Determine the Average Density Near the Surface Using Fractal Approach for a Gravity Data Set Reduction – A Case Study From Iran

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Abstract: The geophysical anomaly resulting from the fractal nature of sources such as nonrandom distribution of density cannot be accurately measured unless its fractal dimension does not exceed the difference of the 2-D Euclidean and fractal dimension of the network. The best value for density is that which minimizes the fractal component caused by topographic effects. In this paper is proposed feractal statistical method for surface average density determination that so-called variogram method. This technique assumes that the topography is fractal. This method is based on minimizing surface roughness of bouguer anomaly. The efficiency of the methods has been illustrated for a case study in Iran. The estimated density is 2.4 gr/cm3 that this value represents the best density to use in the Bouguer slab correction.
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1. Introduction

Knowing the bulk density is obviously important to interpreting gravity data. Whatever the precision of corrected gravity data be more, the results of the quantitative and qualitative interpretations will be more accurete. An error of 0.1 gr/cm3 in the reduction density, corresponding to an error of nearly 0.42 mGal in Bouguer anomaly for every 100 m, is not a very large error in itself but an error of 0.1 g/cm3 in the density may have a large effect on the interpretations of Bouguer anomalies (Yamamoto,1998). The near-surface density of the material under a hill can be determined by a prevalent method devised by L. Nettleton (1939) Nettleton´s method uses a profile measured across a topographic feature to find the best estimate of bulk density for a region. Thereafter, effective and efficient methods for density determinations from surface gravity measurements have been extensively developed (e.g. Parasnis, 1952; Rikitake et al., 1965; Fukao et al., 1981; Murata, 1993). Parasnis (1972) proposed an analytical method for calculation surface average density.

Most of these methods adopted statistical procedures using the correlations among Bouguer anomalies, free-air anomalies, station heights, and reduction density itself from surface gravity data. Thorarinsson and Magnusson (1990) and Chapin (1996) presented fractal analysis methods for Bouguer density determination. these methods associated with subsurface gravity measurements are valid only for quite limited area where the rock unit is reasonably homogeneous in composition. Gravity data are a complex appearance combination of scale-dependent and scale-independent (fractal) components.

The gravity effects of geological structures distributions with various density are essential scale-dependent. while topography is the primary scale-independent component. A necessary condition is that the surface must be fractal, which is to say it maintains its apparent roughness independent of the scale at which we look at it. This study involves gravity data from an region in north of Iran in the 60×55 km^2 area.

2. Material and Methods

Case study region

Figure 1 shows the location of the case study region, Sari. The Sari region has situated in the south of the Caspian sea, Iran. The northern part of this area has been covered by the Quaternary sediments such as loose alluvium, shore line sands, fluvial clay plain, young alluvium, silt and clay flats. The sediments and rocks of the geological formations related to the Neogene and Paleogene era such as silt, marl, silty marly limestone, gypsum, sand stone, silty marl and etc. has organized the middle and southern parts of the mentioned zone. Figure 2 displaies the topography map of the case study region.

Methodology

The detectibility limits of a large-scale geophysical measuring Network such as station spacing in gravity, magnetic depends on the fractal dimension of the network and the anomaly (Lovejoy et al., 1986; Korvin, 1992). The dimension D of a fractal line lies between 1 (the dimension of a straight line) and 2 (the dimension of a plane). Similarly surfaces can also have the fractal dimensions between 2 (a plane) and 3 (a solid volume) (Mandelbrot, 1975).

Plotting the variance of surface relief differences versus distance between points yields a graph on which a linear relationship over some range indicates self-similarity over that range. An estimate of the fractal dimension for that range is obtained from the slope b of a line through the points:

