تفسیر داده های گرانی به روش EULDPH

نوشته: دکتر وحید ابراهیم زاده اردستانی*

Gravity interpretation via EULDPH

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چکیده

در این مقاله درباره معادله همگن اویلر برای تعیین مختصات چشمه به ویژه ژرفا بحث خواهد شد. این روش برای مدلهای مصنوعی و داده های با کیفیت بالا مانند داده‌های ریزگرانی و گرادیومتری بکار گرفته شده است . در مورد داده‌های گرانی با کیفیت پائین به خصوص در منطقه‌ای با زمین‌شناسی پیچیده به ندرت این روش مورد استفاده قرار می گیرد.

این پژوهش از این داده‌ها به منظور محاسبه بی هنجاری بوگه استفاده شده است . سپس بی هنجاریهای بوگه به بی هنجاریهای باقیمانده تبدیل شده اند و پس از آن گرایادن‌های گرانی از روی آنها محاسبه شده است . در ادامه با بکار بردن گرادیانهای گرانی از روش EULDPH، مختصات چشمه مورد نظر تعیین شده است .

دو مثال صحرایی، یکی مربوط به منطقه‌ای در خاور تهران (مردآباد) به منظور پی‌جویی هیدروکربن و دیگری در جنوب خاوری ایران نزدیک مرز افغانستان (نصرت آباد) برای اکتشاف کرومیت در این مقاله ارائه شده اند.

واژه‌های کلیدی: تفسیر گرانی، گرادیان گرانی،روش EULDPH

Abstract

Euler's homogeneity equation for determining the coordinates of the source body especially to estimate the depth (EULDPH) is discussed at this paper. This method is applied to synthetic and high-resolution real data such as gradiometric or microgravity data. Low-quality gravity data especially in the areas with a complex geology structure has rarely been used. The Bouguer gravity anomalies are computed from absolute gravity data after the required corrections. Bouguer anomaly is transferred to residual gravity anomaly. The gravity gradients are estimated from residual anomaly values. Then by applying the gravity gradients, using EULDPH, the coordinates of the perturbing body will be determined. Two field examples one in the east of Tehran (Mard Abad) where we would like to determine the location of the anomaly (hydrocarbon) and another in the south-east of Iran close to the border with Afghanestan (Nosrat Abad) where we are exploring choromit are presented.

Key words: Bouguer anomaly, residual anomaly, gravity gradient, EULDPH.

1. Introduction

Locating depth and corners of a perturbing body are two important tasks in quatitative gravity interpretation. Euler deconvolution method (EULDPH) has firstly been introduced by Thompson (1982). This method is based upon Euler's homogeneity equation. Reid et al. (1990) used it to magnetic data and briefly discussed the application of this technique to gravity survey. The application of this method in the case of gravity gradiometric and microgravity has been introduced by Klingele et al. (1991). EULDPH is an efficient method for locating density contrasts, particularly in the case of interfering anomalies (Marson and Klingele, 1993). EULDPH needs no assumption about the geometry of the source body which is a great advantage. Because the vertical gravity gradient is more sensitive than gravity itself to geology structures and its interpretation is less influenced by neighbuoring disturbing bodies (Stanley and Green, 1976), and it can be ideal data to use it in the method for gravity interpretaion. When the vertical gradient is not measured directly, it can be numerically computed from the Bouguer gravity anomalies. Solving the Euler's homogeneity equations for gravity gradients, the coordinates of the source can be estimated with a high auuracy.

2- Euler's equation

Thompson(1982) showed that if $f\,(x, y, z)$ be a homogenous function of degree N, Euler's homogeneity equation is as follows:

$$(x - x_0)\frac{\partial f}{\partial x} + (y - y_0)\frac{\partial f}{\partial y} + (z - z_0).\frac{\partial f}{\partial z} = Nf, \qquad (1)$$

