EARTH SCIENCES

STRUCTURE OF MESOZOIC DEPOSITS IN THE SAATLY-SABIRABAD AREA BASED ON GRAVITY SURVEYING IN COMBINATION WITH SEISMIC SURVEYING

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https://doi.org/10.5281/zenodo.20186425

Abstract

This article examines the structure of Mesozoic deposits in the Saatly-Sabirabad area using gravity survey data and seismic data on the surface structure of Mesozoic deposits. As is well known, a large volume of geological and geophysical work has been conducted in the Middle Kura Depression, which includes the Saatly-Sabirabad area, revealing numerous promising structures and oil and gas deposits. The section of this area includes deposits ranging from Mesozoic to Cenozoic age. The Cenozoic stage is generally quiescent, while the Mesozoic stage is highly dislocated and therefore clearly visible in the gravity field. Seismic exploration in this region has played a significant role in understanding the structure of Mesozoic-Cenozoic deposits. However, it also faces significant challenges when used in hard-to-reach areas (rough terrain, the presence of rivers and swamps, cultivated areas, etc.). This problem is currently being addressed by correlating geological and geophysical data, particularly gravimetric and seismic data. The Geophysics Department at ASOIU has accumulated sufficient experience to conduct this type of research. The Saatly-Sabirabad area is one such hard-to-reach area. Seismic data is available for individual profiles here, along with a large amount of detailed areal gravity data. This article describes a technology for constructing structural maps based on gravity and seismic data using the MRA-COMR-COM program, as well as the results of predicting a structural map of the surface of Upper Cretaceous deposits in the Saatly-Sabirabad area in the eastern part of the Middle Kura Depression in Azerbaijan.

Keywords: Correlation, regression, structural map scheme, horizon “P”, Poelogen-Neogene deposits, seismic data.

Introduction.

The Saatly-Sabirabad area is located in the eastern part of the Midle-Kura Depression. Various aspects of the Midle -Kura Depression's geological structure have been covered in the works of M.G. Agabekov, A.K. Aliyev, A.L. Ali-Zade, G.L. Akhmedov, A.A. Bakirov, N.B. Vassoevich, V.V. Weber, R.M. Gadzhiev, I.M. Gubkin, K.A. Ismailov, V.D. Kerimov, K.M. Kerimov, S.A. Kovalevsky, V.I. Kulikov, A.V. Mamedov, Sh.F. Mekhtiev, E.E. Milanovsky, M.F. Mirchinok, M.M. Radzhabov, V.V. Fedynsky, V.E. Khain, I.O. Tsimelzon, A.N. Shardanov, E.Sh. Shikhalibeyli, A.K. Shikhlinsky, A.A. Yakubov, and a number of other Caucasus researchers. In this article, the gravity field of the Saatly-Sabirabad area, which regionally belongs to the northern part of the Talysh-Vandam gravitational maximum, is analyzed to refine the geological model of the environment. This depression is characterized by the presence of a highly dislocated Mesozoic volcanosedimentary rock complex beneath monoclinally occurring Pliocene deposits. The geological structure of this area includes deposits ranging from Quaternary to Jurassic in age. Middle-Lower Jurassic deposits were uncovered in the Saatly superdeep borehole and are expressed as a thick andesite-basalt series with a predominance of basalts. Judging by microfaunal data, Jurassic deposits were also uncovered in other areas. Lower and Upper Cretaceous deposits are developed in the Jarly, Sor-Sor, Saatly, Muradkhanly, and other areas. In the Saatly borehole, Upper Cretaceous deposits were encountered at depths of approximately 2,800-3,500 m and are represented by alternating limestones, porphyrites, and basalts. In the adjacent Muradkhanly area, Upper Cretaceous deposits were found in both sedimentary facies and effusive formations. Poleogene-Neogene and Quaternary deposits were encountered in almost all areas of the Midle-Kura Depression and form a thick layer overlying the underlying deposits. A detailed gravity-magnetic survey confirmed and refined previously identified local anomalies and identified a number of new local gravity field features (the North Saatly, South Saatly, and Chovranly gravity maxima). The compiled gravity and magnetic anomaly maps allowed us to confirm and clarify the nature of these local anomalies. Seismic data identified three structural stages: the Mesozoic (highly dislocated), the Paleocene-Miocene (partially dislocated), and the Pliocene-Anthropogenic (quietly lying).

