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Estimate the Crust Thickness using the Gravity Data for the KopehtDagh Region

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Abstract

Thickness determination of the crust using gravity data is one of the fundamental researchers in the earth sciences and Geodesy. Moho depth represents a major change in seismic velocities, the chemical compositions and lithology and its depth is used in determining of overall structure of the crust and zone tectonic. The purpose of this study is to determine the crust thickness of the Kopeht Dagh region that for this aim was used the terrestrial gravity data of Iran's National Cartographic Center (NCC) and Bureau Gravimetrique International (BGI). First was calculated free air anomaly, simple bouguer correction and topographic correction and through them was calculated complete bouguer anomaly to determine crust thickness by using gravity data. Complete bouguer anomaly information entered in inversion process in the frequency space with Parker – Oldenburg method and thus was calculated Moho depth for desired region. We observe about 200 mlGal positive free air anomaly in high areas and about -42 m gal negative free air anomaly in low-lying areas in Iran. According to the results of this research for tectonic zone of Kopeht Dagh was calculated the maximum and minimum of complete bouguer anomaly -83.3 and -216.3 mlGal respectively and finally was determined maximum and minimum of crust thickness 55.9 and 36.6 km in Kopeht Dagh.

Keywords: Anomaly, Bouguer, Crust Thickness, Gravity, Kopeht Dagh

1. Introduction

Below ground level which we step, has its own specific feature unlike its hard and solid surface. State of the material changes with increasing depth. The ground are divided into several layers, based on physical and chemical properties change and the speed of seismic waves in it, that its core layers are crust, mantle, internal and external core. The crust thickness varies from place to place, but generally has its maximum value in below of continental mountains. The thinnest crust can be seen in oceans, especially near the oceanic ridges. The crust forms relatively thin layer on the earth with approximately a thickness of 20 to 70 km in continents and 7 to 12 km in oceans. Below this layer is the mantle. Discriminant boundary between mantle and crust of the earth that for first time was diagnosed with see a sudden increase in the speed of seismic waves in below the areas of thin crust in Europe, in 1910 by Andrija Mohorovicic, called Moho border. Tchalenko[1] said this boundary represents a major change in seismic velocities, the chemical compositions and lithology and its depth is used in determining of overall structure of the crust and zone tectonic. The crust thickness in different areas can be examined by study of Moho depth.

Since Iran has a certain complexity of the viewpoint geological structure and tectonic movements, check the crust thickness is important in study of geological structures of different areas. The point that must be considered in the study of the Moho depth is study of reasons for difference of Moho depth in various regions of the case study area.

One of the aims of Moho depth study can be check and study reasons for the difference crust thickness

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in various regions and check of its association with geological structures and tectonic movements of the case study area. The results of Moho depth study will be a well guide for the interpretations of geology including of checking mountain areas in terms of being rooted or not rooted mountains, study of subduction zones and communication of under its compression areas and stretching areas with crust thickness. Also check of Moho depth and crust status has been one of the most recent studies of seismologists in the world. Accurate recognition of crustal discontinuities is important in determining the correct location of earthquakes, the depth of seismic zone, earthquakes mechanism, lowering relations calculation.

2. Gravity Anomalies

Gravity anomaly is oscillating quantities that express degree of separation of actual gravity field of the earth from its normal field. One of the studies applications on gravity and gravitational anomalies is to obtain discontinuities surface caused by the density difference that is created this anomaly. In general they can express factors that effect on measured gravitational acceleration by Gravity Meter machinery as follows:

1) Mass, shape and rotation of the Earth
2) Measuring point height of gravity acceleration
3) Tidal effects of the sun and moon
4) Move of measuring device of gravity acceleration
5) Gravitational effects due to topographic mass of measurement point and the area around measurement point.

To calculate complete Bouguer anomalies quantity should be made some corrections on the measured quantity of gravitational acceleration.