$$D = 3 - (b/2) \tag{1}$$

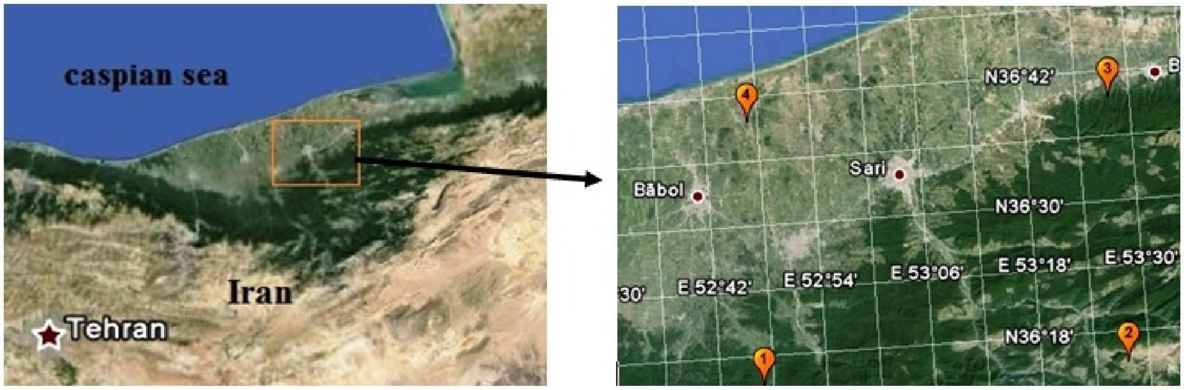

Figure 1. Situation of the case study region has been determined with the orange rectangular in the left picture. In the right picture, the orange cursors display the quadrangle of the case study region

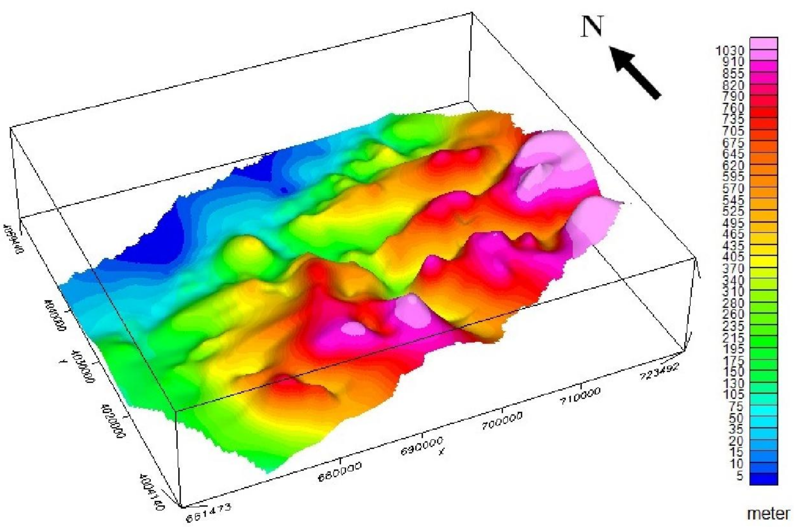

Figure 2. The relief map of the Sari region

The calculations for a given data set are carried out as follows. The maximum distance between points is limited to the diameter of the largest circle that can be fitted within the area under consideration. This maximum distance is divided into several equal classes. The variance of Bouguer anomaly differences is calculated for each class and plotted logarithmically versus the logarithm of the distance value of the class. The plot is then analyzed visually to determine whether a least squares regression line can be fitted to the values, or to some range of the values. Finally, the fractal dimension is derived from the slope of the fitted line.

This approaches are based on computed Bouguer anomalies using different densities. The described method apply for the resulted Bouguer grids using different density values. The expectancy of this methods are to find the density that the final result should be a optimum near-surface density that best reduces all the data.

3. Results

Bouguer density determination

Because the gravity sampling have well covered the eastern part of the study region, we apply the fractal technique for this portion. The expressed purpose of the Bouguer gravity correction is to eliminate the effect of the mass associated with the topography. For achieve this goal we spotted two states. figure 3a shows the gravity reading stations in the under study region (black points) that a circle has been fitted on measurement points. This circle has been divided into 40 equal classes.

