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3D Interpretation of Gravity Anomalies in the Potentially Promising Oil and Gas Region of Ajinohur

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Abstract: This article presents the interpretation of Bouguer gravity anomalies using the 3D prism method in the potentially promising Ajinohur oil and gas region. According to this model, the surface depth of the crystalline basement is calculated by considering the density contrast at the bottom of the low-velocity zones in the upper part of the Earth's crust and the quadratic dependence of the density difference on depth.The study aims to conduct a numerical analysis of the gravity field of the potentially promising oil and gas region of Ajinohur and develop a digital gravity model of the sedimentary layer thickness.For the interpretation of the gravity anomalies in the potentially promising oil and gas region of Ajinohur, a sedimentary basin is viewed as a number of prisms placed in juxtaposition. The decrease of density contrast in sedimentary basins is approximated by a quadratic function. Based on the gravimetric field data of the studied area, the gravity model of the sedimentary layer thickness was constructed using the GR3DSTR computer program.From the gravity model of the sedimentary layer thickness, it was found that the maximum thickness is near Ajinohur Lake, in the Gamigaya-Ajibulag area (16 km), and the minimum is in the structural area of Aydinbulag, Chaykend, and Eastern Dashuz (6-8 km).The sedimentary layer thickness in the area where the Gojashen structures are located is 8 km. The regions of negative local gravity anomalies correspond to areas where the sedimentary layer thickness increases, such as in the Gamigaya-Ajibulag area. Conversely, a decrease in the sedimentary layer thickness is observed in the zone of local gravity maxima (Dashuz, Aydinbulag, Gojashen). The correspondence between the calculated sedimentary layer thickness with seismic sections and well data was also determined.The gravity model of the sedimentary layer thickness is of practical importance in oil and gas exploration and in selecting drilling well locations.

Keywords: Gravity anomaly, Sedimentary basin, Gravity model

Introduction

The selected research area, the potentially promising oil and gas region of Ajınohur, is located in the eastern part of the Gabirri-Ajınohur basin. It is bordered by the Alazan River to the west and the Girdiman River to the east. Extending along the southern slope of the Greater Caucasus Mountain range, it is separated from the Alazan-Ayrichay depression. Geologically, the Ajinohur area lies at the junction of the Kura depression and the Greater Caucasus. Despite the negative results of traditional exploration works conducted here, the region is considered to be potentially promising in terms of oil and gas resources.

Despite the application of geophysical research and geological exploration over many years in the Ajinohur region, many issues regarding the area's oil and gas potential remain unresolved, and the tectonics of the

Mesozoic-aged sediments have not been sufficiently studied. The reason for this is the complex seismic conditions in most parts of the area, the limited ability to use seismic exploration methods, and the deep location of the Mesozoic-aged sediments. It is believed that the lack of Deep Seismic Profiling and well data in the region can be compensated for by gravimetric data. Analyses suggest that studying the deep structure of the Ajınohur region and discovering new oil and gas fields here requires the application of modern geophysical methods (Yusifov & Suleymanov, 2015). It is well known that gravity field anomalies play a crucial role in studying the geological-tectonic structure of the Earth's crust. When these data are analyzed alongside results from other geophysical methods, they offer valuable insights into the geological structure.

Since the end of the last century, digital methods have been increasingly applied to the interpretation of potential fields. In this regard, extensive research has been conducted by Blakely, Simpson, Straxov, Stepanova, Əmiraslanov, Kadirov, Serkerov, and others. Today, the digital analysis of gravity field data has become a significant area within the theory of potential field interpretation. The development and application of gravity field transformation methods to identify density boundaries within the geological structure of any area remains a highly relevant issue.

The main features of the crustal depth structure, based on the gravity field data of the Kura depression, where the Ajınohur region is located, have been studied. It has been found that the crustal foundation in the Gabirri-Ajınohur and Yevlakh-Agjabadi depressions of the Kura tectonic element undergoes significant bending. High-precision gravimetric surveys have led to the discovery of new local uplifts in various areas of the Kura depression, and their geological structure, as well as oil-gas potential, has been predicted by Mammadov Qadirov, Aliyev, Khanbabayev, Hasanov, and others). In these studies, gravimetric palettes and correlation formulas were primarily used.

In recent years, based on the numerical analysis of gravity field data, researchers Blakely (1996) and Kadirov (2000) and Sadygova (2020) have proposed several mathematical methods for separating regional and local gravity anomalies, estimating the depths of the anomaly-causing sources, and refining the structure of the crystalline basement and sedimentary layers.

