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Filtering Gravity Data of Caspian-Guba, Absheron and Shamakhi-Gobustan Oil and Gas Regions

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Abstract: In addition to being a safe approach for the environment, studying the Earth's gravitational field is crucial for resolving numerous scientific and practical geological and geophysical issues. Technological developments in the field of gravitational field measurement have occurred recently. Gravimeter precision has improved, and satellite observations have produced fresh data. The development of techniques for mathematical data analysis is also required by the employment of space technology in the study of Earth's gravimetric field.The lithosphere and crust of the earth can be examined in a novel way with the aid of mathematical techniques. On the other hand, sedimentary basins and uncharted hydrocarbon resources can be studied through the mathematical analysis of gravity data. An urgent topic in geophysics is the mathematical analysis of gravimetric field data in conjunction with other data to better establish the structure of the earth's crust and lithosphere.The actual issue of mathematical interpretation and analysis of high-precision gravimetric data is the focus of this paper. In this paper, the density boundaries giving rise to gravitational anomalies in the studied region were found using the Spector-Grant method. Butterworth and Hartley filters were used to filter the gravimetric data. The power spectrum of the Hartley transform analysis of the Bouguer gravity values indicates that the long and short wavelength components of the gravity field may be distinguished. The interpretation of the regional anomalies shows that these anomalies depend on rising and sinking crystalline basement.

Keywords: Gravity anomaly, Power spectrum, Butterworth filter, Hartley filter

Introduction

The processing of gravity data in the frequency domain allows one to estimate the anomaly source depth using the analysis of the radial spectrum (Spector et al., 1970). In addition, in the frequency domain it is easy to perform filtering, analytical continuation and calculation of vertical derivatives of the gravitational field. These procedures use the discrete or fast Fourier transform. The processing of measured physical quantities based on the complex Fourier transformation requires complex initial data (Blakely, 1995). However, it is natural to deal with real numbers in the real domain. The Hartley transform is a function of real variables and has recently been often used for geophysical data processing. It is an integral transform similar to the Fourier transform and possesses most properties of the latter (Bracewell, 1986). This transform has most of the properties of Fourier transforms. On the other hand, computer programs that use the Fourier transform require more memory and longer computer time. Computational experiments conducted using the Hartley transform show that this transformation requires less memory and time. In this work, the Hartley transform is used to analyze the power spectrum and filter 2D gravity data from the study area.

Method

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

Gravity Field of the Research Area

The gravity field in the study area is represented in the Bouguer reduction in Fig. 1. The research area covers the Caspian-Guba gravity minimum and the Eastern Azerbaijan minimum and part of the Azerbaijan maximum. The Caspian-Guba gravity minimum is located in the northern part of the research area, the Eastern Azerbaijan minimum and the Azerbaijan maximum are located in the southern part. Azerbaijan gravity minimum is distinguished by gravity anomalies down to -135 mGal. The Azerbaijan maximum is characterized by gravity anomalies of up to +80 mGal.

Calculation of the power spectrum and digital filtering of the gravitational field in the frequency domain were performed using the Hartley transform and Butterworth filter (Bracewell, 1990; Kadirov, 2000). Spectral analysis of gravitational field data using the Spector–Grant method makes it possible to estimate the average depth of density boundaries (Spector et al., 1970; Kamto et al., 2021; Sadigova, 2020).

For the purpose of studying the gravity anomalies, the Bouguer anomaly map of Azerbaijan was preliminarily divided into 5-km squared cells, and the Bouguer anomaly values were determined at the grid nodes (Fig 1).
The origin of the coordinate systems is placed at the southwestern corner of the study area. The X- and У-axes are directed to the east and north, respectively. The number of elements in X-axis (Nx) and Y-axis (Ny) is selected as Nx=29 and Ny=40.