Reflectance survey data have revealed the upper stage. The Saatly-Dzharly tectonic zone, including the Dzharly and Saatly-Yuzhny uplifts, has been identified based on the middle Pliocene and the upper layers of the underlying sediments. CDP data have also provided a good understanding of the middle stage and the "P" seismic horizon (named after E.M. Polonsky, chief engineer of the Geophysical Trust), which characterizes the transition from Mesozoic to Cenozoic deposits. These deposits within the study area distinguish two anticline zones: the western (represented by the Zardob, Muradkhanly, and Mil uplifts) and the eastern (including the Karadzhaly, Sor-Sor, Jarly, and Saatly uplifts). CDP seismic exploration also revealed the Amirarkh, Shakhsuni, Arabkubal, Karabudzhag, Saatly-Severny, Kargaly, and Myusly group of uplifts. In recent years, smaller uplifts have been identified, such as the Kargalinskaya, Gyshlakskaya, Karabatskaya, and others. A considerable number of works have been devoted to the study of the tectonics and structure of this area [9-10].

Means and methods

Tools and Methods

As is well known, seismic exploration makes it possible to study and construct reflective wave boundaries between density heterogeneities in rocks, which are associated with certain geological boundaries. However, seismic exploration is very labor-intensive and expensive. Furthermore, seismic exploration is extremely difficult to conduct in mountainous regions and areas with complex, rugged terrain, especially those with dense river networks and wetlands. Seismic exploration can also damage croplands and agricultural lands and can create various environmental problems. To study sedimentary structures and construct a structural map for a specific surface where seismic data is lacking, using available areal gravity data, statistical analysis methods are typically used. These methods are primarily used in modifications of multivariate regression analysis (MRA), correlation methods for anomaly separation (COMS), and various modifications developed for use in specific geological conditions. The technology for predicting specific boundaries or schematic maps for a specific surface using detailed and highly accurate gravity data involves several steps.

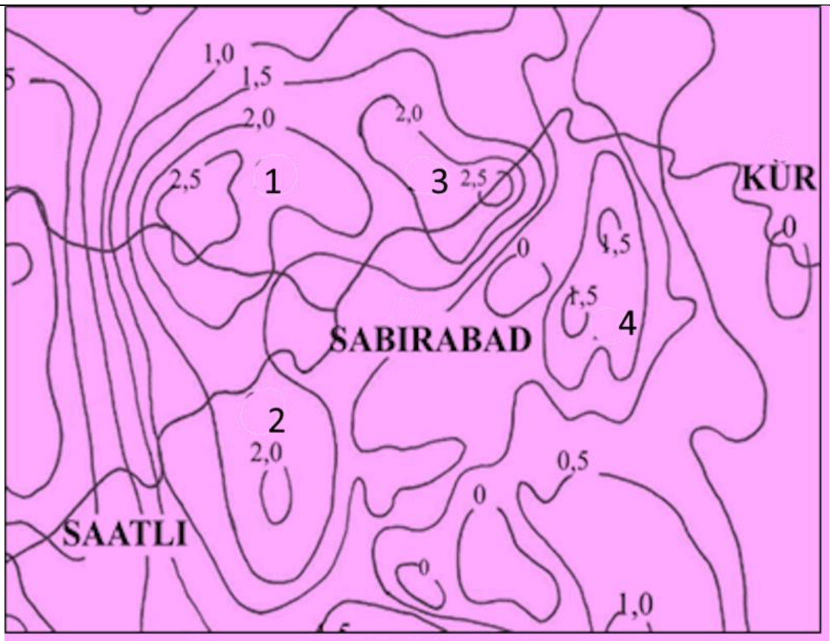
During the first stage, areal gravimetric surveys are performed in the study area, ensuring maximum accuracy of the measured data. Next, Bouguer anomaly values are calculated, taking into account corrections for elevation, the intermediate layer, and, where necessary, corrections for the terrain. A Bouguer anomaly map of the study area is then constructed, reflecting the density heterogeneities of the Earth's crustal rocks in the form of regional and local components of the complex total gravity field. It should be noted that regional and local gravity anomalies are, in turn, divided into relatively large and small ones, which reflect different exploration depths. Therefore, an important procedure for transforming the observed field is to perform transformations to separate the field into its components. For this purpose, the department has developed both individual and integrated data processing programs [7-8]. As a result of transformations using various methods and parameters, maps of local anomalies are compiled, on which reference profiles with seismic exploration data on the depth of the studied boundary are marked. Next, seismic-gravimetric profiles are compiled, on which the values of seismic and gravimetric data are marked by quantization for subsequent preparation of the data for processing on a computer.