Method

3D Modeling of Gravity Anomalies of the Study Area

A map of gravity anomalies in the Bouguer reduction of the study area was compiled to estimate the thickness of the sedimentary layer using gravity field data (Figure 1). The study area is located in the Ganikh-Ayrichay gravity minimum zone, which is characterized by negative gravity anomalies (Kadirov, 2000). Gravity anomalies below -40 mGal are observed in the Mingachevir, Sheki, and Oghuz regions. In particular, the lowest gravity anomaly values were recorded in the northwest of Sheki (-90 mGal) and the Gamigaya-Ajibulag zone (-65 mGal).

For the purpose of studying the gravity anomalies, the Bouguer anomaly map was initially divided into 3 km squared cells, and the Bouguer anomaly values were determined at the grid nodes. The origin of the coordinate system was placed at the southwestern corner of the study area, with the X-axis directed to the east and the Y-axis directed to the north. The number of cells was selected as Nx = 43 and Ny = 38, respectively.

A gravity model of the sedimentary layer thickness was constructed using the GR3DSTR computer program based on the gravimetric field data of the studied area. The density parameter of the sedimentary layer was approximated as a quadratic function, based on the known density values of the rocks, and entered into the program (Bhaskara & Ramesh, 1991).

The thickness of the sedimentary layer is investigated based on the quantitative analysis of the gravity field, considering the following conditions: a) a density contrast in the range of 0.3-0.4 g/cm³ at the bottom of the low-velocity zone, and b) a variation in density difference with depth, according to a quadratic function. In a section of the Earth's crust surrounding the crystalline basement, the density difference of rocks with depth can be approximated by the following quadratic function:

$$\Delta\rho(z)=a_0+a_1z+a_2z^2 \quad (1)$$

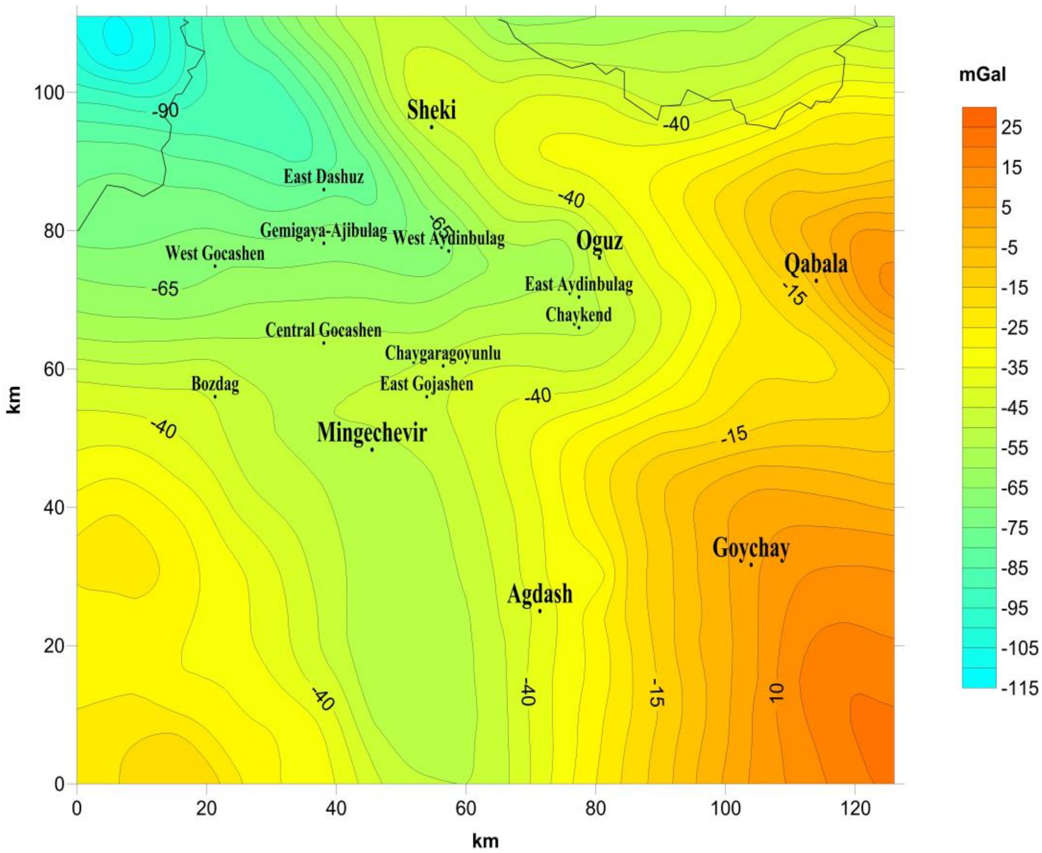

Figure 1. Bouguer gravity anomalies in the potentially promising oil and gas region of Ajinohur