2.1 Correction as for Mass, Shape and Rotation of Normal Earth

Because of non-uniform distribution of density on the earth, measured gravitational acceleration has been different from one point to another and equipotential surfaces around earth will not be flat and smooth. An equipotential level that is used in gravitational studies is geoid level that according to definition is equipotential level that to a best way is elegant on the high seas. With placement of related parameters for elliptic WGS84 can be reached to the following formula:

$$g_0 = 9.7803267714 \frac{1+0.00193185138639}{\sqrt{1-0.00669437999013\, sin^2 \lambda}} \quad (1)$$

A quantity that obtains from the above equation is called earth's normal gravity acceleration or theory gravity acceleration.

2.2 Measurement Point Height than the Geoid Level and Free Air Anomaly

With respect to general relation $g(\mathrm{r}) = -\frac{\gamma M}{r^2}$ for gravity acceleration is obviously whatever the distance of measurement point of gravity acceleration be higher from its caused source, measured acceleration quantity will be less. $\delta g^{FA} = 0.3086 H_p^0$ called free-air correction and free air gravity anomaly equation as follows:

$$\Delta g_{fa} = g_{obs} - g_o - g_{fa} \quad (2)$$

In the above equation Δg_{fa} is free air anomaly quantity, g_0 is theory acceleration and g_{obs} is measured gravity acceleration quantity.

2.3 Calculating of Simple Bouguer Anomaly by Infinite Flat Layer Method

Simple Bouguer correction of all masses of higher than sea level is estimated with a long homogeneous layer with a thickness equal to measuring point height above sea level.

Gravity acceleration from an infinite flat layer will be calculated from the following equation:

$$g_{sb} = 2\pi\gamma\rho h \quad (3)$$

In which h is layer thickness, γ is universal constant of gravitation, ρ is medium layer density, g_{sb} gravity from layer.

$$g_{sb} = 0.1119 * 10^{-5} h \quad (4)$$

In the metric system, g_{sb} is in meters per second squared, h is in meters and in CGS system, g_{sb} is in gal and h is in centimeters.

2.4 Gravitational Effects due to Topography around Measurement Point

To calculate complete Bouguer anomaly, correction due to the roughness effect around measurement point that is called topographic correction, it should be added to anomaly of simple Bouguer quantity (Figure 1).

If we show the effect of topography with g_{tc} for anomaly of complete bouguer quantity can be written as follows:

$$\Delta g_{cb} = \Delta g_{cb} + g_{tc} \quad (5)$$

In the above equation Δg_{cb} is simple Bouguer anomaly and g_{tc} is gravity acceleration caused by topography. One of the most common methods for calculating the effect of topography is traditional method of Hammer circles. Since the topography has no particular order, it was not possible to calculate this effect from analytical way and should be used numerical integral on the desired area. In Hammer circles method the case study area is divided into parts in order to obtain the topography effect. Topographic distribution is calculated in any particular area, after obtaining the correction of each section, effects resulting from all sections are added together to calculate the total effect.

Blakely[2] showed Topographic correction equation is as follows:

$$g_{tc} = \gamma\sigma\Delta\theta\left[\Delta a - \sqrt{(a+\Delta a)^2 + \Delta H^2} + \sqrt{a^2 + \Delta H^2}\right] \quad (6)$$

The above equation show gravitational effect resulting from a portion. The gravitational effect of topography will be calculated around viewed point by gathering above relation on the entire area around measurement point.

$$g_{TC} = \gamma\sigma\sum_{l}\sum_{j}\Delta\theta_j \left[a_{l+1} - a_l + \sqrt{a_l^2 + \Delta H_{j.l}^2} - \sqrt{a_{l+1}^2 + \Delta H_{j.l}^2}\right] \quad (7)$$

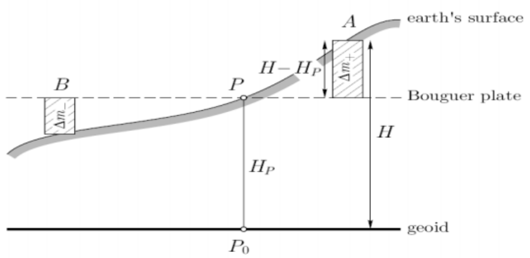

Figure 1. Topography effects.

