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Practical Method for Isolation of Residuals Determined from Polynomial Fitting to Gravity Data (Case Study Bandar Charak. Hormuzgan. Iran).

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ABSTRACT

The fitting of a first order polynomial in x and y to gravity data by least squares with matlab programming and surfur is discussed. The first degree polynomial order is fitted to the Bouguer gravity anomaly data to produce the first residual gravity anomaly map of Bandar charak. The residual gravity data was computed by subtracting the regional trend from the Bouguer gravity field. The regional trend in the Bandar charak is the first degree surface fit and represents anomaly of long wavelength while the residual component have their origin from short wavelength sources (shallow sources). This quantitative approach is advantageous over the wavelength filtering methods. The result of this low order fitting shows that the residual gravity field is characterized by positive and negative gravity anomalies in Bandar charak region of Iran.

Keywords: Bouguer gravity anomaly data, gravity field, matlab programming, linear least square, surfur

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INTRODUCTION

The gravity method was the first geophysical technique to be used in oil and gas exploration. Despite being eclipsed by seismology, it has continued to be an important and sometimes crucial constraint in a number of exploration areas. In oil exploration the gravity method is particularly applicable in salt provinces, over thrust and foothills belts, underexplored basins, and targets of interest that underlie high-velocity zones. The gravity method is used frequently in mining applications to map subsurface geology and to directly calculate ore reserves for some massive sulfide ore-bodies. There is also a modest increase in the use of gravity techniques in specialized investigations for shallow targets. Also it has application in agriculture and archeology .Data reduction, filtering, and visualization, together with low-cost, powerful personal computers and color graphics, have transformed the interpretation of gravity data. Also in gravity methods, Euler and Werner deconvolution depth and edge -estimation techniques can help define the lateral location and depth of isolated faults and boundaries from gravity data. Complex geology with overlapping anomalies arising from different depths can, however, limit the effectiveness of deconvolution fault-detection results.(M. N. Nabighian et al.(2005);Toushmalani Reza,(2010a);Toushmalani Reza,(2010b) Toushmalani Reza,(2010c); Toushmalani Reza,(2010d);;Toushmalani Reza,(2011) Toushmalani(2013a) Toushmalani(2013b)).

Gravity and magnetic fields data are composed of anomalies of different sizes from various depths. In order to model the anomalies of interest (geological sources), it is desirable to separate anomalies caused by deeper features from those caused by shallow sources. Anomalies with long wavelength (large width) are generated by deeper sources while short wavelength anomalies are from shallow sources. However, long wavelength signals can have shallow source depths. In this case, the large shallow masses need to be supported by the strength of the lithosphere. Various processing techniques are used to isolate the residual field, which is generated by geological sources of interest from the regional trend (long wavelength component) in potential field data. The various techniques include: the derivative methods, which sharpen up anomalies over bodies and tend to reduce anomaly complexity and also designed to look at fault and contact features. The second vertical derivative serves specifically to emphasize the expression of local features and removes the effects of large anomalies (regional influences); the matched residual filter technique (Urquhart, 2008) removes the long wavelength component from potential field data and thus the shallow sources are better resolved.

The matched residual technique involves the computation and examination of the shape of the spectrum of deeper and shallow bodies. Upward continuation suppresses signals from short wavelength sources at shallow depth and reveals the signals from long wavelength sources while downward continuation enhances the response of the sources at depth by magnifying the short wavelength relative to the long wavelength, thus bringing the shallow sources more in focus. The graphical method is also employed in which case the regional background is estimated by visual inspection. In band-pass filtering, if large or deeper sources are of interest, all anomalies that have wavelength smaller than a certain value are removed. However, long wavelength which represents the most regional trend may also be cut out to analyze the remaining anomalies. That is, all frequencies between certain values are passed while others are eliminated. It is also possible to isolate certain