In the second stage, a correlation analysis is performed between seismic and gravimetric data using statistical methods. This analysis establishes correlations between seismic and gravity data and their various transforms. Regression equations are developed for optimal statistical variants, which are used to calculate the depth of the studied surface in the forecast space and to create structural diagrams of the studied surface in two- and three-dimensional versions. This process is very labor-intensive and is therefore performed on a computer using specialized software. The Geophysics Department of ASOIU has developed the corresponding MRA-COMR-COM software [1-4,6], which has been tested using actual and simulated examples.

Results and discussion

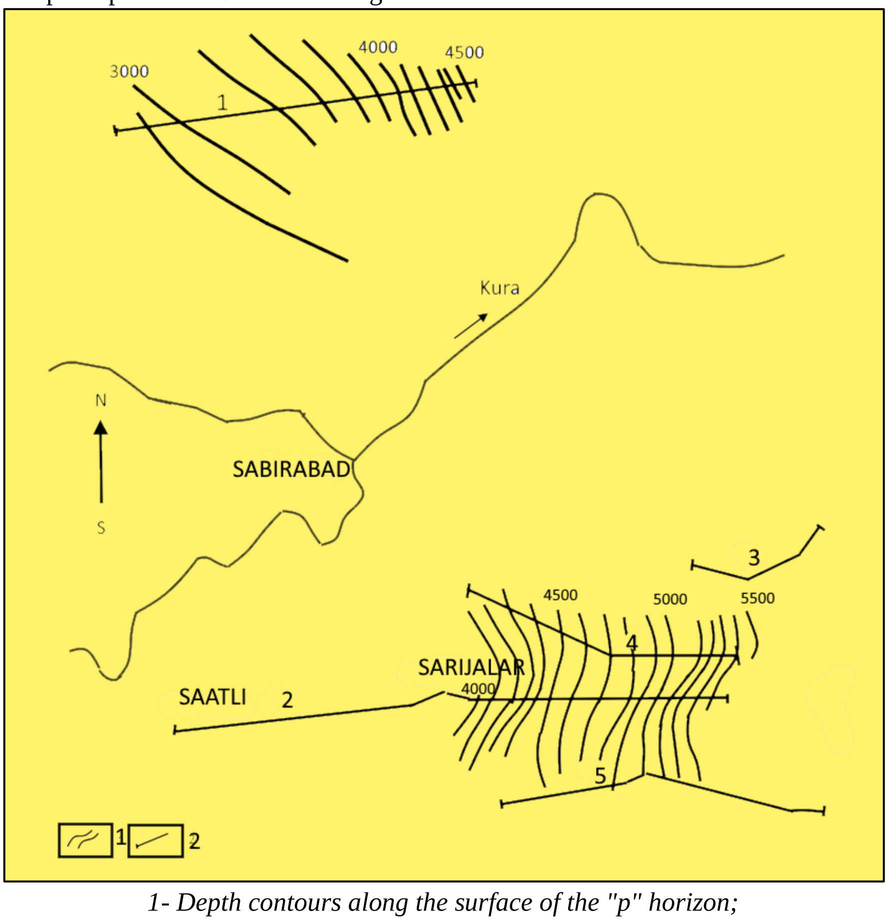
Various correlation methods and modifications of the integrated interpretation of gravity anomalies are widely used in Azerbaijan to predict geological boundaries and seismic horizons based on gravity data using statistical methods. Gravity data is typically combined with magnetic, seismic, and drilling data. When the local structure is well reflected in the gravity field, the COMR correlation separation method [5] is successfully applied. If the local structure is poorly reflected in the observed gravity field, the multivariate regression analysis (MRA) method is applied using local gravity anomalies obtained from various gravity field transformations. In the eastern part of the Middle Kuran Basin, the developed COM (combined) method, which leverages the advantages of MRA and COMR, was successfully applied and implemented in the MRA-COMR-COM Fortran program.

Below are the results of forecasting the seismic horizon SP-"P", characterizing the transition from Cenozoic to Mesozoic deposits, based on the integrated interpretation of gravity, seismic, and drilling data in the area of the confluence of the Kura and Araks rivers, which is difficult to access for seismic exploration. Initially, maps of local gravity anomalies of the Saatly-Sabirabad area were compiled. One of these maps - a map of the local anomaly R(g) - is shown in the figure below (Fig. 1). Since the "P" horizon is well reflected in the gravity field, the COMS-A method of correlation separation of fields was used to predict the structural scheme of the area poorly studied by seismic exploration. Processing was carried out on a computer using the FORCE-FORTRAN MRA-COMR-COM program in COMR-A mode developed at the department.