Where the Z-axis is directed towards the center of the Earth, a_0 is the density value at the surface, and a_1 and a_2 are the constants of the quadratic function. For the three-dimensional modeling of gravity anomalies, the part of the Earth's crust surrounding the crystalline basement can be considered a collection of multiple adjacent prisms. The following formula expresses the equation for the gravity anomaly of a prism, where the density contrast varies with depth according to a quadratic function.

$$\begin{aligned}\Delta g(x,y) = {} & \gamma a_0 \left| z\arctan\frac{xy}{zR} + \frac{x}{2}\ln\frac{R-y}{R+y} + \frac{y}{2}\ln\frac{R-x}{R+x} \right|_{x=X_1}^{X_2} \Bigg|_{y=Y_1}^{Y_2} \Bigg|_{z=Z_1}^{Z_2} \\ & + \gamma a_1 \left| \frac{z^2}{2}\arctan\frac{xy}{zR} - \frac{x^2}{2}\arctan\frac{yz}{xR} - \frac{y^2}{2}\arctan\frac{xz}{yR} \right. \\ & \left. + xy\ln(2R+2z) \right|_{x=X_1}^{X_2} \Bigg|_{y=Y_1}^{Y_2} \Bigg|_{z=Z_1}^{Z_2} + \gamma a_2 \left| \frac{z^3}{3}\arctan\frac{xy}{zR} \right. \\ & \left. - \frac{x^3}{3}\ln\frac{R-y}{R+y} - \frac{y^3}{6}\ln\frac{R-x}{R+x} + \frac{2}{3}xyR \right|_{x=X_1}^{X_2} \Bigg|_{y=Y_1}^{Y_2} \Bigg|_{z=Z_1}^{Z_2} \end{aligned} \quad (2)$$

Here, X_1=x+T, X_2 = x-T, Y_1=y+W, Y_2=y-W , $R = \sqrt{X^2 + Y^2 + Z^2}$, γ - gravity constant, T and W - the half-dimensions of the bottom of the prism.

The GR3DSTR computer program, developed by R. Bhaskara and B. Ramesh in FORTRAN-77, is used for three-dimensional modeling of gravity anomalies, accounting for the density contrast with depth (Bhaskara & Ramesh, 1991).

Results and Discussion

Application of GR3DSTR Program for Modeling Gravity Anomalies of the Study Area

The structure of the sedimentary layer in the Ajınohur prospective oil and gas region has been detailed in several monographs based on well and seismic exploration data (Kerimov, 2009; Yusifov & Aslanov, 2018). Geophysical and geological research conducted in the studied area so far has identified four seismic complexes within the sedimentary layer. These sedimentary complexes are as follows: 1) Quaternary sediments, 2) Neogene, 3) Paleogene, and 4) Cretaceous.

If we assume that the density difference at the boundary between the Cenozoic (Paleogene) and Mesozoic (Cretaceous) layers is 0.27 g/cm³ and at the boundary of the crystalline basement it is 0.15 g/cm³, we can determine the quadratic dependence of the density difference on depth. In determining the quadratic dependence of the density difference ($\Delta\rho$) on depth at the bottom of the low-velocity zone, the density difference is considered to be 0.4 g/cm³. Figure 2 illustrates the quadratic dependence of the density difference on depth. The coefficients of the quadratic function, which describe the relationship between density difference and depth, are provided below:

$$a_0 = -0.0009,\ \ a_1 = 0.0306,\ a_2 = -\ 0.4026$$

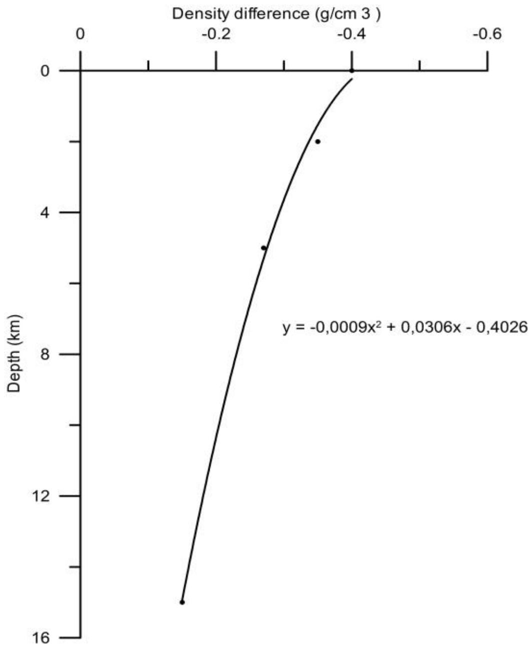

Figure 2. The dependence curve of the density difference on depth

The sedimentary layer thickness was calculated using the GR3DSTR program, based on the calculated values of the Bouguer gravity anomaly and the coefficients of the quadratic function. Figure 3 shows the gravity model of the sedimentary layer thickness obtained after 10 iterations. The sedimentary layer thickness model shows significant thickness near Ajınohur Lake and the Gamigaya-Ajibulag area, with an average thickness of 16 km. In the areas surrounding this zone to the north and south, the sedimentary layer thickness decreases. In the Aydinbulag, Chaykend, and Eastern Dashuz areas, the average thickness ranges between 6 and 8 km, while in the area of the Gojashen structures, it is 8 km. The regions where the sedimentary layer thickness increases correspond to negative local gravity anomaly areas, specifically in the Gamigaya-Ajibulag area. In the local gravity maximum zones of Dashuz, Aydinbulag, and Gojashen, a decrease in sedimentary layer thickness is observed (Kadirov et al., 2024). The correspondence of the calculated sedimentary layer thickness with seismic sections and well data was determined (Yusifov & Süleymanov, 2015).

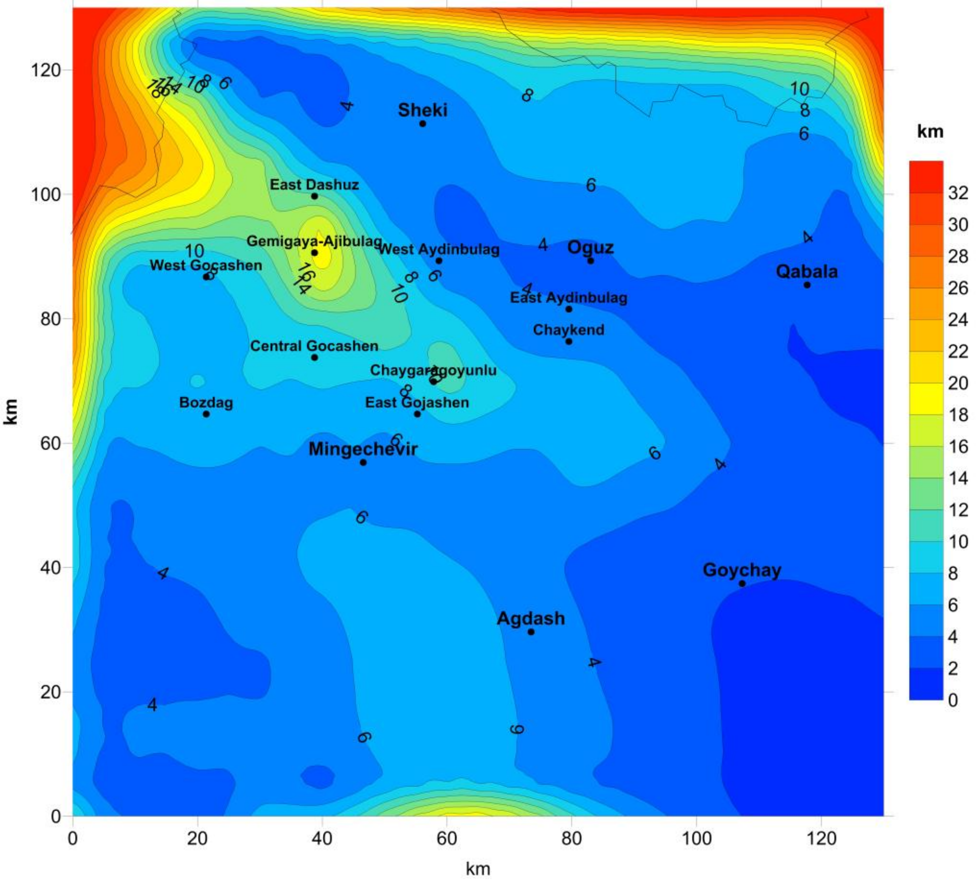

Figure 3. Gravity model of the sedimentary layer thickness in the potentially promising oil and gas region of Ajinohur