anomalies with respect to orientation (Fogarty 1985). In this case, a look is taken at features that have trends between certain orientations (strike-pass filtering). Beltrao (1991) proposed a regional-residual separation method based on polynomial fitting in which the coefficients are determined by a robust procedure consisting of iteratively re-weighted least squares solutions. By successively assigning small weights to large residuals, their influence in the fitted regional is minimized regardless of the true residual anomalies signs. The term robust as applied to a statistical estimator, means insensitive to small departure from the idealized assumptions for which the estimator is optimized (Press et al., 1992). Abdelrahman et al. (2003) presented a procedure to select the optimum polynomial order, based on the correlation between residuals of successive orders. Abdelrahman et al. (1985) showed that the least-squares derivatives method which involves the determination of amplitude coefficients related to the density contrast can be used to compute the thickness of buried faulted slab from numerical derivative anomalies. They concluded that the success of this method depends on the accuracy with which the residual anomaly is separated from the observed gravity anomaly. Even though some of the above techniques have been applied successfully, they still have some setbacks. Band-pass filtering requires assuming the cut-off wavelength and can smear the separation due to non-vertical filter roll-off. The graphical method, although simple, is very subjective due to the fact that the estimation of the regional trend relies on the judgment of the operator. In downward continuation, if the plane of calculation is below the top of the causative body, high-frequency ringing is produced by the calculation and minor noise present in the original observed gravity field is amplified in the downward continued field and may mask or partially obscure signals of interest (Hearst and Morris, 1994). In upward continuation method when there is overlap between numbers of closely spaced high-frequency anomalies, upward continuation may result in the merger of the individual features to form a single apparent broad feature. Roach et al. (1993) assessed the possible methods for separation of regional and residual gravity data of Tasmanian gravity field. He noted that polynomial fitting (trend surface analysis) provided the best numerical approach. Therefore it is more appropriate to compute from a gridded data, the best fit smooth surface using the least-squares polynomial fitting order and then remove the regional background. This quantitative approach is superior to the gravity anomaly wavelength filtering. If one knows the specific regional trends, major geological feature of interest can be adequately modeled. The Bouguer gravity anomaly is frequently used in geophysics to infer geological information from observed gravity (Keller et al., 1985). A regional anomaly component of Bouguer gravity field distorts and sometimes masks the relationship that exists between the shapes of the anomalies and the near surface geology (Gupta and Grant, 1985). Therefore, in this paper, it became imperative to prepare and compile the first residual gravity anomaly map of the Bandar charak. The residual gravity map is important from the stand point of defining geological structures and boundaries which are targets of geophysical exploration. The residual gravity map will be useful for the determination of the thickness of the basin and the study of the underlying basement. It will also be handy for tectonic studies, anomaly transformation and mineral exploration in the Bandar charak.

Multiple Regressions

Multiple regression estimates the outcomes (dependent variables) which may be affected by more than one control parameter (independent variables) or there may be more than one control parameter being changed at the same time.

An example is the two independent variables x and y and one dependent variable z in the linear relationship case:

$$z = a + bx + cy$$

For a given data set $(x_1, y_1, z_1), (x_2, y_2, z_2), \dots, (x_n, y_n, z_n)$, where $n \geq 3$, the best fitting curve $f(x)$ has the least square error, i.e.,

$$\Pi = \sum_{i=1}^n [z_i - f(x_i, y_i)]^2 = \sum_{i=1}^n [z_i - (a + bx_i + cy_i)]^2 = \min.$$

Please note that a , b , and c are unknown coefficients while all x_i , y_i , and z_i are given. To obtain the least square error, the unknown coefficients a , b , and c must yield zero first derivatives.

$$\begin{cases} \frac{\partial \Pi}{\partial a} = 2 \sum_{i=1}^n [z_i - (a + bx_i + cy_i)] = 0 \\ \frac{\partial \Pi}{\partial b} = 2 \sum_{i=1}^n x_i [z_i - (a + bx_i + cy_i)] = 0 \\ \frac{\partial \Pi}{\partial c} = 2 \sum_{i=1}^n y_i [z_i - (a + bx_i + cy_i)] = 0 \end{cases}$$

Expanding the above equations, we have

$$\begin{cases} \sum_{i=1}^n z_i = a \sum_{i=1}^n 1 + b \sum_{i=1}^n x_i + c \sum_{i=1}^n y_i \\ \sum_{i=1}^n x_i z_i = a \sum_{i=1}^n x_i + b \sum_{i=1}^n x_i^2 + c \sum_{i=1}^n x_i y_i \\ \sum_{i=1}^n y_i z_i = a \sum_{i=1}^n y_i + b \sum_{i=1}^n x_i y_i + c \sum_{i=1}^n y_i^2 \end{cases}$$

The unknown coefficients a , b , and c can hence be obtained by solving the above linear equations.