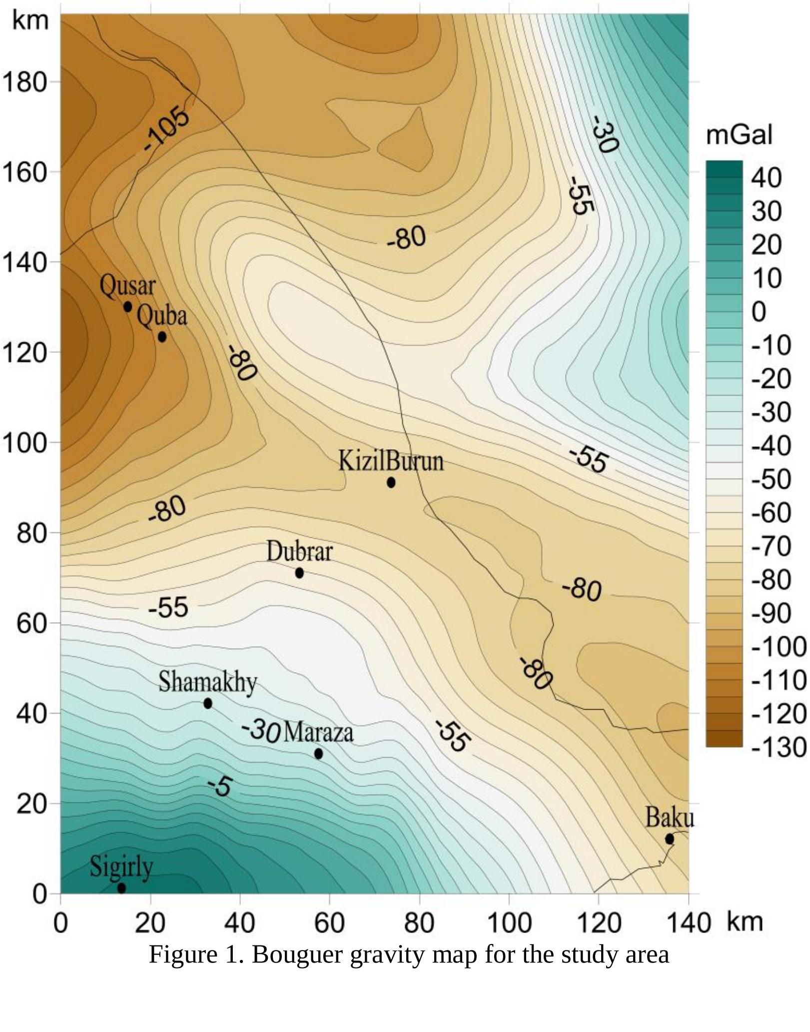

Figure 1. Bouguer gravity map for the study area

Results and Discussion

Power Spectrum and Filtering of Gravity Data

The logarithmic power spectrum of the Bouguer anomalies is presented in Fig. 2. According to its slope, the power spectrum is divided into two regions providing information about long and short waves. The low- and high-frequency regions of the power spectrum related to deep and shallow gravity sources were assumed to represent the respective regions of regional and local anomalies. The cutoff frequency separating the regional and local regions is determined by the intercept of the straight lines approximating the power spectra in long- and short-wave intervals. In the case under consideration, the cutoff frequency (wavenumber) is kc = 0.16 km^{-1}. The depths to gravity anomaly-producing boundaries deter-mined from the long- and short-wave slopes are 16,6 and 1.8 km, respectively, (Spector et al., 1970). The separation of the gravity field into regional and local components was performed with the use of the Butterworth filter. The ideal low-frequency Butterworth filter has the form

$$H_B(k) = \frac{1}{\sqrt{1+\left(\frac{k}{k_c}\right)^{2n}}},$$

where k is the wave number, k_c is the cutoff wave number, n is an integer that determines the filter order. In the present study, n = 1 was assumed.

The application of the Butterworth filter was reduced to the following opera-tions. The Hartley transform provided the frequency-domain representation of the Bouguer anomaly grid values. The Butterworth filter was constructed in the frequency domain in the direction of rows and columns, allowing for the cutoff frequency, and was then multi-plied by the Hartley spectrum. Finally, the result was inversely transformed into the space domain.

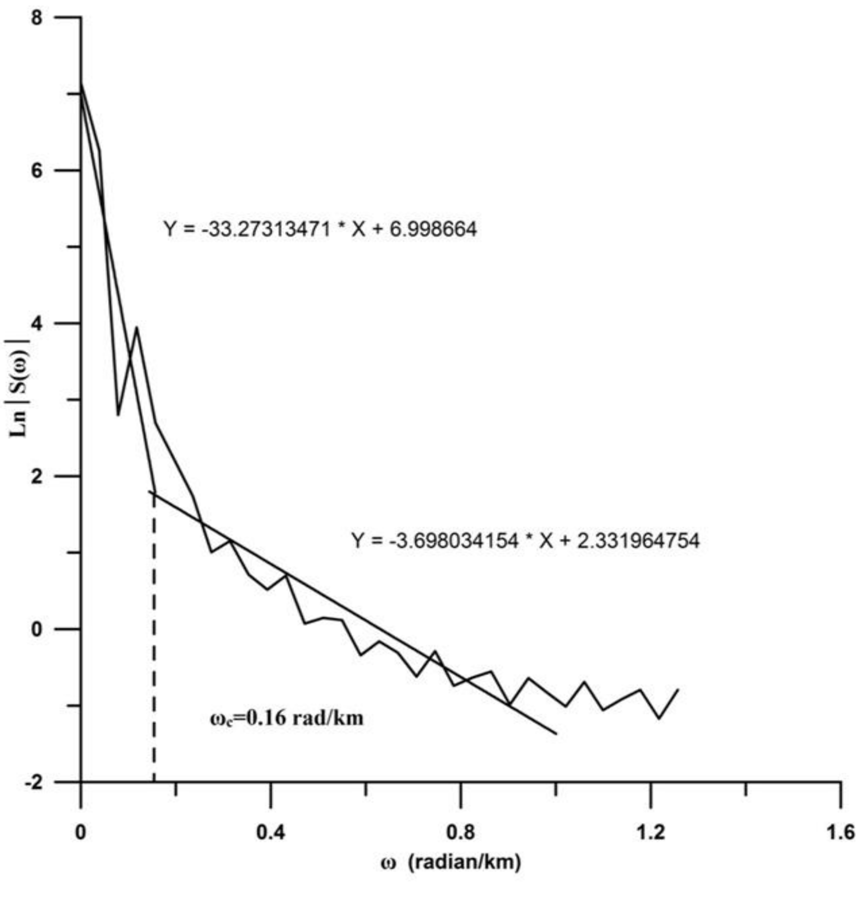

Figure 2.The logarithmic power spectrum of the gravity field.

