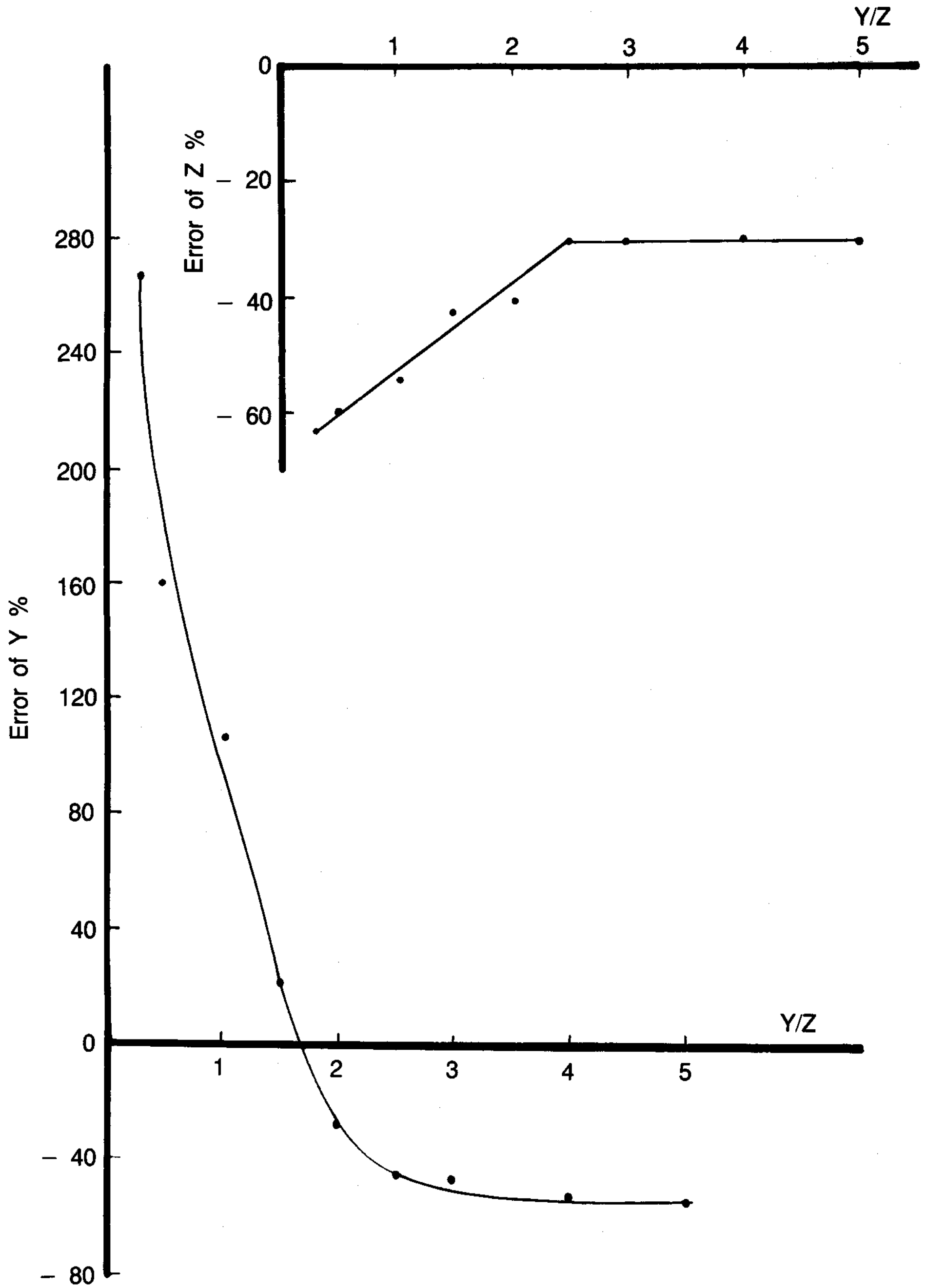

Figure 4. Calculated theoretical error curves of y and z.

Correction of the obtained results:

After calculating the depth to the center and the half length of the cylinder by application of the given method the errors are then immediately deducted from Fig. (4) by the knowledge of the ratio y/z. Therefore the corrected values are obtained whatever the error.

Table 1
Errors of the calculated depth to the center and half length of the cylinder.

	error of Z %	error of Y %
0.3	−63	+268
0.5	−60	+160
1	−54	+108
1.5	−42	+22
2	−40	−28
2.5	−30	−44
3	−30	−47
4	−30	−52
5	−30	−56

Remark:

In the derivation of the accuracy of the method the influence of noise has not considered because the method is applied only to isolated closed anomaly especially at its center which is limitable for application.