3. Oldenburg Method, Inversion Process and Iterative Algorithm to Calculate the Height of the Layer

Parker-Oldenburg's Inversion Method is based on direct Parker algorithm. Parker[3] showed how the Fourier series can be used to calculate the gravitational or magnetic anomalies caused by rough and uneven layers. One of the oldest methods of modeling the gravitational and magnetic fields is comparing the observed and calculated field from the model.

In general, the advantage of using a Fourier series to obtain a gravitational anomaly as follows:

1) Going up speed of calculations
2) Use of high volume input

Oldenburg[4], proposed a method in which achieved the discontinuity Moho depth with knowing anomaly of complete bouguer in the observation level according to Parker method. This method is based on the Parker algorithm. According to this method, we can write the following equation for obtain the height of the layer:

$$F\left[h(x)\right] = \frac{-F\left[\Delta g(x)\right]e^{|k|z_0}}{2\pi\gamma\rho} - \sum_{n=2}^{\infty}\frac{|k|^{n-1}}{n!}F\left[h^n(x)\right] \quad (8)$$

$$h(x) = F^{-1}\left[\frac{-F\left[\Delta g(x)\right]e^{|k|z_0}}{2\pi\gamma\rho}\right] - F^{-1}\left[\sum_{n=2}^{\infty}\frac{|k|^{n-1}}{n!}F\left[h^n(x)\right]\right] \quad (9)$$

Based on Oldenburg method we can obtain discontinuity Moho depth with knowing density difference between crust and mantle ($\Delta\rho$) and also average Moho depth (Z_0) for case study area with having anomaly of complete bouguer and using of inversion process.

4. Geological Structure of KopehtDagh

KopehtDagh region that its name derived from highest geological structure of the area namely KopehtDagh Mountain form structurally the boundary between Iran and Turan. KopehtDagh region is formed northern Limit of Alps-Himalaya mountain belt in north-eastern Iran and its two major mountain namely KopehtDagh and Binalud with together have created long mountain belt as length of 600 km and a width of 200 km, the highest elevation in the series is 3000 meters and have a clear boundary with a height of 100 meters of Turan plate. We consider the western border of KopehtDagh region and caspian Lake coast and about 55° eastern and the eastern border of about 60 degrees eastern, a place where seismicity is significantly decreased (Figure 2).

5. Information Analysis

We calculate the quantity of free air anomaly by applying corrections for normal ground and free air. Used data are terrestrial gravity data from national cartographic organization and BGI and we observe about 200 mlGal positive anomaly in high areas and about -42 m gal negative anomaly in low-lying areas in according to the map (Figure 3).

With calculating correct of simple Bouguer and topographic correction was calculated complete bouguer anomaly and was prepared the following map (Figure 4).

Maximum amount of complete bouguer anomaly in KopehtDagh zone is -83.2 mlGal and minimum value is -216.3 mlGal. We used Gomez program for the inversion process after calculating the complete bouguer anomaly. According to the results of seismic studies for this area, was considered the input parameters in the inversion program as $= 0.3\frac{gr}{cm^3}$, $Z_{0=46}\,km$ and was calculated Moho depth of the area and was drawn up the following map (Figure 5).

