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# POSSIBILITIES OF GRAVIMETRIC EXPLORATION IN DETERMINING GEOLOGICAL STRUCTURE AND OIL-AND-GAS CONTENT

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A B S T R A C T

In recent years, integrated geophysical exploration studies, incorporating seismic and gravimetric methods, have been implemented in the Kura Depression of Azerbaijan. Currently, there are broad opportunities available for conducting these research studies. Modern 2D and 3D seismic acquisition techniques that meet current industry standards, advanced gravimetric instruments (e.g., Scintrex CG-6 Autograv), and newly developed data processing and interpretation methods enable these challenges to be addressed at a high technical level. The obtained results indicate that the hydrocarbon potential of many fields has either been insufficiently studied or remains unexplored. The results obtained reveal the existence of new structural complexities and oil-and gas-bearing areas has been identified, and the possibility of discovering new deposits has been suggested. In the prepared article, the integrated analysis of seismic and gravimetric data was carried out for the Alimardanly uplift in the Kura–Aghstafa interfluve, combining gravimetric results with data from drilled wells. Additionally, along the profile crossing the western part of the Qamarli structure within the Ganja OGR, the study examined the geological structure and hydrocarbon potential of a high-amplitude new structural uplift, provisionally named the Western Qamarli. In the future, detailed integrated geophysical surveys-including seismic, gravimetric, and magnetometric methods-over the newly identified structural complexities and characteristic gravity minima (indicative of hydrocarbon potential) are expected to enable the discovery of additional oil-and gas-bearing fields and deposits in the Kura Depression. At the same time, leveraging the capabilities of gravimetric exploration will help reduce the risk of drilling non-productive (dry) wells.

**Keywords:** anomaly; characteristic gravity minimum; gravity force; gradient; Gravimetric exploration; high porosity; hydrocarbon potential; local maximum; regional profile; seismic exploration.

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## 1. Introduction

During the 1940s–1980s, oil and gas exploration in the onshore areas of Azerbaijan expanded significantly, leading to high production levels. Since the end of the mentioned period, oil and gas production in the onshore regions began to decline.

The gravimetric survey method, one of the geophysical exploration techniques for oil and gas, began to be widely applied in the Kura Basin of Azerbaijan from the 1970s and continues to be utilized to the present day. From 1970 to 2007, gravimeters of the QNU-KS and QNU-KV models, manufactured in Russia, were employed for oil and gas exploration purposes. The observations obtained with these gravimeters exhibited a root mean square (RMS) error of 0.04-0.06 mGal. Since 2007, higher-precision gravimeters manufactured in Canada, namely the AutoGrav CG-5 and CG-6 models, have been employed, with an RMS observation error of 0.001 mGal. This has significantly reduced potential errors not only in the study of geological and tectonic structures but also in the exploration of oil and gas fields [1-4].

Scientific research has been conducted using gravimetric exploration to address a wide range of issues. These include the study of the dynamic characteristics of gravity signals influenced by crustal deformation processes, investigations of mud volcanoes and salt domes, microgravity surveys in archaeological research, studies of regional tectonics, construction of three-dimensional models of the area, seismic investigations, and other related applications [5-18]. At the same time, in some modeling studies, gravimetric and seismic data are integrated and analyzed in a comprehensive manner. [19].

In recent years, in the Kura Basin of Azerbaijan, extensive studies have been carried out to identify prospective areas using 2D seismic exploration in combination with gravimagnetometric survey methods along regional profiles of varying lengths. As a result of these studies, substantial information on the geological structure and hydrocarbon potential was obtained, and recommendations were made for conducting comprehensive geophysical exploration (seismic and gravi-magnetometric) in areas considered prospective [20].

