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Digital Analysis of Gravity Data of the Absheron Peninsula

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Abstract: The depth structure of the crust of the Absheron Peninsula was studied based on gravimetric data. Modern methods of mathematical processing and interpretation were used in the research work. Numerical analysis of gravity data of the research area was performed using Hartley transform and Butterworth filter. The Spector-Grant method was used to determine the average depth state of the masses causing the anomaly based on the values of the gravitational field power spectrum. The power spectrum of the gravitational field of the research area was analyzed to determine the cutoff frequency and the average depth of the density interface that form gravity anomalies. The average depth values of the density interface forming gravity anomalies were determined to be 6.8 and 36 km. As a result of applying the Parker-Oldenburg's method to the regional gravity anomalies of the Absheron Peninsula and adjacent areas, a model of the depth of the crust-lithosphere boundary (Moho) was created. Inversion estimation of the gravity field using the Parker-Oldenburg's method show that the depth of the Moho boundary on the Absheron Peninsula varies between 40-46 km. A gravity anomaly map of the Moho boundary was created applying the forward modeling algorithm. The main purpose of the research is to study the gravity anomalies of the Absheron Peninsula as a result of spectral analysis and to get the gravity model of the depth of the Moho boundary by applying the Parker-Oldenburg's method.

Keywords: Absheron peninsula, Gravity anomaly, Gravity model

Introduction

The Absheron Peninsula is located on the western shores of the Caspian Sea, at the southeastern end of the Greater Caucasus. The Absheron Peninsula is located in the western segment of the Absheron-Balkhan uplift zone of the Caspian mega-depression, and since it occupies a transitional position between the South-Eastern Caucasus and the Caspian basin, its internal structure belongs to the structures of the mountain-fold system. The main peculiarities of the Earth's crust have been studied by a number of researchers on the basis of gravity field data of the Absheron Peninsula (Hajiyev, 1965; Kadirov, 2000a). In recent years, many mathematical methods have been proposed based on numerical analysis of gravity field data to separate regional and local gravity anomalies, to estimate the depths of anomaly-causing sources, and to clarify the structure of the crystalline basement and sedimentary layer (Serkerov, 2000; Kadirov, 2000 b; Blakely, 1996).

The aim of the article is to carry out a numerical (spectral) analysis of the gravity field of the Absheron Peninsula and adjacent areas and to get a gravity model of the Moho boundary using the Parker-Oldenburg's method.

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

Gravity Anomalies of the Research Area

The research area is located in the area of minimum gravity on the map of Bouguer gravity anomaly compiled for the territory of Azerbaijan (Hajiyev, 1965; Tsimelzon, 1979; Kadirov, 2000a). The distribution of gravity anomalies in the Bouguer reduction of the research area is shown (Figure 1). A negative anomaly area is observed in the Absheron Peninsula and adjacent areas. The minimum area covering the Absheron Peninsula, Gobustan, Absheron Ridge, the Baku Archipelago and the seaward part of the Pre-Caspian-Guba zone is called the Azerbaijan minimum gravity.