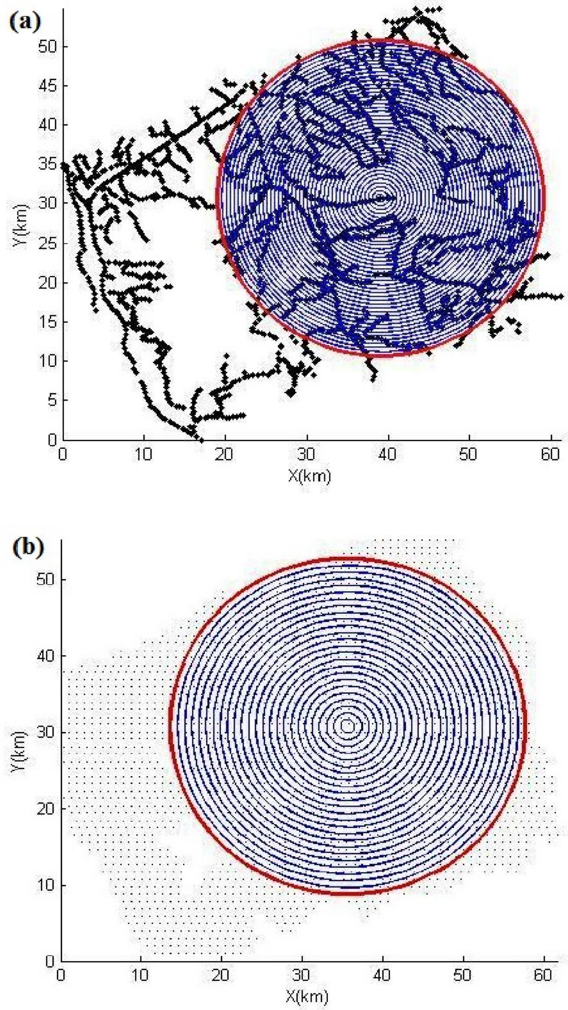

Figure 3. (a) the black points indicate the gravity reading stations in the study region. the circle has been divided into 40 equal classes. (b) the black points indicate the interpolated points with kriging method. the circle has been divided into 25 equal classes.

A matlab code has been developed that compute the Bouguer anomalies using various densities and after cubic interpolation sample from each Bouguer grids with equal intervals.

The variogram was plotted for the Bouguer anomalies with 12 categories of the densities values from 1.7 to 2.8 gr/cm^3, according to classification of the figure 3a. Figure 4b presents the curve the fractal dimention versus the density for figure 3a. The minimum value of the fractal dimention namely 2.74 is depending to 2.4 gr/cm^3 density. In second state kriging interpolation and sampling with 1000 m interval was completed using the geosoft software for the Bouguer anomalies. figure 3b shows the gravity sampling points that a circle with 25 equal classes has been drawn.

For the Bouguer grids was plotted the variance of each class versus distance. Figure 4a presents the curve the fractal dimention versus the density for figure 3b. The minimum value of the fractal dimention for the 25 classification namely 2.65 is depending to 2.4 gr/cm^3 density. This density can be considered the least fractal, in other words, the effects of topography are minimized at this density.

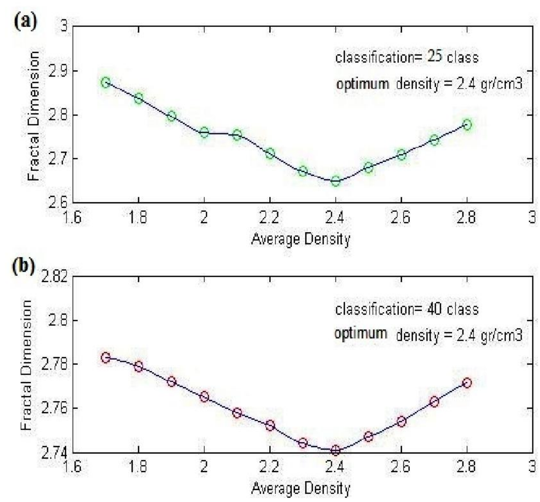

Figure 4. (a) Curve the computed fractal dimension versus the density for 25 classification. (b) Curve the computed fractal dimension versus the density for 40 classification.

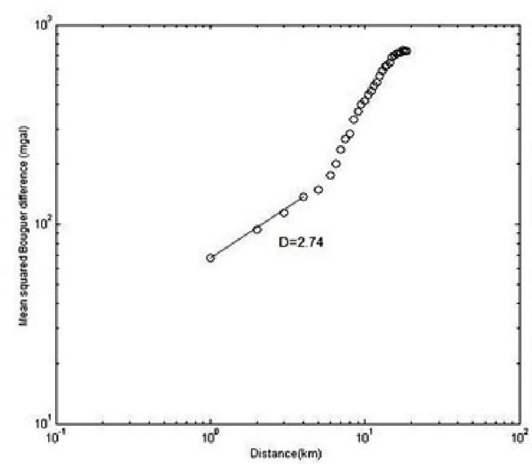

Figure 5. Variogram for computed Bouguer anomaly with assumption 2.4 gr/cm^3 density and 40 classification in the Sari region. The fitted line indicates a fractal surface. Only classes with a minimum of 30 anomaly differences are plotted.

Figure 5 shows the plot of the resulted mean squared Bouguer difference from 2.4 gr/cm^3 density versus the distance for 40 classification. Only classes with a minimum of 30 anomaly differences are plotted. A straight-line least-squares has been fitted to the first four classes. According to equation 1 calculated the 2.74 value for the feractal dimention. Similarly for the 25 classification a straight-line least-squares has been fitted to the second until fourth classes (figure 6). The computed fractal dimention is 2.65.