Theses equations can be written in matrix form as:

$$\begin{bmatrix} \sum 1 & \sum x_i & \sum y_i \\ \sum x_i & \sum x_i^2 & \sum x_i y_i \\ \sum y_i & \sum x_i y_i & \sum y_i^2 \end{bmatrix} \begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix} = \begin{bmatrix} \sum z_i \\ \sum x_i z_i \\ \sum y_i z_i \end{bmatrix}$$

This is in the form of $A.B=C$.



The elements of the matrices A and B are known. Since this is a low order system of equations the elements of the matrix of unknowns c can easily be evaluated from Cramer's formula.

Introduction to Surfer

Surfer is a grid-based mapping program that interpolates irregularly spaced XYZ data into a regularly spaced grid. Grids may also be imported from other sources, such as the United States Geological Survey (USGS). The grid is used to produce different types of maps including contour, vector, image, shaded relief, 3D surface, and 3D wireframe maps. Many gridding and mapping options are available allowing you to produce the map that best represents your data.

To Create a Grid File from an excel Data File

Create an excel data file. The data must be organized in columns: all X data in one column, all Y data in another column, and all Z data in a third column. Click the Grid | Data command, to display the Open Data dialog. Specify the name of the excel data file, and click Open. To link to a database instead of a data file, click the Database button. In the Grid Data dialog, specify the parameters for the type of grid file you want to produce. Click OK and the grid file is created. During gridding, the status bar at the bottom of the Surfer window provides you with information about the progress of the gridding process.

To use the Grid | Math command

Click the Grid | Math command. In the Grid Math dialog, click the Add Grids button. Select any number of grid files and click Open. All grids must contain the same number of grid rows and columns, and the same X and Y ranges. In the Output Grid File section, click the button to specify a different path or file name for the grid file to be created. In the Enter a function of the form $f(A,B, \dots)$ where A, B, \dots are the variables in the list above. box, enter a function that represents the output grid file, and where A and B refer to the input grid files. In this case A is Buguer anomaly and B is regional linear trend. As a mathematical function we defined $A-B$. Click OK to create the new grid file (residual grid).

Map Types

Several different map types can be created, modified, and displayed with Surfer. These map types include contour, Image Maps and Shaded Relief Maps, Vector Maps, 3D Surfaces, 3D Wireframes.

Contour Maps

A contour map is a two-dimensional representation of three-dimensional data. Contours define lines of equal Z values across the map extents. The shape of the surface is shown by the contour lines. Contour maps can display the contour lines; they can also display colors and patterns between the contour lines.



Image Maps and Shaded Relief Maps

Image maps and shaded relief maps are raster images based on grid files. Image maps assign colors based on Z values from a grid file. Shaded relief maps assign colors based on slope orientation relative to a light source.

Vector Maps

1-grid and 2-grid vector maps display direction and magnitude data using individually oriented arrows. For example, at any grid node on the map, the arrow points in the direction of steepest descent ("downhill") and the arrow length is proportional to the slope magnitude. In Surfer, vector maps can be created using the information in one grid file (i.e. a numerically computed gradient) or two different grid files (i.e. each grid giving a component of the vectors).

3D Surfaces

Surfaces are three-dimensional color representations of a grid file. The colors, lighting, overlays, and mesh can be altered on a 3D surface.

3D Wireframes

Wireframes are three-dimensional representations of a grid file. A wireframe is created by connecting Z values along lines of constant X and Y. At each XY intersection (grid node), the height of the wireframe is proportional to the Z value assigned to that node. The number of columns and rows in the grid file determines the number of X and Y lines drawn on the wireframe.