A real interpreted example:

The selected anomaly is taken from the Bouguer anomaly map of Kharga Oasis area, Western Desert of Egypt, Fig. (5). The $g_{o,o,o}$ value is 32.75 mgl and the calculated values of $g_{o,o,h}$ are 43.18, 58.49 mgals at 1 and 2.5 km, respectively, according to the method of Constantinescu and Botezatu (1961).

Fig. (6) shows the variation of y gainst z from which the depth to the center z is 3.0 and 3.1 km with the mean of 3.05 km. Also the characteristics average value of A is 2.25. Therefore the cylinder length is 13.73 km. From Fig. (6) the errors in z any y are 34 and 24% (both negative) respectively. Therefore the real values are 2.31 nd 9.06 km. Considering the density contrast 0.42 g/cm^3 as estimated from wells, the radius is 1.45 km.

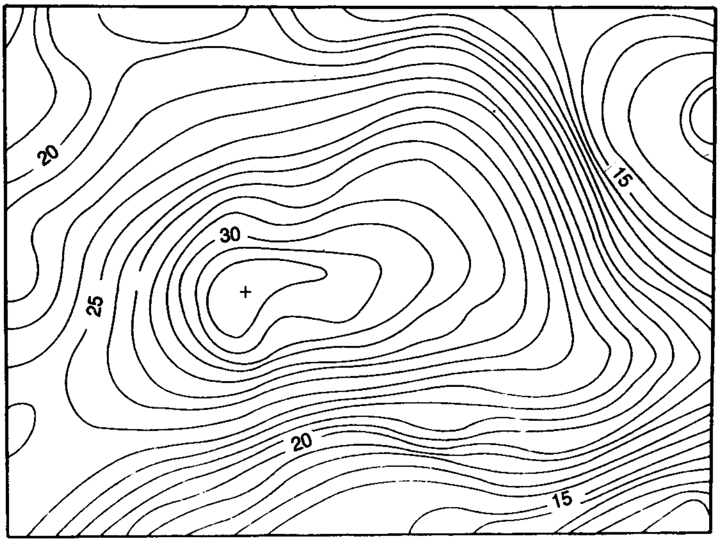

Figure 5.a Bouguer anomaly used in the application of the developed method (contour interval 1 mgal).

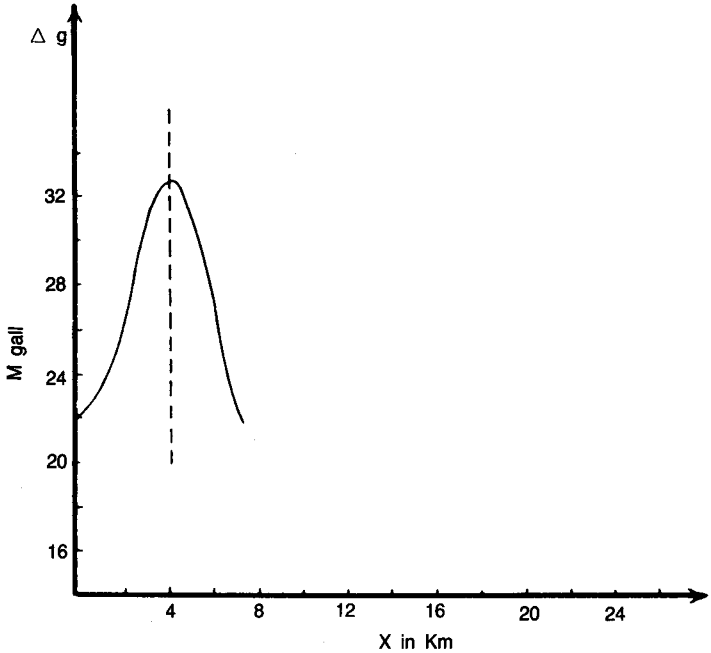

Figure 5.b Gravity profile along selected anomaly to be interreted by the developed method