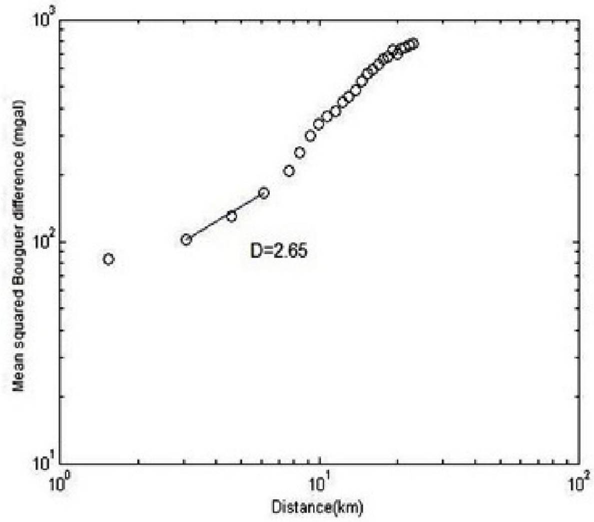

Figure 6. Variogram for computed Bouguer anomaly with assumption 2.4 gr/cm^3 density and 25 classification in the Sari region. The fitted line indicates a fractal surface

Figure 7 shows the Bouguer anomaly map of the area under consideration using 2.4 gr/cm^3 density.

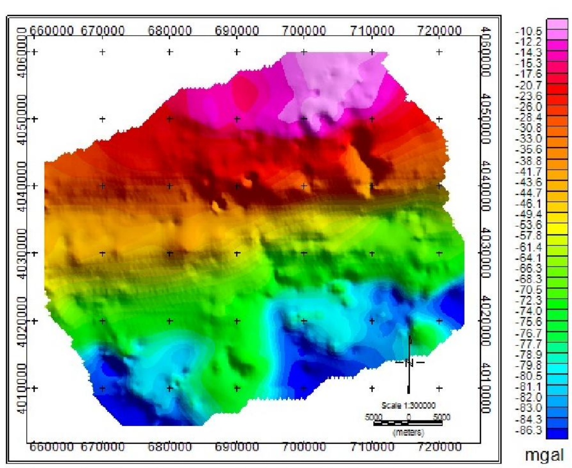

Figure 7. The Bouguer anomaly map. the 2.4 gr/cm^3 density value has been adopted

4. Discussions

The feractal behavior is the essential condition for determine the average density near the ground surface using the Bouguer anomalies. The linear relationship in figures 5 and 6 indicates a fractal surface. The more well-known approach is the Nettleton´s method that widely used to obtain an optimal average density value, but in some regions specific the flat area diminish of its efficiency. The feractal method restrain its proficiency in areas with the different morphology. In this paper examined two kind of the interpolation, kriging and cubic with different classification. The consequence for each two states is identical, that is 2.4 gr/cm^3 density.

Obtained optimum density 2.4 gr/cm^3 has good conformity with geological formation in the Sari region and is best density that reduces all the gravity data set.

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References

1. Yamamoto A. Estimating the Optimum Reduction Density for Gravity Anomaly: A Theoretical Overview. Jour. Fac. Sci., Hokkaido Univ., Ser. 1998: VII (Geophysics), Vol. 11, No.3, 577-599.
2. Nettleton L.L. Determination of density for the reduction of gravimeter observations. Geophysics. 1939; 4: 176-183.
3. Parasnis D.S. A study of rock density in the English Midlands. Mon. Not. R. Astron. Soc. Geophys. Supp!. 1952; 6: 252-271.
4. Rikitake T, Tajima H, Izutuya S, Hagiwara Y, Kawada K, Sasai Y. Gravimetric and geomagnetic studies of Onikobe area. Bul!. Earthq. Res. Inst., Univ. Tokyo. 1965; 43: 241-267.
5. Fukao Y, Yamamoto A, Nozaki K. A method of density determination for gravity correction. l Phys. Earth. 1981; 29: 163-166.
6. Murata Y. Estimation of optimum average surficial density from gravity data: An objective Bayesian approach. J. Geophys. Res. 1993; 98: 12097-12109.
7. Parasnis D.S. Principles of aPPlied geophysics. Third edition, Chapman and Hall, London,. 1979; 275 pp.

8. Mandelbrot, B. B. Stochastic models of the Earth's relief, the shape and the fractal dimension of the coastlines, and the number-area rule for islands: Proc. Nat. Acad. of Sci. 1975; 72: 3825-3828.
9. Chapin A. A deterministic approach toward isostatic gravity residuals—a case study from South America, Geophysics. 1996; 4: 1022–1033.
10. Lovejoy S, Schertzer S, Ladoy P. Fractal characterization of homogeneous geophysical measuring network: Nature. 1986; 319: 43-44.
11. Korvin G. Fractal models in the earth sciences: Elsevier Science Publishers. 1992.
12. Thorarinsson F, Magnusson S. G. Bouguer density determination by fractal analysis: Geophysics. 1990; 55: 932-935.

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