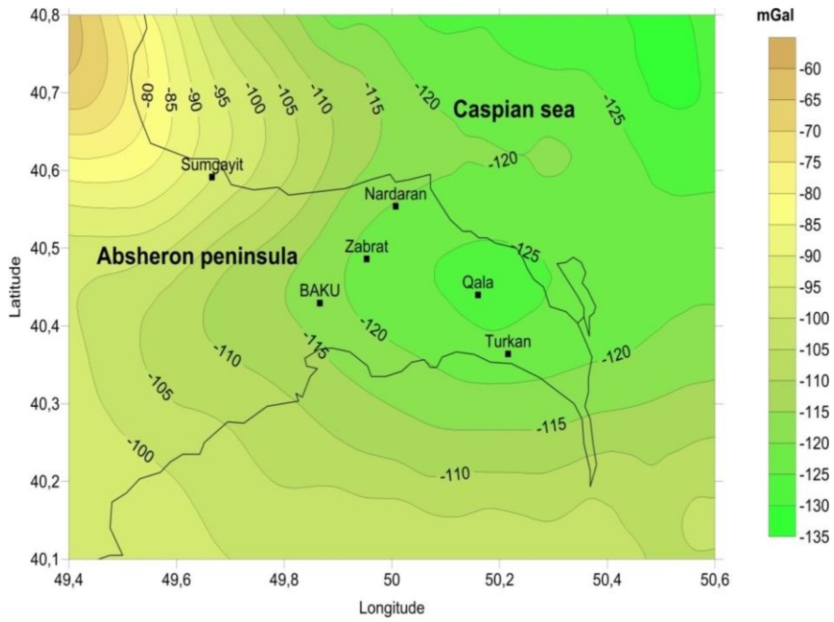

Figure 1. Bouguer gravity map of the Absheron Peninsula

The extremum value (-125 mGal) of the negative anomaly is located in the north of the Absheron Peninsula. This minimum area is bounded by the Azerbaijan maximum in the south-west part. The Dubrar relative maximum is located in the north-western part of the research area. Analysis of the gravity field shows that the average depth of the crystalline basement in the Absheron Peninsula is 18 km. The maximum depth of subsidence of the crystalline basement (23 km) is noted in the area of Yavany Mt.–Pirsaat–Gobustan and around Gala. In the zones of Dubrar Mt. and Yavany Mt.–Sangachal, the crystalline basements occurs at 6 and 12 km, respectively. The major part of the regional anomalies is caused by the topography of the pre-Mesozoic crystalline basement (Kadirov, 2000c).

The Power Spectrum of the Gravity Field of the Absheron Peninsula

Spectral analysis of gravity field data using the Spector-Grant method allows us to estimate the average depth of anomaly-causing density interface (Spector & Grant, 1970; Kamto et al., 2021; Kadirov, 2000a; Kadirov et al., 2024). A map of gravity anomalies in the Bouguer reduction was created of the research area to estimate the depth of the anomaly-creating sources in the frequency domain of the gravity field data in the research area (Figure 1). In order to interpret gravity anomalies, the coordinate origin is placed in the southwest corner of the Bouguer anomaly map, and the area is divided into a grid with a step of 5 km. The Bouguer anomaly value was determined at the intersection points. The X axis points the eastward and the Y axis points the northward. The number of elements on the X axis (N_x) and Y axis (N_y) was chosen as N_x=23 and N_y=17.

The Hartley transform was applied to gravimetric data at the intersection points of the 23x17 grid of the research area, divided by 5 km steps. The dependency graph of the logarithm of the power spectrum on spatial frequency was created to determine the depth of the anomaly-causing objects (Figure 2). The resulting graph consists of straight-line segments, the curves of which decrease as the frequency increases. Each line part corresponds to a discrete density interface.

The average depth of anomalous objects is determined by the following formula:

$$h = \frac{LnA(k_2) - LnA(k_1)}{2(k_2 - k_1)} \tag{1}$$

where k_1 and k_2 are the spatial frequencies at points 1 and 2, from which the value of - *LnA(k)* is taken. The *LnA(k)* values of the logarithm of the power spectrum are taken from the straight line drawn to these values.