## 2. Method and object of research

The research methodology is determined by the nature of

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the geological problem. To evaluate the oil and gas-bearing deposits, it is necessary to carry out detailed gravimetric surveys in search of local structures. Detailed gravimetric survey is required to identify local structures, and to assess the hydrocarbon potential of deposits; therefore, it is essential to optimize the spacing between observation points and, accordingly, the distance between survey profiles. Since the sizes of the identified structures in many areas are not too large (≈ (2-3)×(4-5) km), it is enough to take the distance between observation points as 100 m, and the distance between profiles as 400 m. [21]. Conducting observations at small intervals requires considerable effort and does not necessarily provide additional information. However, in zones with high gradients associated with faults or wedge-shaped structures, the observation spacing can be reduced to 50-25 m, and the profile spacing can be adjusted accordingly to achieve the required depth of investigation for predicting hydrocarbon accumulations. In this case, by increasing the number of observations falling into a narrow zone, it will be possible to more accurately determine the consistency of the observation values, as well as the location of the crack and wedge, and, by compacting the profile, the contour of the oil and gas field. In general, the prediction of oil and gas potential is carried out under certain conditions based on the results of gravimetric surveys. The first condition is the presence of a characteristic gravity minimum overlying a local gravity maximum, and in the next step it is important to track this minimum across multiple profiles. Prediction the oil and gas potential of the study area is carried out by analysing isolated characteristic gravity minima, regardless of their size, in combination with available geological, other geophysical and well data. In addition, the direction of the profiles applied in oil and gas exploration studies must be straight, and when conducting such works, it is important that field gravimetric studies are carried out in accordance with the instructions and the accuracy of the device [22]. Studying oil and gas content under these and other conditions that we have not listed prevents erroneous conclusions based on minimums not related to oil and gas, as reflected in the Bouguer gravity anomaly.

Gravimetric data are primarily interpreted in two ways: graphically and analytically (through transformations). When methods such as third-derivative potential analysis, fully normalized gradients, and similar techniques are applied to separate bed-type anomalies, they often yield erroneous results. For instance, in areas with steep slopes-possibly associated with faults-features such as mud volcanoes, salt domes, and diapiric folds can appear as gravity minima, which may be mistakenly interpreted as indicators of petroleum potential. Extensive experience has demonstrated that graphical methods provide more accurate results when studying oil and gas resources [1, 3, 4, 20].

Many of the world's leading oil and gas companies extensively utilize gravimetric and magnetic survey results to identify hydrocarbon reserves [23-28].

### 3. Results of the study and discussion

The article examines the issues of studying the geological structure and forecasting oil and gas potential along a profile crossing the Alimardanly uplift located in the Kura-Gabirri interfluve area and extending westward from the Gamarli structure of the Ganja oil and gas region, based on the integrated analysis of seismic and gravimetric data.

Studies conducted in the oil- and gas-bearing regions of Azerbaijan have shown that structural uplifts associated with Meso-Cenozoic sediments are reflected in the gravity field as local maxima [1-4, 20]. Tectonic faults, in turn, are expressed by changes in the horizontal gradient of the gravity anomaly curve [29, 30].

To separate the maxima associated with the Alimardanly and western Gamarli structural uplifts from the gravity field, a regional background curve (2) was constructed (figs. 1 and 2). A local gravity maximum was identified within the Alimardanly uplift area, as determined by seismic exploration using the CDP (Common Depth Point) method [31]. The high-intensity part (2.2 mGal) of the local gravity maximum covers the crest of the Alimardanly uplift (Pk 1889-1972) (fig. 1).

Approximately 5 km west of the Gamarli structure, based on 2D seismic data, a local gravity maximum reflecting the structural configuration of a high-amplitude uplifted zone with an intensity of about 8.0-9.0 mGal has been identified (fig. 2). According to the results of gravimetric and 2D seismic surveys, the newly identified uplift has been provisionally named the Western Gamarli structure.

To confirm its existence as a distinct structure, detailed integrated geophysical (seismic and gravimetric) exploration is required in this area.

An increase in porosity within the rocks composing the geological section, together with hydrocarbon saturation, leads to a significant mass deficit within the corresponding intervals of the section. This, in turn, results in a relative decrease in the gravity field and causes oil and gas accumulations to be reflected as characteristic local gravity minimum.