where x_0, y_0 and z_0 are the coordinates of the source. Klingele et al. (1991) proved that the vertical gradient of the gravity effect of a point mass is a homogenous function of degree –3. Therefore in equation (1) the function f can be replaced by the vertical gradient of gravity. If we assume that a source body can be represented by an appropriate distribution of point sources on the body's upper surface, N is a structural index (Thompson 1982). The value of this index has to be determined in practice, and so the unknowns are x_0, y_0 and z_0. To apply the Euler's equation (1) for interpretation of gravity data is quite strightforward. A suitable square window (3×3 or greater) of gridded data is required. Therefore a 3 × 3 window produces 9 linear equations with three unknowns. This overdetermined system of linear equations can be solved by least square procedure. The window moves to the areas which contain anomaly and this process will be repeated for different N. A rejection criterion (Thompson, 1982) based on the uncertaintity of the solution, is established and the accepted solutions are plotted on the (x, y) plane. The solutions are rejected if the standard deviation of the unknowns, evaluates from the covariance matrix of the linear system is bigger than say, 5 to 15 percent of the calculated depth (Marson and Klingele, 1993). Optimal choice of structural index cause the clustering of the results in x,y plane. The standard deviation of the unknowns and clustering of solutions speed up the interpretation process and at the same time to keep the interpreter's judgement. To use equation (1), the vertical and horizontal derivatives should be computed. To compute the horizontal derivative a five point Lagrangian differentiation operator (Abramowitz and Stegun, 1970) is used,

$$\frac{d^k f(x)}{dx^k}\bigg|_{x=x_j} = \frac{k!}{m!h^k}\Sigma_{i=0}^{m} A_i f(x_i), \qquad (2)$$

where for first order derivative k is 1, and for five points operator, m is 5. The coefficients A_i are presented by Abramowitz et al. (1970) in the related tables. Computing the vertical gradient the surface ground data continued to 0.10 meters, where the gradient between the two levels is believed to be constant. Then the gradient is computed by subtracting the 0.10 meter height data from the ground surface data and dividing it by the height difference. The relation used for upwards continuation is based on Fourier transform method (Grant and West, 1965),

$$g_z(x, y) = \frac{1}{4\pi^2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} F_0(p, q)exp[\sqrt{p^2 + q^2}z - i(px + qy)]dpdq \qquad (3)$$

where F_0 (p,q) is the Fourier transform of the data g_0 (x,y), which is the Bougour or residaul anomaly at the ground surface, p and q are the discrete frequencies and $g_z(x,y)$ is the gravity data at heigh z, where z is positive downwards.

3.Numerical Results

To determine the coordinates of the perturbing body based on the EULDPH method, a computer code in Fortran 77 has been prepared. The input to the program is residual anomaly. Then the vertical gradient will be computed through implementing equation (3). Horizontal derivatives from vertical gradient are provided by using equation (2). The Euler's equation is then used to locate the point sources.

The first data set which has been used is low-quality gravity data from Nosrat Abad where we are surveying for Choromit. The network of the measured points is shown figure 1. Figure 2 shows the Bouguer anomaly map of the area. The most probable area for existing Choromit is in the west of the area as it has been shown on the figure 2 (black color area). The residual anomalies have been computed by the orthonormal method (Sarma and selvaraj, 1990) and the results are shown in figure 3. In the figure the anomaly is decleared clearly with magnitude more than 2.6mGal and in the area between x= 36 to 60 and y= 160 to 200. Then the first vertical derivatives are computed by using eqn. (3) and figure 4 represents the plan of the values. The black color area with the center about x = 40 and y = 70 with the amplitude more than 7mGal shows the position of the main source. The second vertical derivative plan figure 5 shows the same area as figure 4 with the amplitude about or more than 24.6mGal. To consider the first and second vertical derivative plans the center of the most probable area for the existance of the Choromit is about x= 40 and y= 75. The results of using EULDPH method for determining the location of the anomaly and its depth are shown in figure 6 where the depths are also labled as the values close to the points in meter. The depth solution for a single point was rejected if the standard deviations of the three unknowns were bigger than 15 percent of the estimated depth. The suitable structural index was found to be N = 2 by the trial and error and according to the clustering of the results. The results of EULDPH representing the points of the anomaly are scatered in the area as it is shown in figure 6. A number of Choromit lens can be distinguished by considering the adjacent points.

Another survey is in the area where we are looking for the hydrocarbon. The network of the measuring points are shown in figure 7. The Bouguer anomaly plan is presented in figure 8 where the location of the anomaly is quite obvious (the black color area in the west of the area) with magnitude less than −120mGal. The residual anomalies are planned in figure 9 where the main perturbing body is decleared with the magnitude less than −5mGal in the black color area. To compute the first vertical derivatives in figure 10 the position of the main anomaly has been limited to the smaller area with the center about x= 6600 and y= 100. The second vertical derivative map (figure 11) confirms the same area as in figure 10 for existing the anomaly. To consider the first and second vertical derivative plans a box has been selected between x= 6000 to 7000 and y= 0 to 200 as the most proble area for existing the anomaly. In this box some windows including 4×4 points in x and y directions have been determined and the results produced using EULDPH method are shown in figure 12. The average depth of the points shows that the layer including the proble anomaly has a slim dip toward the south as far as 160meter from the first profile of measurements which has a good match with geological observations. The structural index is found to be 3 by trial and error considering the best clustering of the results. The criterion for rejecting was selected 15 percent of the standard deviations of the estimated depth. To test the solution in this latter area, using some other quantitative methods or different geophysical methods such as seismic methods seems to be necessary.