RESULTS AND DISCUSSION

Simple algorithm

```
1)calculate
totalx1=sum(X(:));(X=xlocation of all station matrix n*1 size)
totalx2=sum(Y(:));(Y=ylocation of all station matrix n*1 size)
powerx1=X.^2;
totalxpower=sum(powerx1(:));
powerx2=Y.^2;
totalxpower2=sum(powerx2(:));
xiyi=X.*Y;
totalxy=sum(xiyi(:));
totalggg=sum(ggg(:));
x1ggg=X.*ggg;
totalx1ggg=sum(x1ggg(:));
x2ggg=Y.*ggg;
totalx2ggg=sum(x2ggg(:));
totalxydata=sum(xydata(:));(xy data=ones(n,1))
```

2) design A matrix as bellow:

```
A=[totalxydata totalx1 totalx2;totalx1 totalxpower totalxy;totalx2 totalxy totalxpower2];
```

3) design C matrix as bellow

```
C=[totalggg totalx1ggg totalx2ggg];
```

4) $AA=A^{-1}$;

5) Calculate unknown coefficients

```
c=D*AA;
```

6) plot result

```
scatter3(X1,X2,ggg,'filled')
```

```
hold on
```

```
x1fit = min(X1):200:max(X1);
```

```
x2fit = min(Y):200:max(Y);
```

```
[X1FIT,X2FIT] = meshgrid(x1fit,x2fit);
```

```
TFIT = c(1) + c(2)*X + c(3)*Y;
```

```
mesh(X1FIT,X2FIT,TFIT);
```

7) save TFIT as a excel file and convert it to grid data with surfer or matlab

8) save Data=[X Y ggg] as a excel file and convert it to grid data with surfer or matlab (the same size of TFIT)

9) calculate Residual=Datagrid –TFITgrid with surfer or matlab

10) plot all type of graph with surfer or matlab

The result of the polynomial fitting is presented in the form of regional gravity field and the residual gravity field .The coefficients obtained from the analyses of the Bouguer gravity field are

C (1) =-3.34e-07

C (2) =0.0336

C (3) =-0.0164

Therefore, the regional gravity field over the charak is given by:

$$TFIT = C (1) + C (2)*X + C (3)*Y$$

The procedure of polynomial fitting by least squares technique to obtain the regional field data is commonly used in processing geophysical data. However, Ojo, and Kangkolo (1997) pointed out that the unguarded use of this procedure with measured field data may lead to erroneous regional fields. This is due to the fact that the least-squares technique pre-supposes a random variation of the residual. The degree of polynomial increases with increase in the size of survey area. Selection of too high an order polynomial might result in the introduction of inappropriate signal. The residual Bouguer gravity map is more closely related to the geology than the Bouguer gravity anomaly map.

