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R. A. Umurzakov
Tashkent State Technical University, raximshokirov1@gmail.com

S. A. Rabbimkulov
Tashkent State Technical University

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QUANTITATIVE ANALYSIS OF THE RELATIONSHIP BETWEEN THE SIZE AND LOCATION OF OIL AND GAS FIELDS WITH GRAVITATIONAL ANOMALIES OF THE FERGANA DEPRESSION

R. A. Umurzakov[1*], S. A. Rabbimkulov[1]

[1]*Tashkent State Technical University, Tashkent, Uzbekistan*

raxim.umurzakov@tdtu.uz , umrah@mail.ru, mr.geolog.88@mail.ru

Abstract: *Based on the analysis of published materials, it is noted that the degree of connection between the indicators of the anomalies of the gravitational field and oil and gas content remains unclear. The aim of the research was to study the nature of the dependence and assess the degree of connection between the size and location of oil and gas fields with gravitational anomalies using the example of the Fergana oil and gas region. To solve this problem, the published material on the geological structure and data on the sizes (effective volume) of deposits, as well as data on deep anomalies of the gravity field in the Fai reduction, were used. The study involved about 70 deposits. Analysis of variance showed that the "influence" of the deep anomaly factor on the effective volume of the fields in the Fergana depression is significant and reliable with a probability of 0.99. At the same time, the share of the influence of this factor on the effective volume of oil deposits in relation to the total impact of all factors is 42%, and for oil and gas - 62%. This testifies to the significant influence of deep subcrustal processes that create corresponding gravitational effects on the formation of the size and location of oil and gas fields in the Fergana depression. According to local gravity anomalies, the impact on the location and effective volumes of deposits is significant, but the reliability is low. The degree of influence on them remains unclear. The results obtained can be used to develop methods for forecasting promising areas for performing high-priority geological exploration works.*

Keywords: *Deposits, oil and gas, gravitational anomaly, quantitative estimation, effective volume, analysis of variance, strength of influence, reliability*

Introduction. Geophysical data reflecting the structure and development of oil and gas regions, at present, are gaining even greater importance due to the limited possibilities in depth of other methods of studying the subsoil.

The importance of using gravimetric information to understand the problems of geodynamics and study the structure of not only the upper horizons, but also the deep subcrustal levels is noted in a number of published works [1,2]. Such possibilities of using geophysical materials as basic data for structural constructions not only for the upper crustal environment, but also for the underlying lithospheric mantle were demonstrated by a comprehensive interpretation of the gravitational field and the transformed relief along with geological data [1].

Researchers note that the greatest results are obtained with the integrated use of gravity modeling with seismic tomography methods, which allows studying density inhomogeneities of the crust and upper mantle [3,4]. The interest of oil workers in such studies is determined by the need to solve problems related to the conditions for the formation and distribution of oil and gas fields. The solution to these problems directly depends on knowledge of the nature of the geodynamic processes taking place in the bowels of the Earth, and especially in the subcrustal, upper mantle part.

Density inhomogeneities of these sections of the lithosphere, which influence the magnitude (and probably the type) of the stress-strain state, determine the regime of geotectonic development and the formation of individual regional structures [3]. And since density inhomogeneities are reflected in gravimetric anomalies, guided by the ideas noted above, the task was to study the degree of influence of gravitational anomalies on the size and distribution of oil and gas fields using the example of the Ferghana oil and gas region. The choice of this region was not accidental.

Tectonically, it is an intraorogenic (or, according to the generally accepted terminology (see Geological Dictionary, 1978), an intermontane) depression (Fig. 1), is characterized by a relatively more detailed study of the geological structure and, until now, is of interest from the point of view of oil and gas potential.

