A SIMPLE DIAGRAM FOR GRAVITY INTERPRETATION BY GRADIENTS FOR A LATERAL VARYING FORMATION

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ABSTRACT

A simple diagram is constructed for the interpretation of the gravity anomaly arising from a formation of linear density variation. The diagram can be easily used if the horizontal gradient is also known. With the help of a modern gravimeter the gradient can be accurately measured. The diagram enables the position of the origin, the depth, the width and the density variation of the postulated structure to be derived without the use of any computing facilities. The procedure is demonstrated by a worked example using theoretical data.

INTRODUCTION

In the last few years, there have been numerous attempts to improve the gravity interpretation by applying the horizontal and vertical gradients for the detection of the stratigraphic traps (Sigmund & Anzoleaga 1975, Stanley 1977). These attempts are not new for geophysical exploration. With the modern gravimeter, the horizontal gradients can be accurately measured while there are practical difficulties in measuring the vertical gradients. Stanely and Green 1977 pointed out that the vertical gradient could be calculated accurately from the measured horizontal gradient.

In this paper, the author presents a simple chart to help in resolving the gravity anomalies due to formations of linear density variation.

FUNDAMENTAL RELATIONS

Considering the gravity formula corresponding to a laterally varying density formation (Fig. 1) given by El-Awady 1977:

$$\Delta g = 2k \mu_1 \left[(b+x)\left(\tan^{-1} \frac{x+b}{t} - \tan^{-1} \frac{x-b}{t}\right) + 0.5\, t\, l\, n\, \frac{(x-b)^2+t^2}{(x+b)^2+t^2} \right] \quad (1)$$

where as:

k : the universal gravitational constant,
$\mu 1$: the linearity factor of the surface density variation,
b : the half width of the structure and
t : the mean depth.

The gravity value at the origin is given by:

$$\Delta g_o = 4 k \, \mu_1 \, b \, \tan^{-1} \left(\frac{b}{t} \right) \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (2)$$

Differentiating equation (1) w.r.t. x we get:

$$\Delta gx = 2k \, \mu_1 \left[\tan^{-1} \frac{x+b}{t} - \tan^{-1} \frac{x-b}{t} - \frac{2bt}{(x-b)^2+t^2} \right] \quad \dots \dots \dots \quad (3)$$

The maximum and minimum values of equation (3) are found to occur at distances x_M (at maximum) and x_m (at minimum) respectively. These two points may be obtained by differentiating equation (3) with respect to x and equating to zero, we get:

$$- x_M = \frac{1}{3} b - \frac{2}{3} \sqrt{b^2 + \tfrac{3}{4}t^2} \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (4)$$

$$x_m = \frac{1}{3} b + \frac{2}{3} \sqrt{b^2 + \tfrac{3}{4} t^2} \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (5)$$

Taking the ratio of the absolute values of x_M and x_m we obtain:

$$\frac{|x_M| + |x_M|}{|x_M| - |x_m|} = 2 \sqrt{1 + \tfrac{3}{4} \left(\frac{t^2}{b^2} \right)} \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (6)$$

From equations (4) and (5) we get also:

$$|x_m| - |x_M| = \frac{2}{3} b \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (7)$$

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Substituting the values of x_M and x_m in equation (1), we determine the gravity values at the two inflection points $\triangle g(x_M)$ and $\triangle g(x_m)$. Similarly by substituting x_M and x_m in equation (3) we obtain the gradient values at the maximum $\triangle gx_M$ and minimum $\triangle gx_m$ points. The ratio of the gravity values at the inflection points and the ratio of the gradients at the minimum and maximum points are used in plotting the diagram.

LOCATION OF THE ORIGIN POINT OF THE PROFIL

In practice a field curve will have an arbitrary origin. This necessitates, first, the detection of the position of the mid point of the structure. The origin point may be readily located from the diagram. The ratios $\triangle(g(x_m)/\triangle g(x_M)$ and $\triangle gx_m/\triangle gx_M$ can be calculated from the gravity and the horizontal gradient profiles. Using these two ratios and knowing the absolute sum of the two distances $|X_m| + |X_M|$, it is possible to determine the mean values of x_M and x_m, from which the origin point can be located and also the width of the structure can be calculated.

APPLIED EXAMPLE

For testing the diagram a worked example using theoretical data is interpreted. The gravity profile and its gravity gradient obtained over the structure are illustrated in figure 1. The parameters measured from the profiles and those calculated from the diagram are as follows:

Parameters measured and calculated from the gravity and gradient profiles

The value of gravity at inflection point $\triangle g(x_m)$	= 10.7 mgal
The value of gravity at the other inflec. point $\triangle g(x_M)$	= 9.85 mgal
The ratio of the two gravity values $\triangle g(x_m)/\triangle g(x_M)$	= 1.086
The value of the gradient at minimum $\triangle gx_m$	= -2.85 Eotvos
The value of the gradient at maximum $\triangle gx_M$	= 2 Eotvos
The ratio of the two gradients $\triangle gx_m/\triangle gx_M$	= -1.425
$\mid x_m \mid + x_M \mid$	= 7.5 km.