Maxima: 1 - North Saatly; 2 - South Saatly; 3 - Sabirabad; 4 - East Sabirabad.
Fig. 1. Map of the local R(g) anomaly for the Saatly-Sabirabad area (in mGal)

The analysis was carried out between the depth of the "P" horizon and the parameters of the gravity field Δg_{Bouger}, R(g), Wzzz along seismic-gravimetric profiles with conditional numbers No. 2, 3, 4, 5. To increase the stability of the forecast in the northern part of the study area along the compiled profile No. 1 intersecting the isolines of the "P" depths, the corresponding values Δg_{Bouger}, R(g), Wzzz were taken and an analysis was carried out between their parameters (Fig. 2).



1- Depth contours along the surface of the "p" horizon;
2- Seismic profiles
Fig. 2. Saatly-Sabirabad area of the eastern part of the Midle-Kura Depression

As the results of the analysis showed, for all profiles a good correlation is observed between the depth of occurrence of Hp and the parameters $\Delta g_{Bouger,}$ R(g), Wzzz (Table 1).

Table 1

Results of analysis for profile No. 4

N	R	NN	S	F	R_{mal}	SS	FF	R_{rem}
2	-0,98	12	41,33	0,02	6,96	32,83	33,3	0,98
3	0,96	7	45,38	0,83	7,66	31,94	35,1	0,98
4	-0,99	4	18,6	5,95	3,00	61,69	9,4	0,95
5	-0,98	8	49,96	0,14	8,44	30,84	37,7	-0,98
6	0,96	13	135.47	0,14	23,04	31,88	83,4	-0,98
7	-0,99	11	233,83	0,34	39,79	29,73	49,1	0,99
8	-0,99	3	140,10	34.00	6,75	20,04	92,3	0,98
9	-0,98	5	135,96	0,09	23,12	19,71	92,3	0,99
10	0,96	9	64,64	4,42	10.96	23.69	69,7	0,99
11	-0,99	14	963,12	0,00	163,97	18,24	107,7	0,99
12	-0,99	15	73,13	173,43	12,41	22,37	71,7	0,99

As can be seen, a good relationship is observed in the case where the length of the transformation polynomial N=3 and the statistical characteristics turned out to be equal:

S = 18, 60 ; F = 5,95 ; R_{mal} =3,00 ; SS = 61, 69 ;FF = 9,4; R_{rem}=0,95 (1)

The analysis of correlation links involving all profiles showed that a good link is observed with the transformation length N=3 for the values of the statistical parameters:

s = 51,17; F=2.51 ; R_{mal} =3,05 ; SS = 140,04; FF = 34,4; R_{rem}=0,98 (2)

Below are the results of the correlation analysis taking into account all profiles (Table 2).