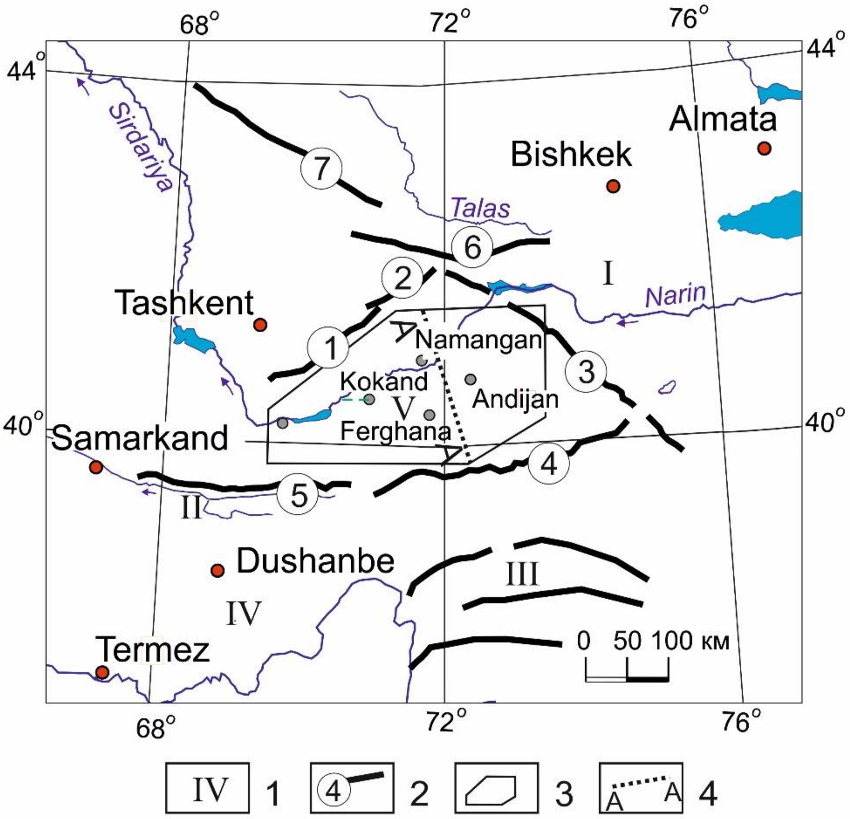

Fig. 1. Overview map of the location of the Fergana Basin.
1 - the largest structural and geomorphological elements of Central Asia: I - Northern Tien Shan, II - Southern Tien Shan, III - Pamir, IV-South Tajik Depression, V-Fergana Depression; 2- axis of mountain elevations: 1- Kurama, 2-Chatkal, 3- Ferghana, 4- Alai,
5 Turkestan, 6- Kyrgyz, 7-Karatau; 3 - research area; 4- profile line A-A of the geological section.

Here, geological studies were carried out with varying detail by V.N. Weber, V.A. Obruchea, K.P. Kalitsky, A.D. Arkhangelsky, D.V. Nalivkin, N.B. Vossoevich. Most of the published works on the geology and oil and gas potential of the region under study date back to the 70s-80s of the last century and are associated with the names of A.M. Akramkhodayev, A.M. Gabrilyan, O.S. Vyalov, B.B. Tal -Virsky, O.A. Ryzhkov, Z.R. Zokirov, T.L. Babadzhanov, G.Kh.Dikkenshtein, F.Kh. Zunnunov and many others. Concerning various aspects of geology, stratigraphy, tectonics, oil and gas potential of the region, they served as a scientific basis for the discovery of a large number of oil and gas fields here.

In subsequent years, studies were aimed at detailing the sections and the features of the placement of deposits in the productive horizons of individual areas. The studies of B.B. Sitdikov, G.S. Abdullaev, P.M. Usmanov, A.I. Gadoev, A.D. Gonchar, M.R. Nurmatov, I.Kh. Halismatov, A.I. Ismailov, A.Kh. Urmanov, R.I. Kalomazov and others. The published works examined various aspects of geological conditions, deep structure, placement features, types of deposits, and the influence of neotectonic indicators on oil and gas potential.Despite the accumulated material on geophysical fields, no direct research was conducted to study the influence of geophysical field indicators on the features of the location of hydrocarbon deposits, with the exception of some comparisons of the layout of the fields with the materials obtained. It should be noted about the increase in the volume of detailed surveys for individual profiles, or areas, to identify local structures and / or direct searches for deposits (performed in 2015 by V.G. Gadirov and others).

The features of the geological structure of the Ferghana depression with a thick stratum of orogenic continental deposits (fig. 2) and a huge range of neogene-quaternary movements, with an amplitude of only relative subsidence of more than 8 km (fig. 3) determines the need for new approaches to the interpretation of geophysical data to identify promising areas.