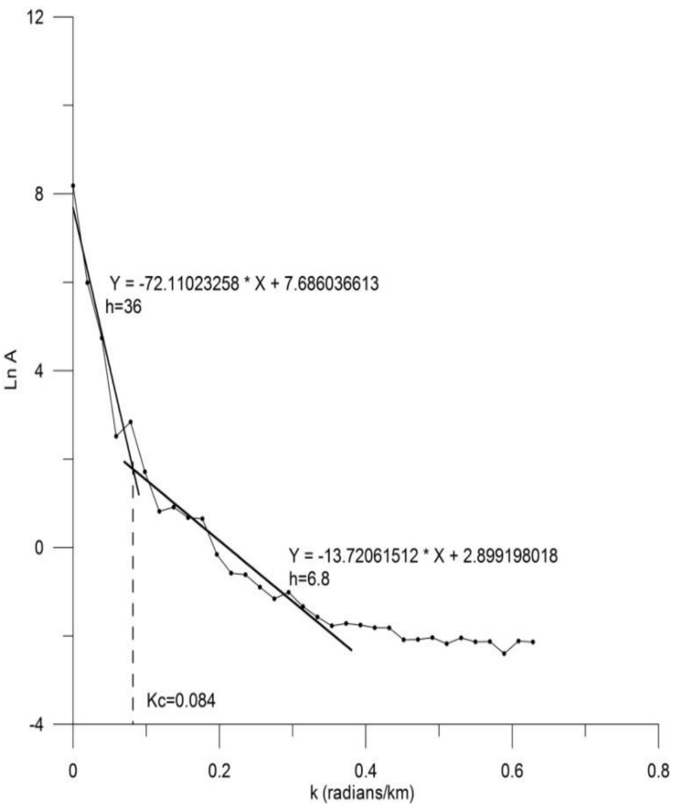

Figure 2. Logarithmic curve of the power spectrum of the Bouguer gravity field of the Absheron Peninsula and adjacent areas

Low-frequency and high-frequency fields associated with deep and shallow gravitational anomaly sources appear in the logarithmic curve of the power spectrum, respectively. Low-frequency and high-frequency areas are regional and local anomaly areas. The interface of the regional and local anomaly areas is determined by the intersection point of the straight lines built for these areas. The frequency corresponding to this point is called the cutoff frequency. It is possible to distinguish regional and local anomalies using a filtering operation and a cutoff frequency (Sadigova, 2018; Sadygova, 2020).

The cutoff (spatial) frequency (wave number) of the logarithm curve of power spectrum of the Bouguer gravity field was determined as k_c=0.084 rad.km^{-1} in the research area. According to the slope of the curve, the average depth of the density interface, intense anomaly-causing in the Earth's crust, was determined to be 36 km in the long-wave region and 6.8 km in the short-wave region.

According to the values of power spectrum of the gravity field, the anomaly-causing density interface with an average depth of 6.8 km is assumed to be related to the surface relief of Mesozoic sediments. The tectonic structure of the Absheron depression during the Mesozoic has been poorly studied by deep drilling and geophysical researches.

Method

The Parker-Oldenburg's method is an inversion method used for the analysis of gravimetric data in geophysics and the analysis of the structure of the Earth's crust. This method is used to identify underground structural alterations and to obtain information about its geological structure. This is mainly effective in the analysis of gravitational anomalies, especially in the researcg of the boundary between the Earth's crust and the lithosphere.

One of the main tasks of geophysical study is to determine the geometry of the interface from gravity anomaly, Parker-Oldenburg algorithm was used to obtain the 3D geometry of interface topography from the relationship between the Fourier transform of gravity data and the sum of the interface topography's Fourier transformation.

The Parker-Oldenburg inversion algorithm is defined as follows:

$$F\left[h(x)\right] = -\frac{F\left[\Delta g(x)\right]e^{(-kz_0)}}{2\pi G\rho} - \sum_{n=2}^{\infty}\frac{k^{n-1}}{n!}F\left[h^n(x)\right] \quad (2)$$

This algorithm is given as equation (2) iteratively from the given depth and density of an interface by (Parker, 1973), to calculate the gravity anomaly of uneven homogeneous layer by using the Fourier transform where, $F(\Delta g)$ is the Fourier transform of the gravity anomaly, G is the gravitational constant, ρ is the density contrast across the interface, K is the wave number*,* $h(x)$ is the depth to the interface (positive downwards) and z_0 is the mean depth of the horizontal interface. Oldenburg (1974) rearranged this equation to calculate the undulating interface depth.