Table 2

Analysis results for all profiles

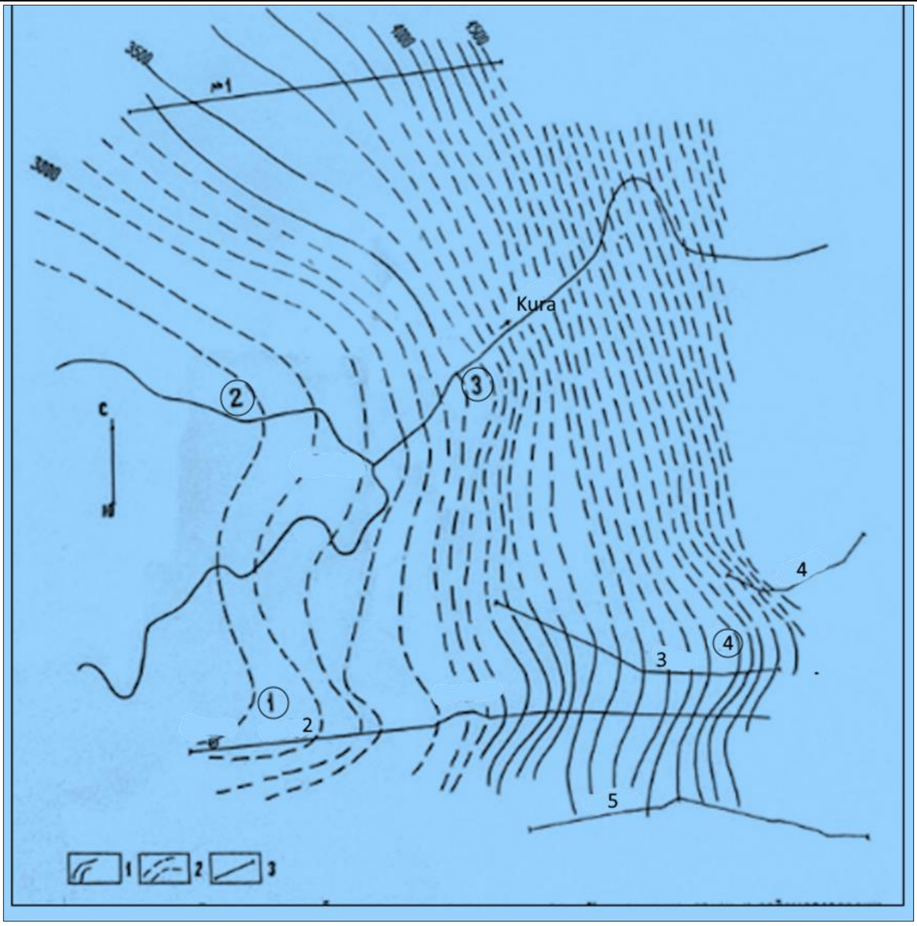
N	R	NN	S	F	R_{mal}	SS	FF	R_{rem}
2	-0,92	7	81,12	0,04	4,98	133,43	37,9	0,98
3	0,05	4	51,17	2,51	3,04	140,04	34,4	0,98
4	-0,94	11	13,62	14,12	0,52	256,03	10,3	0,95
5	-0,54	2	13,68	0,99	0,51	206,68	15,8	0,96
6	0,11	12	12,71	1,16	0,60	204,74	16,1	0,97
7	-0,94	8	10,95	1,35	0,72	241,25	11,6	0,95
8	-0,75	13	0,63	300,46	0,99	2967,79	0,1	-0,27
9	-0,39	5	5,29	0,01	0,94	270,13	9,2	-0,95
10	0,14	9	22,21	0,06	0,96	326,60	6,3	-0,92
11	-0,93	14	8,10	7,52	0,86	671,06	1,5	-0,77
12	-0,83	15	4,65	3,03	0,95	857,67	0,9	-0,69
13	-0,62	10	8,08	0,33	0,86	369,34	4,9	-0,91
14	-0,29	6	8,06	1,01	0,86	412,51	4,0	-0,89
15	0,14	3	45,48	0,03	2,67	140,44	34,2	0,98

The regression equation obtained for N = 3 is as follows:

Δg_{Bouger} =0,576 x -0,198 y + 0,012 H_p , (3)

where Hp = (Δg_{Bouger} – x 0,576 + y 0,198 y)/0,012 (4)

This equation was used to predict the Hp depth in the unexplored seismic portion of the Saatly-Sabirabad area, located at the confluence of the Kura and Araks rivers. Analysis of the variation curve of Hp depth deviations from predicted values shows that the maximum of this curve corresponds to the 50-100 m interval. This allowed us to predict and construct a structural diagram with a 100 m contour interval (scale 1:50,000). The structural diagram (Fig. 3) shows a general west-to-east subsidence of the "P" horizon, against which four structural protrusions are identified: South Saatly, Saatly, Sabirabad, and North Nasimkend.



1 - SH-"P" contour lines based on seismic data; 2 - SH-"P" contour lines based on gravity and seismic data; 3 - seismic profiles (numbers are arbitrary); Highs: 1 - South Saatly; 2 - Saatly; 3 - Sabirabad; 4 - North Nasimkend.

Conclusions:

1. The geological and geophysical characteristics of the Saatly-Sabirabad area in the eastern part of the Midle-Kura Depression were analyzed in light of new geological and geophysical data. The study area comprises Mesozoic-Cenozoic deposits. The lower layer is composed of highly dislocated Mesozoic volcanosedimentary deposits, which exhibit excessive density and are therefore clearly reflected in the gravity field as local anomalies.

2. Correlations between the gravity field parameters of the study area and seismic data were analyzed. A computer-based correlation between gravity and seismic data was established for the Saatly-Sabirabad area using the FORCE-FORTRAN MRA-COMRCOM program developed at the department. Statistical analysis tables of seismic-gravimetric data for individual and all profiles were compiled. Optimal parameters were selected for generating regression equations.

3. Based on the established correlation between seismic-gravimetric data and the optimal parameters of the regression equation, depths along the surface of Cretaceous deposits were predicted on an areal basis in areas lacking seismic data. A structural map was constructed, highlighting the South Saatlinsky, Saatlinsky, Sabirabadsky, and North Nasimkendsky structural protrusions within a depth range of 3,000-4,500 m. The identified protrusions are oriented northeast and east. The obtained results can be used to guide further seismic-gravimetric work to identify structures with potential for oil and gas production.

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