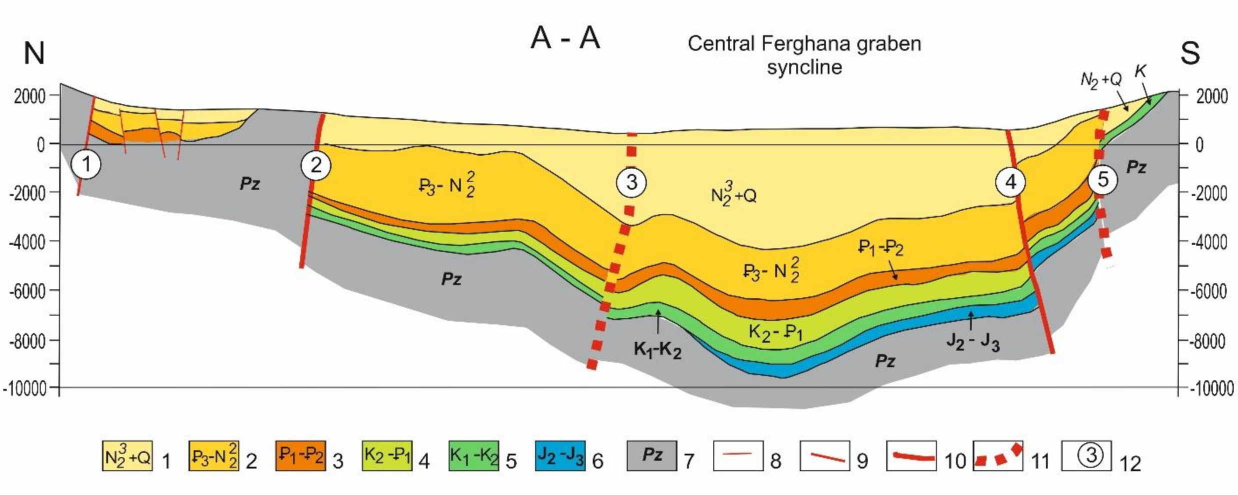

Fig. 2. Schematic section along the profile A-A across the strike of the Ferghana depression (compiled using data [Ibragimov, 1978]).
Geological complexes: 1–Upper Pliocene–Quaternary, 2–Oligocene – Middle Pliocene, 3 – Eocene – Paleocene, 4 – Upper Cretaceous – Eocene, 5 – Lower – Upper Cretaceous, 6 – Middle – Upper Jurassic, 7 – Paleozoic; 8 - discontinuous violations; 9- faults; 10 - regional faults; 11 - Flexure-fracture zone (FFZ); 12 - numbers of explosive violations, numbers in circles: 1 - Chatkalo-Atoynaksky, 2 - North Ferghana, 3 - North Fergana FRZ; 4 - Kapchigaysky 5 - Andijan FRZ.

Before proceeding to the consideration of the methodology and the description of the results of our research, we give a brief description of the geological structure of the Ferghana depression. Two large stratigraphic complexes are distinguished within the study region: the paleozoic folded base and the mesozoic -cenozoic sedimentary cover (see Fig. 2). Paleozoic sediments were studied mainly in the frame of the hollow and valleys of numerous rivers.

Deposits of cambrian and ordovician are not widespread, deposits of silurian, devonian, carboniferous, and less permian are much wider. Of particular interest from the point of view of, oil and gas potential is the section of the mesozoic-cenozoic sedimentary cover, most of which was discovered by deep wells and studied by geophysical methods. In the upper part of the section, cenozoic molasses reach a thickness of several tens of centimeters in the instrument parts of the basin up to 2-5 km or more in the middle part (see fig. 2).

In the upper part of the section, they are represented by siltstones, marls, sandstones, conglomerates, with interlayers of light brown clay rocks, lower in the section - clays, calcareous siltstones with small interlayers of sandstones and gravelites. The motley and variable section of the Mesozoic sediments is characterized by a change in marine and continental facies.High gradients of vertical movements along the sides and intensive immersion of the central part of the depression, with the extension on the edges, creates a common graben-synclinal (ramp) structure with an asymmetric shape of the depression, with some approach of the axial zone to the south side (see Fig. 3).