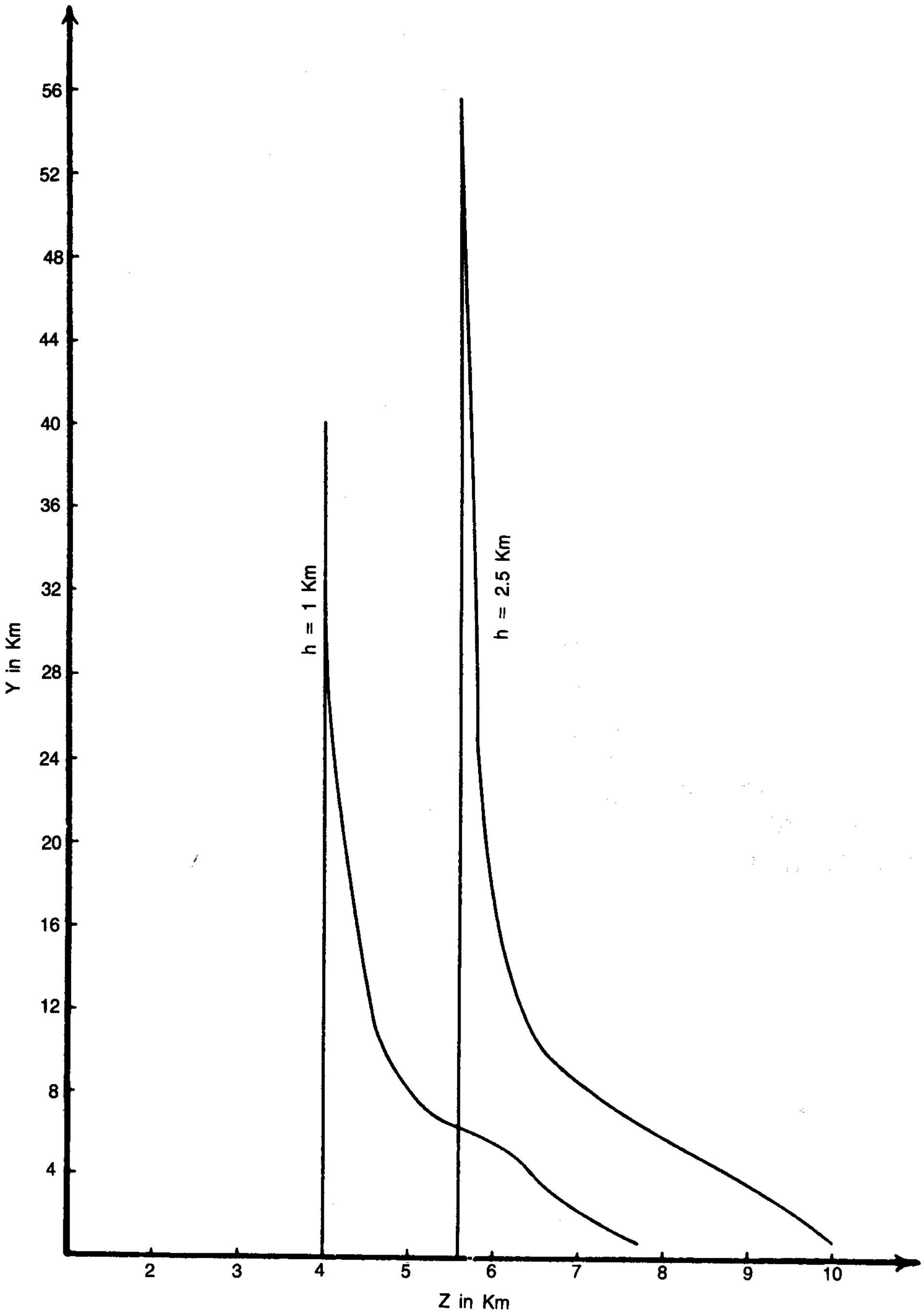

Figure 6 Relation between y and z for the anomaly shown in F Fig. 5.

When this cylinder is infinite in length the error would be 11%. This indicates that our method gives more accurate results compared with those for the infinite case.

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نوموجرامات لتفسير الشذوذ التثاقلي الناجم
عن اسطوانة أفقية محدودة الطول

عليه الحســـيني و عصمت عبد العـال

تهدف هذه الدراسة إلى التوصل إلى طريقة جديدة لحل المشكلة العكسية للشذوذ التثاقلي الناجم عن كتلة اسطوانية محدودة الطول وذلك باستخدام طريقة الاستمرار السفلي . وقد أعدت لهذا الغرض منحنيات مميزة بجانب شرح تفصيلي لكيفية استخراج الثوابت المختلفة لمثل هذا الجسم الجاذب . وهذا وقد حسبت مدى الدقة لهذه الطريقة على عدة نماذج نظرية ذات أبعاد افتراضية وتم الحصول على منحنى الدقة لحساب القيمة المصححة لبعد مركز هذه الاسطوانة عن سطح الأرض ، وكذلك لطولها . وقد طبقت الطريقة المقترحة على مثال حقيقي بمنطقة الواحات الخارجة بصحراء مصر الغربيـة .