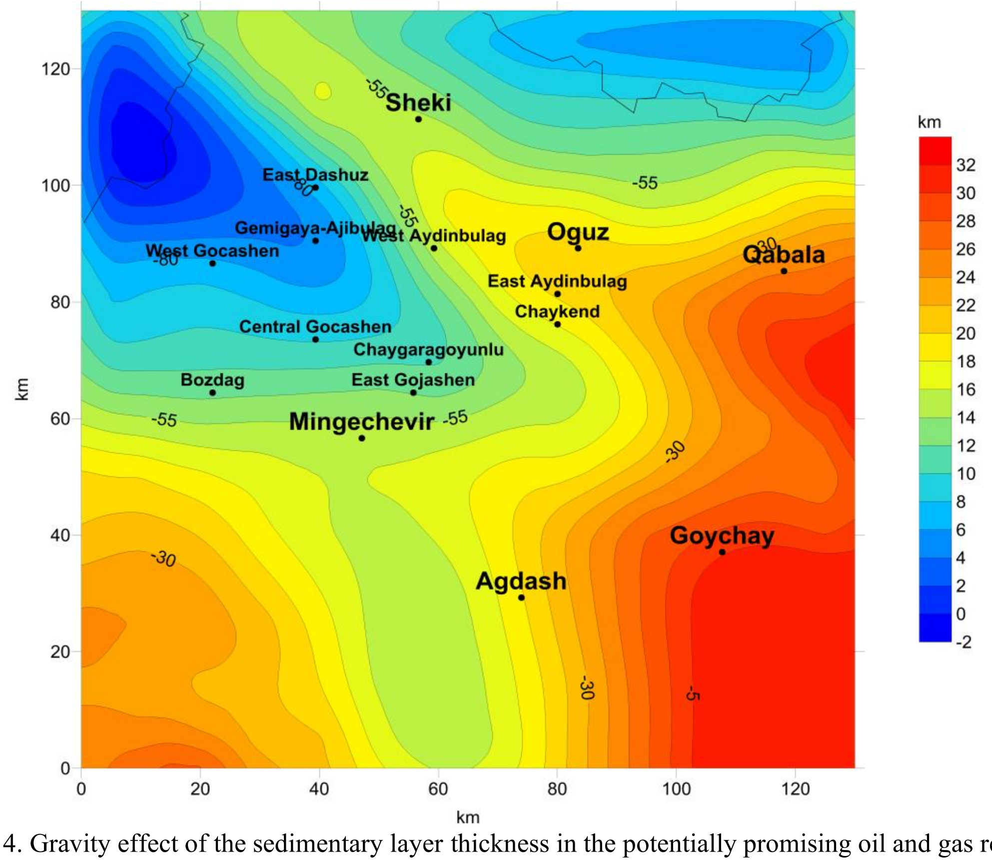

Figure 4. Gravity effect of the sedimentary layer thickness in the potentially promising oil and gas region of Ajinohur

Figure 4 illustrates the gravity effect calculated based on the obtained sedimentary layer thickness distribution in the potentially promising oil and gas region of Ajinohur. The minimum gravity effect, ranging between -55 and -80 mGal, was recorded in the northwestern part of the map, specifically in the Gamigaya-Ajibulag and Northwestern zones.

If we compare the gravity effect of the sedimentary layer with the Buge anomaly map (after a 30 mGal correction), we can observe that the values are consistent. This indicates that the selection of 10 iterations for calculating the sedimentary layer thickness distribution is correct.

Conclusion

The gravity model of the sedimentary layer thickness was developed using the GR3DSTR computer program, based on the gravimetric field data of the studied area. In the gravity model, the highest thickness values are observed in the Gamigaya-Ajibulag area (16 km), while the minimum thickness values are found in the Aydinbulaq, Chaykend, and East Dashuz structures (6-8 km).

Recommendations

The methodology developed in this study is both theoretically and practically significant and can be applied to other regions. The gravity model of sedimentary layer thickness is particularly valuable in oil and gas exploration as well as in the selection of well locations.

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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