4.Conclusion

One can see from numerical results that the algoritm works nicely. In the case of choromite exploration by low-quality data we reached to accurate solution which is partly approved by drilling in the area. However in petroleum exploration, EULDPH can play a vital role in combination with other quantitative interpretation methods even though we are investigating in a vast area and with a complex geology structure and probably low-resolution data. Considering the estimation of the location of the anomaly some other methods like analytic signal (Nabighian, 1984) can help the process of interpretation, especially in the case of hydrocarbon investigation that the clustering of the results and the depth solution is under question.

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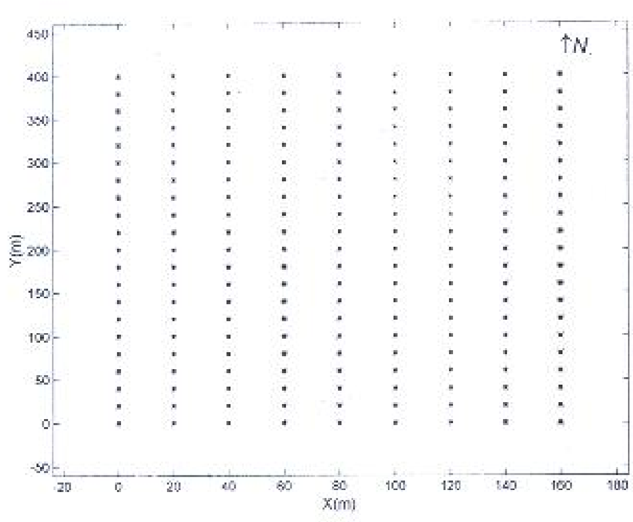

Figure 1: Network of the measured points.

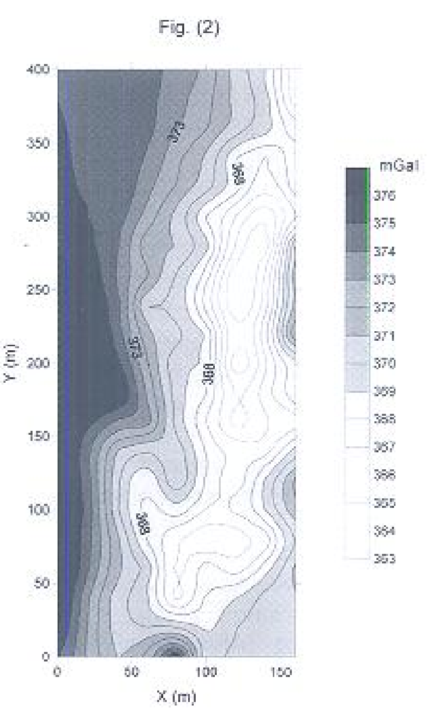

Figure 2: Bouguer anomaly map of Nosrat Abad (mGal).

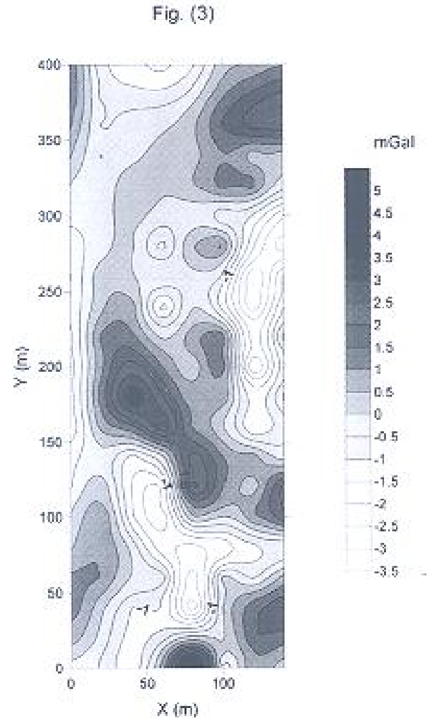

Figure 3: Residual anomaly map of Nosrat Abad (mGal).