The results of the low- and high-frequency filtering with the' cutoff frequency kc = 0.16 km-1, using the Hartley transform are shown in Figs. 3. In Fig. 3,a a strip of deep minimum is visible. The minimum value of anomalies is fixed in the marine part (–155 mGal). The relative maximum is observed in the area of Guba (–85 mGal) and Dubrar (–80 mGal). These gravity anomalies extend to Maraza. A negative anomaly to the minimum value is determined in the area of Shamakhy (–105 mGal) and in the west of Baku in the area of Güzdek (–120 mGal).

In Fig. 3,b the zone of positive anomalies occupies the area in the north-west and south-east of the studied area. The maximum value of this anomaly, equal to 1 mGal, was noted in the Guba region and the northern part of the Absheron peninsula. The negative anomaly occupies the north-eastern and south-western parts of the region. The minimum meaning of this anomaly, equal to –8 mGal, observed in the sea and in the district of Geybet (–6 mGal). A number of closed negative anomalies are observed Charkhy (–2 mGal), Ledzhet (–3 mGal), Sarvan (–3 mGal) and Yashma (–3 mGal) districts.

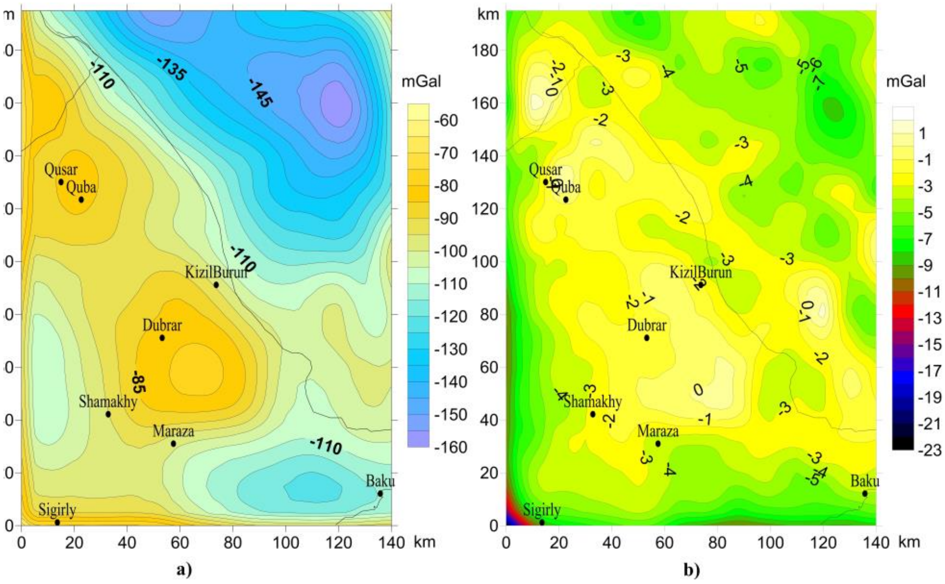

Figure 3. Results of the low-frequency (a) and high-frequency (b) filtering with the use of the Hartley transform

The depths of gravity anomaly-producing bodies determined from the power spectrum slope are consistent with seismic and borehole data. According to DSS data, the depth to the crystalline basementin the Gusarchay-Gusar-Yalama zone is determined to be 8–18 km. In the central part it has depths of 14–18 km (Akhundov et al., 1996). Such changes in the crystalline basement are consistent with changes in regional gravity anomalies. The 16,6-km depth is associated with the crystalline basement surface, and the 1.8-km depth, with a surface within Cenozoic deposits.

Conclusion

The analysis of the power spectra of the gravity field in the study area revealed anomaly-producing bodies at mean depths of 16.6 and 1.8 km. The 16.6-km depth is associated with the surface of the crystalline basement, and the 1.8-km depth, with a sur-face within Cenozoic deposits.

Recommendations

The reliability of the processing results based on the application of the Hartley transform and 1-D Butterworth filter to the gravity data of the study area is confirmed by their close agreement with the results of previous investigations. The results of this paper lead to the conclusion that the Hartley transform is appropriate for the numerical analysis of gravity data. The methodology developed in this work is theoretically and practically important and can be applied in other regions. At the same time, local gravity anomalies have practical significance in oil and gas search and well site selection.

Scientific Ethics Declaration

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

Acknowledgements or Notes

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