The present equation (2) is a useful tool for calculation of density interface topography iteratively from Δg and z_0. From the beginning of the iteration, assignment of $h(x) = 0$ or an approximated value is assigned to the right part of the equation. Its inverse Fourier transform provides the first estimation of the topography. This topography value was used in calculation of the right hand sight of the equation to achieve the second topography approach. Until the convergence criterion is achieved; or until reaching the determined iteration number; or until the difference between successive steps is smaller than the convergence criterion, the iteration process continues. 3DINVER.M MATLAB program, developed by Gomez and Agarwal (2005) to compute 3D density geometry of the interface's from gridded gravity anomaly was used.

Results and Discussion

Estimation of the Depth of Moho Boundary in the Absheron Peninsula Using the Parker-Oldenburg's Method

Figure shows the results obtained from the application of the 3DINVER.M function. As a result of inversion estimation of the gravity field using the Parker-Oldenburg's method, a depth distribution model of the Moho boundary for the Absheron Peninsula was created (Figure 3). The depth of the surface varies between 40-46 km. The maximum valuesof the depth of the Moho surface are observed in the Gala and Turkan areas of the Absheron Peninsula and in the Caspian Sea (46 km). The depth decreases to 44 km in the northwest of the Absheron Peninsula (around Sumgayit and Baku).

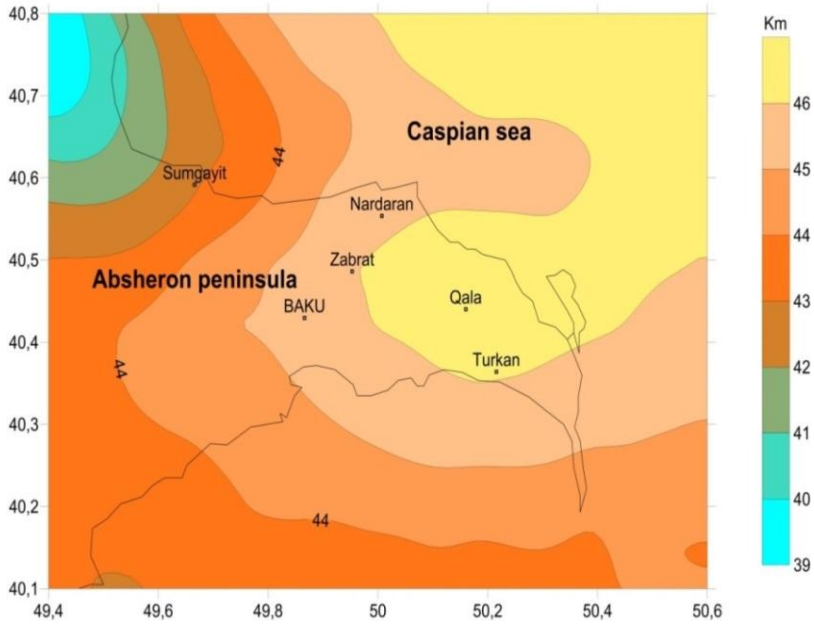

Figure 3. Depth distribution model of the Moho boundary in the Absheron Peninsula

Figure shows the gravity anomaly map obtained from the depth distribution model of the Moho boundary of the Absheron Peninsula using the forward modeling algorithm (Figure 4). The anomaly value is higher in the northeastern areas of the Absheron Peninsula (Nardaran, Caspian Sea).