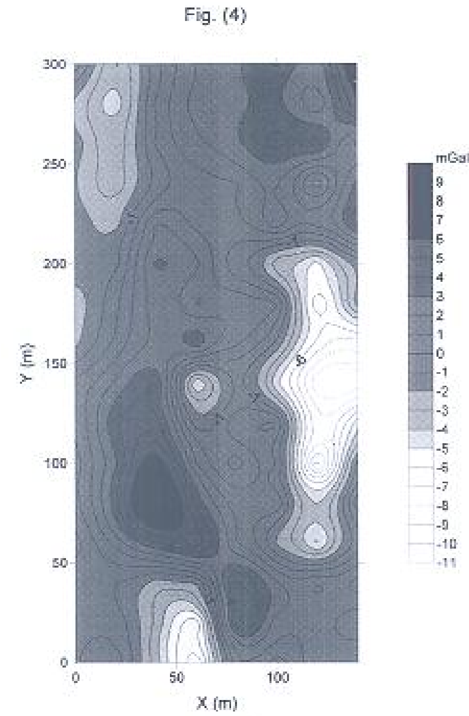

Figure 4: First vertical derivative map of Nosrat Abad (mGal).

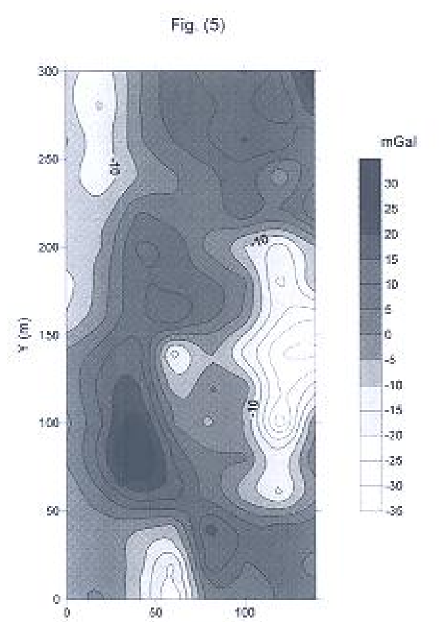

Figure 5: Second vertical derivative map of Nosrat Abad (mGal).

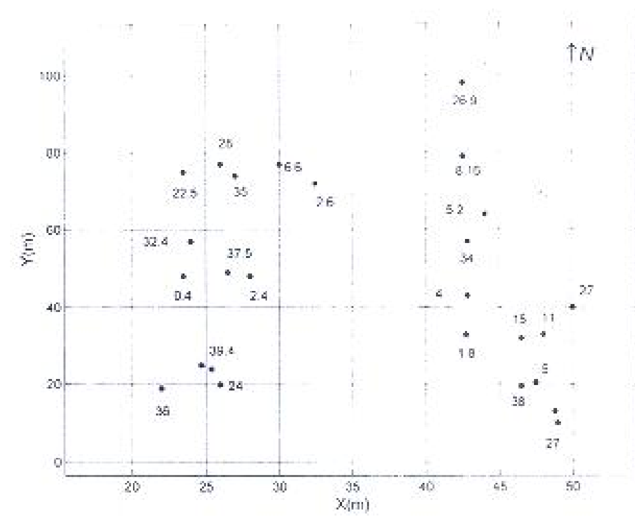

Figure 6: Coordinates of the perturbing body in Nosrat Abad.

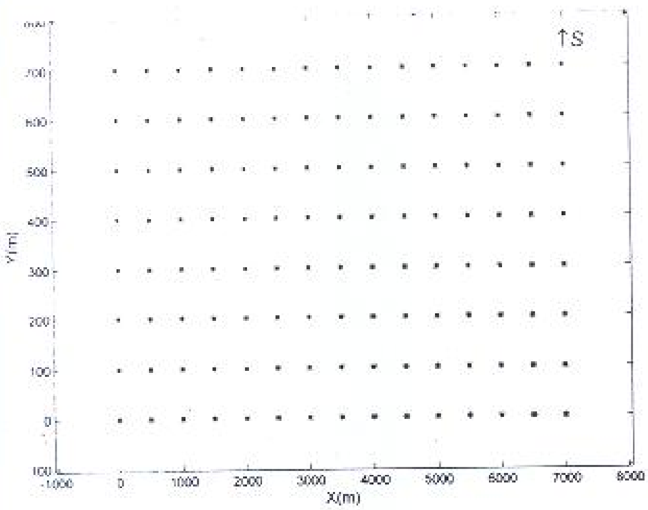

Figure 7: Network of the measured points.