Plot all Map Types

Figure 1. Matlab plot of Bouguer gravity map and regional map

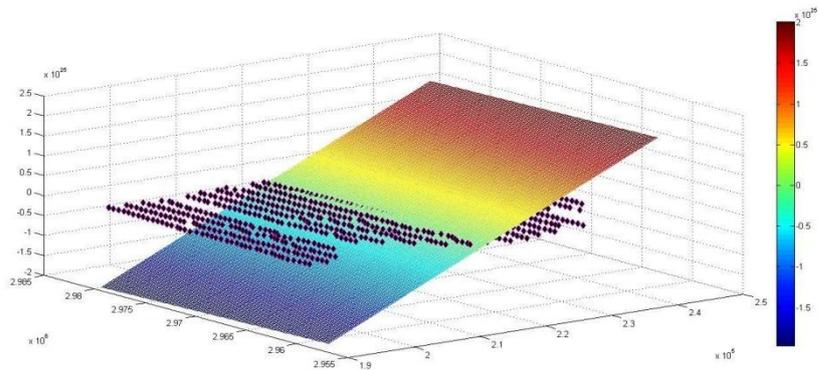


Figure 2. Contour Maps (a) Bouguer gravity map (b) regional map (c) residual map

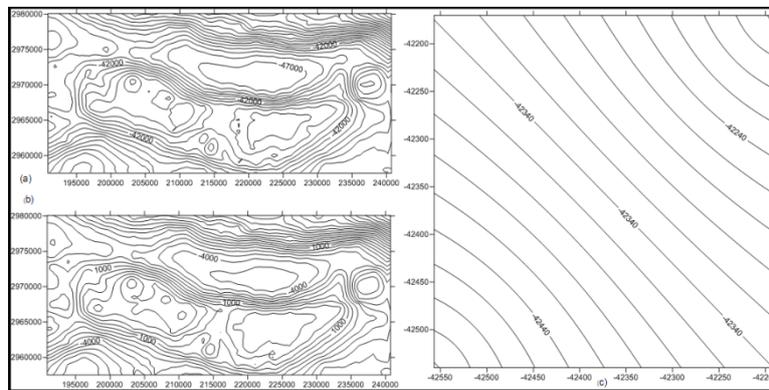


Figure 3. 3D Surfaces (a) Bouguer gravity map (b) regional map (c) residual map

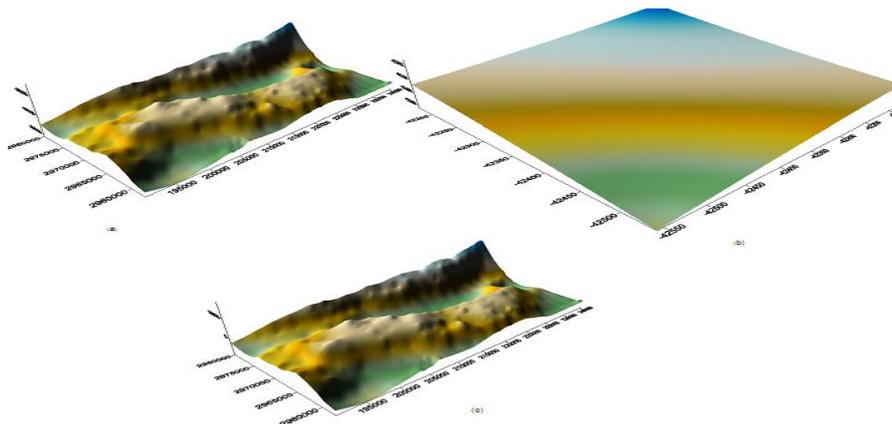


Figure 4.3D Wireframes(a) Bouguer gravity map(b)regional map (c)residual map

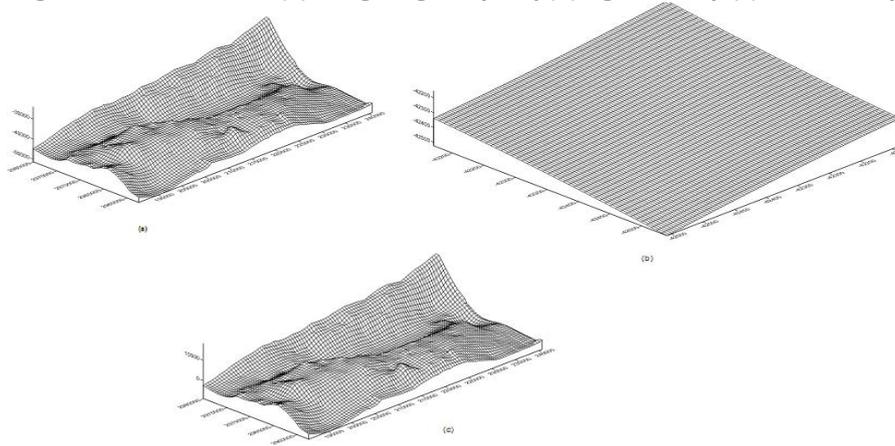


Figure 5. Image Maps and Shaded Relief Maps(a) Bouguer gravity map(b)regional map (c)residual map