The identification of gravity minima associated with hydrocarbon presence is carried out through the analysis of microstructures of the gravity field and their relation to local gravity maxima (figs. 1 and 2). In this approach, local maxima are reconstructed (4), and the difference between the observed and reconstructed maxima (5) defines the characteristic gravity minima that indicate hydrocarbon-bearing zones [21]. Gravimetric investigations conducted across multiple areas of the Middle and Lower Kura depressions have demonstrated that, in forecasting the oil and gas potential of structures, the delineation of characteristic gravity minima based on the gradients of potential fields is critically important [1-4].

The manifestation of hydrocarbon-bearing areas as characteristic gravity minima in gravimetric data has been substantiated through a joint analysis of gravity survey results and data from 28 deep wells drilled in the Khydyrly-Bandovan area [22]. The results indicate that no characteristic gravity minima were observed in the 11 wells where hydrocarbon potential was not confirmed. In wells that produced oil and gas shows, characteristic gravity minima with intensities of 0.05-0.1 mGal were detected. In contrast, in six deep wells that produced hydrocarbons of commercial significance, the identified characteristic gravity minima exhibited intensities ranging from 0.3 to 0.4 mGal.

Similar studies were also conducted using data from several deep wells drilled within the Kura Depression of Azerbaijan. The findings showed that characteristic gravity minima were absent in non-productive wells, while in wells with hydrocarbon shows, minima with intensities of 0.05-0.1 mGal were distinguished. In wells containing