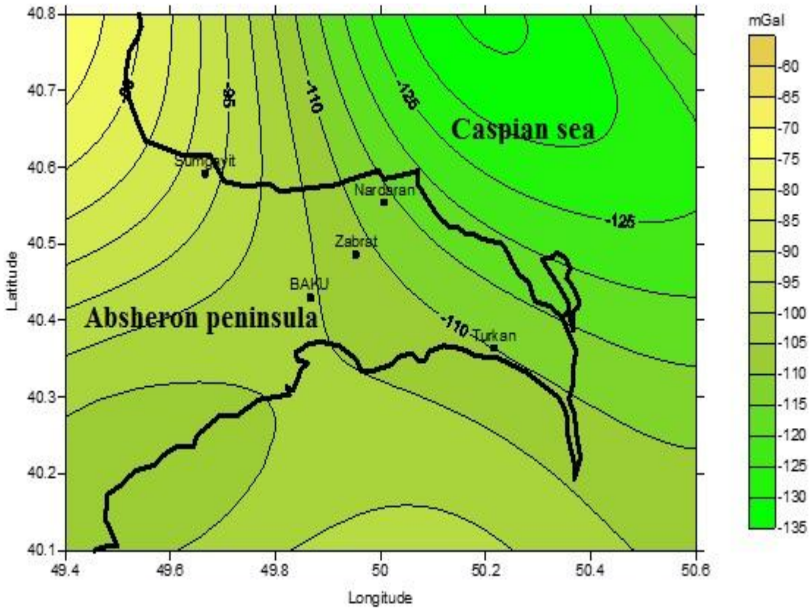

Figure 4. Gravity anomaly map obtained from the depth distribution model of the Moho boundary by inversion estimation

The difference map between the gravity anomalies obtained and observed from the estimated model of the Moho boundary is shown (Figure 5). The difference between the gravity anomalies estimated and observed from the Moho surface varies between -15 and 12 mGal. Negative differences of more than -10 mGal are observed in the territories of Baku, Turkan and Zabrat. Positive differences of up to +10 mGal are observed in the northeastern and southwestern parts of the map.

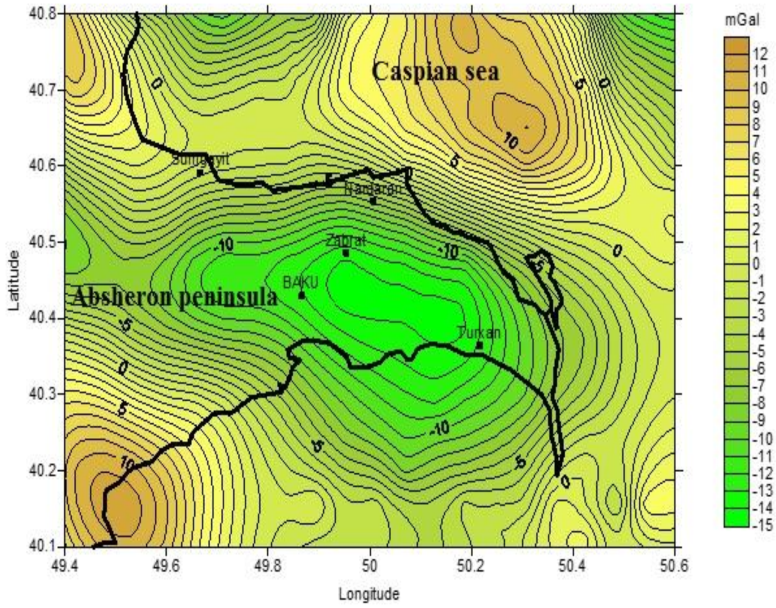

Figure 5. Difference map between gravity anomalies observed and obtained from the estimated model of Moho boundary

Conclusion

The depth of geological boundaries based on density alterations in the Earth's crust was estimated by using the spectral analysis method of the Bouguer gravity field. The spatial frequency in the logarithm curve of the power spectrum is determined as k_c=0.084 rad.km^{-1}. The long-wave components reflect a deep density interface in the Earth's crust, and the average depth of this interface is estimated to be 36 km. The short-wave components show a shallower geological boundary with a density alteration at a depth of 6.8 km. As a result of inversion estimation using the Parker-Oldenburg's method, a depth distribution model of the Moho surface for the Absheron Peninsula was created. The model shows that the depth of the Moho boundary varies between 40-46 km, and the greatest depths are observed in the Turkan and Gala areas of the peninsula.

Recommendations

The results obtained can be used by scientific and industrial organizations to address various geological, geophysical, and geodynamic problems, and to investigate new geological structures.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the authors.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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