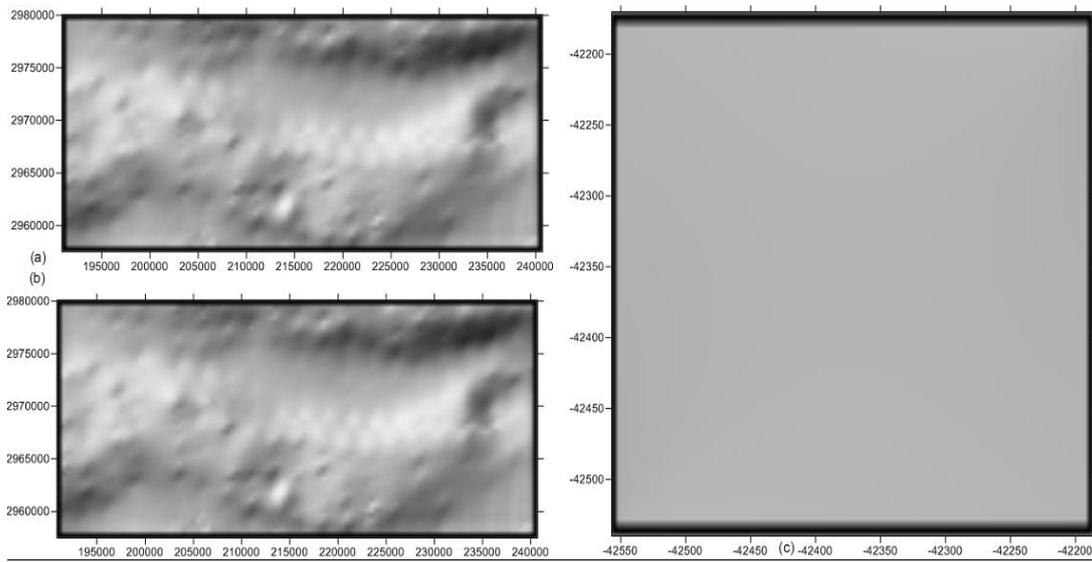
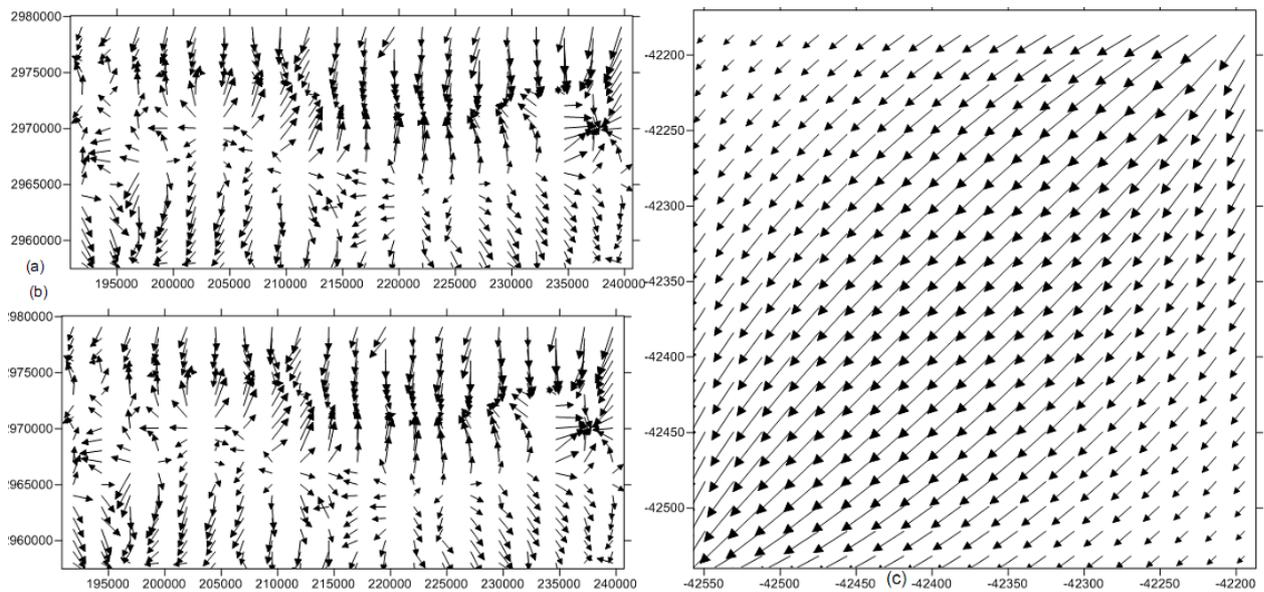


Figure 6. Vector Maps(a) Bouguer gravity map(b)regional map (c)residual map



CONCLUSION

The first order degree polynomial fit to the Bouguer gravity field is more amenable in this study because it represents the surface that best describes the regional gravity background of the Bandar charak. The area of study is relatively small and therefore the low order polynomial is more appropriate to this study. This approach is more quantitative than the wavelength filtering methods because if one knows the specific regional trends, major geological features of interest can be adequately modeled. Our algorithm is very simple for performing in all area.

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