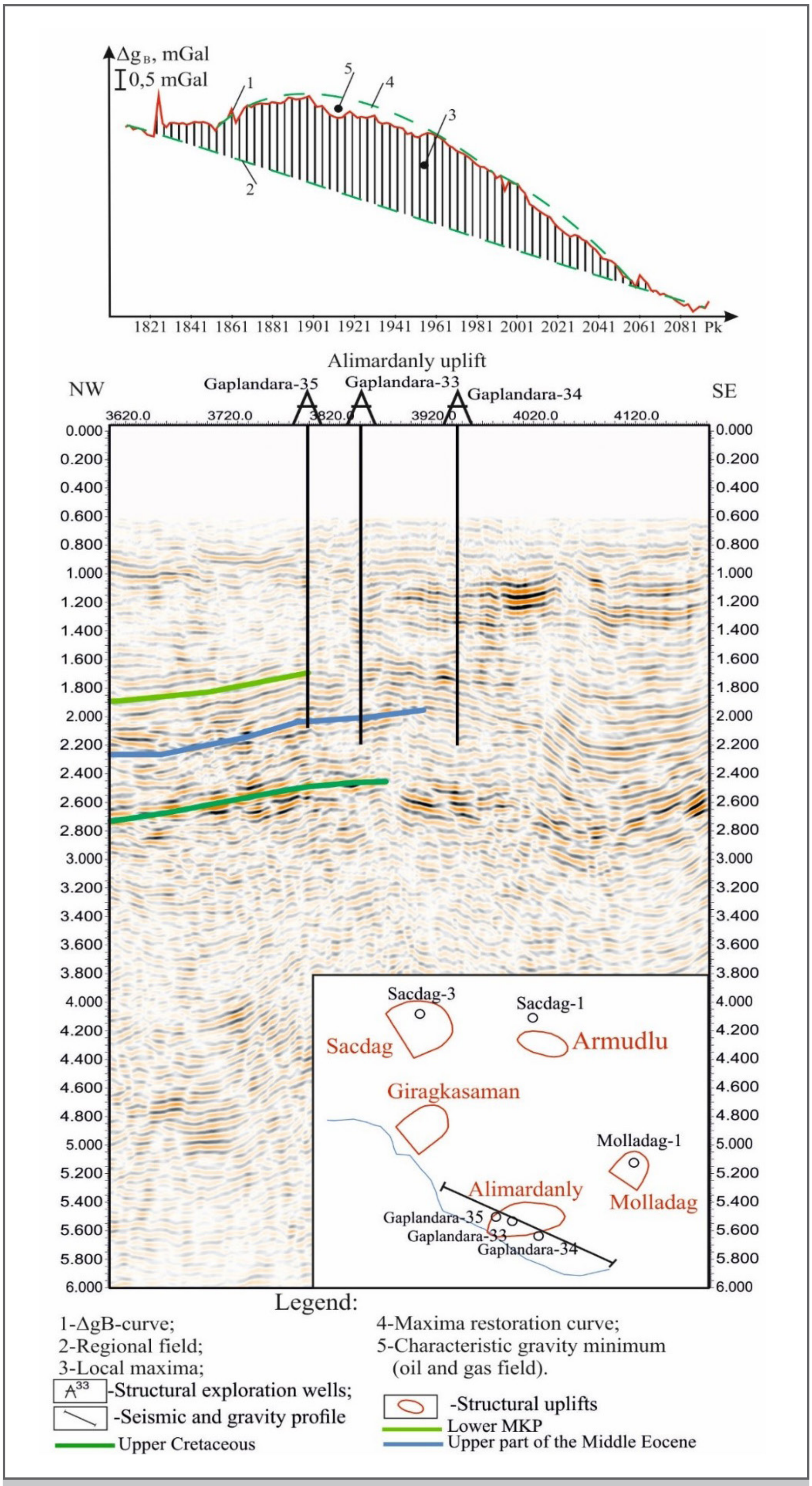


**Fig. 1. Results of gravimetric and 2D seismic data (Alimardanly uplift area)**

commercially significant oil and gas accumulations, characteristic gravity minima with amplitudes of 0.3-0.6 mGal were identified [20].

A comparison between the gravimetric data and the data obtained from wells No. 35, 33, and 34 drilled in the Gaplandara area of the Alimardanli uplift is presented fig. 1). In the area of wells No. 35 and 34, which were drilled to depths of 2100 m and 2200 m and encountered gas shows, a distinct gravity minimum with an amplitude of 0.05 mGal has been delineated.

In the well No. 33 area, where commercial gas production reached (80.000 m³/day), a characteristic gravity minimum with an amplitude of 0.3 mGal was determined. Had well No. 35 been drilled in the station area No. 1911 (characteristic gravity minimum area with an intensity of 0.4 mGal), a higher flow rate could have been achieved.

Had well No. 34 been drilled within the station area No. 2023 sector, it could have achieved high-rate gas production and led to the discovery of a new commercially productive reservoir zone. This would have eliminated the need to drill non-productive wells within the field, resulting in substantial cost savings, as well as avoided the additional operational effort associated with wells that proved non-commercial for oil and gas.

A characteristic gravity minimum with an amplitude of 2.0 mGal was identified over the conventionally designated Western Qamarli uplift (fig. 2). In many fields across Azerbaijan where wells have produced gas at rates of 100.000 m³/day, the amplitude of the characteristic gravity minimum has not exceeded 0.3-0.35 mGal [22]. The identification of a 2.0 mGal gravity minimum in the uplift area under study (Western Qamarli) represents an exceptionally high amplitude. It is considered that if detailed, integrated geophysical exploration is conducted over the proposed new uplift in the future, and the results are confirmed, there is a high probability of discovering a significant hydrocarbon accumulation in this area.

It should also be noted that the identified characteristic gravity minimum corresponds to areas where the Maykop surface and the Sarmat deposits within the Maykop, as well as the lower Maykop strata and Middle Eocene deposits, overlap with the Mesozoic surface ($K_2$). In many oil and gas-bearing fields of the Middle Kura Depression, geophysical and geological data indicate that the overlap zones identified within the various subdivisions of the Paleogene-Mesozoic sequence, along with the horizons they contain, are considered by numerous specialists [30] to be highly significant for the formation of hydrocarbon traps.