Parameters calculated from the diagram:

The mean value of the ratio $(\mid x_m \mid + \mid x_M \mid)/(\mid x_m \mid - \mid x_M \mid) = 2.27$

$\mid x_m \mid - \mid x_M \mid = 3.304$ km.
$x_M = 5.4$ km.
$x_m = 2.1$ km.
$\triangle g_o = 13.8$ mgal
b (half width) = 4.99 km.
b/t (mean value from gravity and gradient diagram) = 1.625
depth t (mean) = 3.07 km.
$\mu 1 = 0.1017$ g/cm^3

CONCLUSION

In the present investigation, discrete linear variation of density contrast has been assumed throughout the structure. A simple curve has been developed for direct gravity interpretation which depends mainly on the gravity effect and on the horizontal gradient of such a structure. The diagram deduced, gives a more realistic way of approximating the actual density inside the formation. The depth, width and density variation of the structure can be easily determined.

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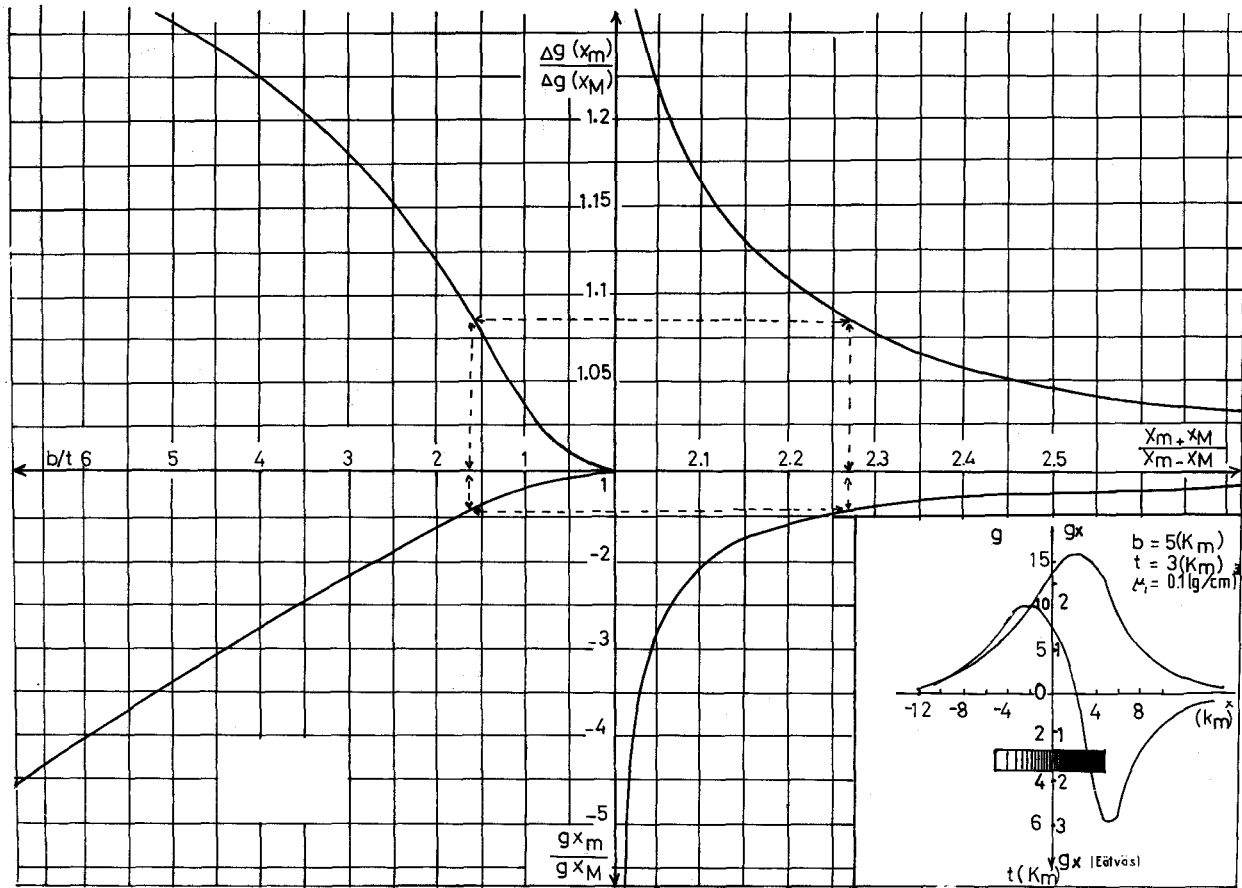
Fig. 1: A diagram for gravity interpretation

Fig. 2: An applied example.

استخدام رسم بياني مبسط لتقييم المحصلة الأفقية
للشواذ التثاقلية لتركيب جيولوجي تتغير كثافته أفقيا

محمد محمد العوضي

يـدور هذا البحث حـول دراسة المحصلة الأفقيـة للشواذ التثـاقلية لتـركيب جيولوجي تتغير كثافته أفقيا وتقييم هـذه المحصلة للتعرف عـلى عمق وأبعاد هـذا التركيب وقد أعد لهذا الغرض رسما بيانيا مبسطا يستخدم أساساً في التقييم وقد تم تطبيق هذه الطريقة على بعض الأمثلة لأثبات صلاحيتها .