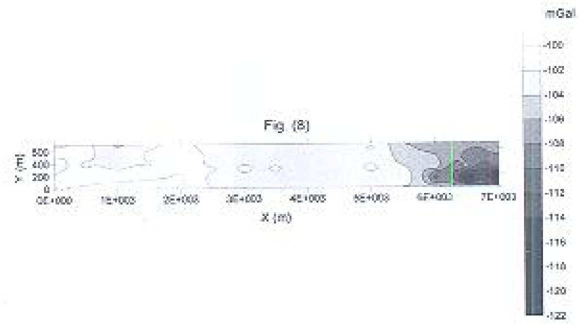

Figure 8: Bouguer anomaly map of Mard Abad (mGal).

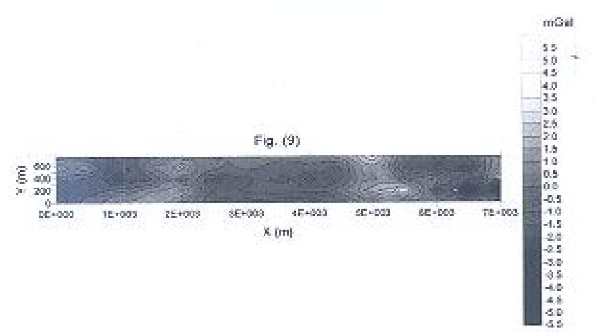

Figure 9: Residual anomaly map of Mard Abad (mGal).

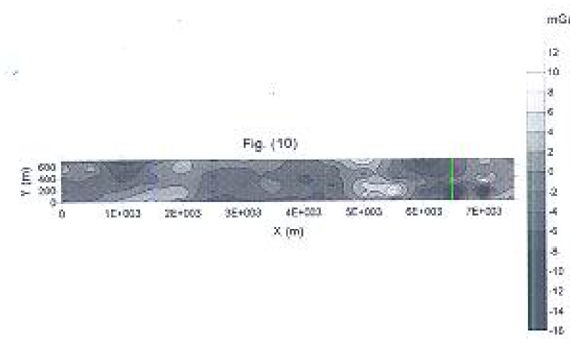

Figure 10: First vertical derivative map of Mard Abad (mGal)

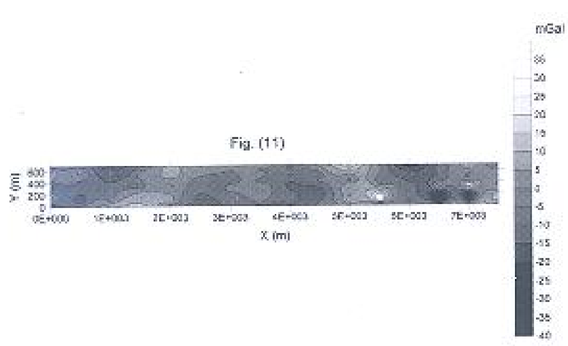

Figure 11: Second vertical derivative map of Mard Abad (mGal).

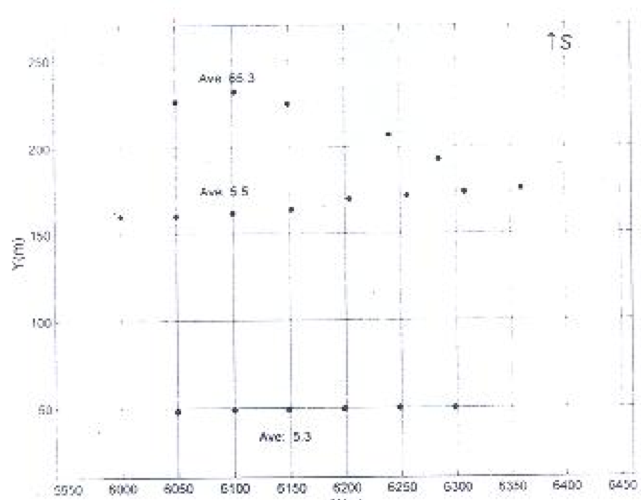

Figure 12: Coordinates of the perturbing body in Mard Abad.

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