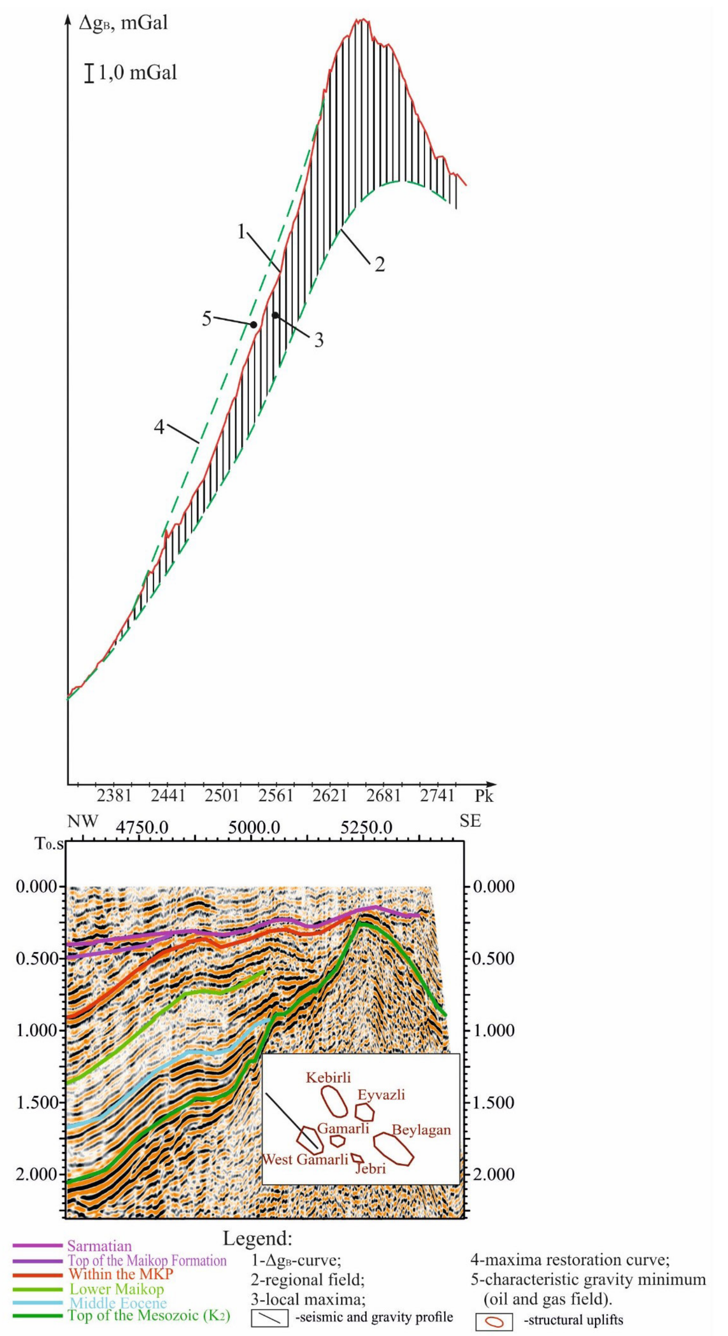


**Fig. 2. Results of Gravimetric and 2D Seismic Data (Western Gamarli Area)**

## Conclusions

1. A new structure has been identified within the Ganja oil-and-gas region (provisionally named the Western Qamarli structure), where the presence of hydrocarbon accumulations is presumed. Based on the results of preliminary investigations, the implementation of detailed integrated geophysical exploration (seismic and gravimetric) surveys in this area is justified.

2. An integrated analysis of well data and gravimetric measurements has demonstrated that gravity minima are associated with hydrocarbon-bearing wells, whereas gravity minima were not observed in non-productive wells. This will play an important role in selecting drilling locations for hydrocarbon exploration and will lead to the discovery of new oil and gas fields and deposits, as well as prevent the drilling of non-productive wells.

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