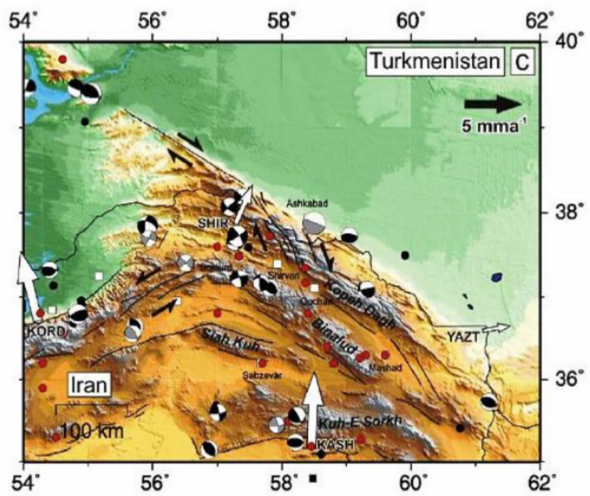

Figure 2. Map of Iran's North East by Stoklin[5].

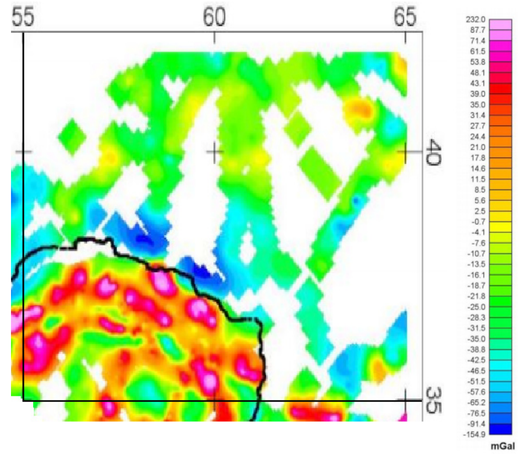

Figure 3. Free-Air anomaly.

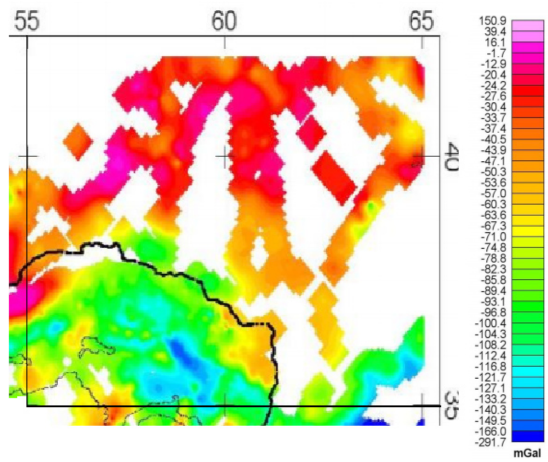

Figure 4. Bouguer anomaly.

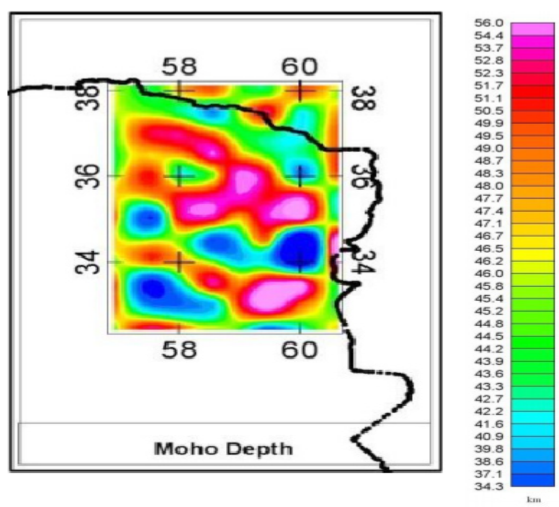

Figure 5. Moho Depth.

As we can see from the map, maximum of Moho depth is 55.9 km in KopehtDagh zone and minimum crust thickness is 36.6.

6. Conclusion

Crust thickness was measured between 36.6 to 55.9 Km by using of terrestrial gravity data in the desired range. Comparison of the results of this study and the results obtained by the Dehghani and Makris[6] indicate a good correlation between the results of the two studies and also shows that Parkr-Oldenburg method has a relatively high speed of convergence so that Moho depth was calculated for the area in fourth iteration.

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