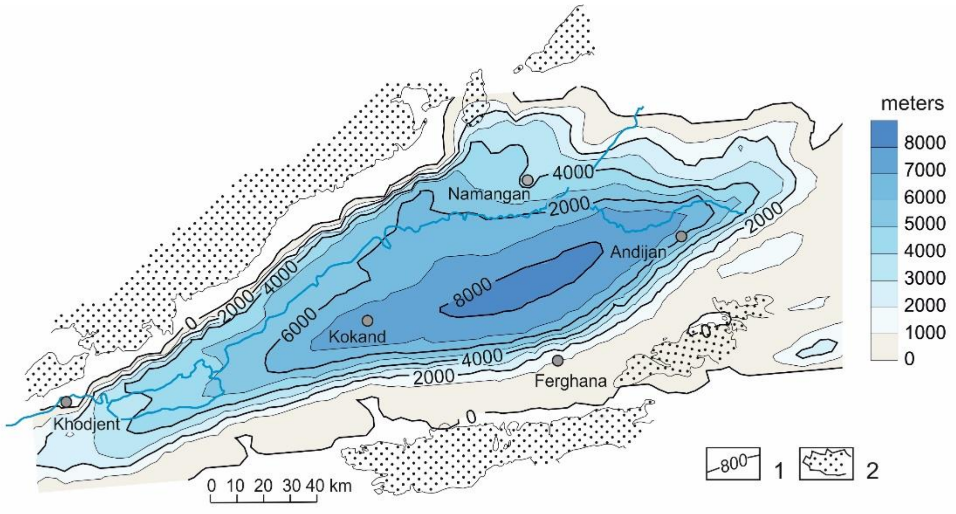

Fig. 3. Schematic map of the thickness of the Neogene-Quaternary sediments of the Ferghana basin (compiled using data [Zunnunov et al., 1973; Ibragimov, 1978]).
1 - isopach; 2 - outputs of the Pre-Mesozoic sediments on the day surface.

In such conditions, to identify new forecasting criteria, a revision of the existing geophysical materials, reflecting the underlying structural features of the subsoil, is required from new positions. For this, we used data on the anomalies of the gravitational field. The fact that data on the gravitational field can be used to search for oil and gas deposits is noted in the published literature [5].

Depending on the goals and objectives, gravimetric observations can be grouped in two directions: 1) observations for direct searches, the possibility of which is determined by the presence of a connection between the anomalies of the gravitational field and oil and gas fields, the anomalies of which can reach up to 1 Mg [5]; 2) regional observations to identify intense gravity anomalies associated with large structures promising oil and gas; the magnitude of the values of anomalies, as noted in the thesis by V.G. Gadirov (2014), can reach from 10 to 50 mGal. Such structures that create increased anomalies are usually anticlinal folds, salt domes and others, which are outlined according to gravimetric surveys. The possibilities of such studies are due to the special physical conditions of the subsoil, and above all, the difference in the density of reservoir rocks from the environment. Therefore, in regional and detailed exploratory research, gravity exploration is effective.

Studies on direct searches of oil and gas deposits by geophysical methods within the Ferghana oil and gas region based on high-precision gravimetric surveys, performed by

Uzbekgeofizika JSC in the author's version according to the method [6,7] made it possible to determine that individual structural uplifts - Uchtol, Palvantash, Kutarma, are displayed in the gravitational field by local maxima with high intensity, on the order of 1.0-1.8 mGal. Also, local minima of gravity were discovered at the Palavantash field with an intensity of 0.4-0.5 mGal, which are associated with oil and gas content. These studies Gadirova V.G. Together with their Uzbek colleagues, carried out in 2015 within separate areas of the Ferghana depression, they showed that the presence of a deposit is expressed by the minima of the gravitational field against the background of its relatively high values.

Analysis of published works shows that gravity exploration is effectively used in the search for promising areas. Areas with negative gravitational anomalies in the form of subvertical channels where large oil deposits turned out to be revealed. Such structures were found in various oil and gas bearing regions: in the region of Western Siberia [8,9] where they are marked as a subvertical element of geophysical fields, indicating a lower density and increased magnetization. The presence of vertical channels of fluid flows and confinement to such zones of newly formed oil deposits are associated with Earth degassing processes [10].

Different authors call such zones differently. Such definitions are found, for example, as “subvertical geological object”, “fracture and stress zone”, “high conductivity zone”, “fluid flow channels”. In the works of Uzbek geologists, they are called “channels of deep heat and mass transfer” (DHMT channel) [9]. When describing such zones, geophysical signs of channel reflection are noted, such as a “wave scattering zone” of high “seismic turbidity” [6,10]. The migration routes of hydrocarbons and the predisposition of hydrocarbon deposits near these zones are associated with them [10].

Researchers also explain the observed differences in physical parameters by the nature of the distribution of tectonic stresses and strains in the geological environment [Gadirov, 2012], a decrease in density over the reservoir due to the migration of light hydrocarbon fractions to the Earth’s surface [9]. Within the Bukhara-Khiva and Surkhandarya regions, such channels were detected by the nature of the distribution of electrical resistivity [11].

The above brief review shows that there is a lot of diverse data indicating the influence of the physical parameters of the medium on the formation and placement of hydrocarbon deposits. For all the variety of studies, none of them attempted to determine the level of reliability and significance of this relationship. The presence of such a relationship determines the relevance of studies to identify areas with different physical parameters and their influence on the distribution of oil and gas fields not only in Uzbekistan, or in the Ferghana Depression. This work was aimed at filling this gap - the analysis of available materials was carried out, the degree of connection between the anomalous gravitational fields of the Ferghana Depression and the spatial distribution and size of oil and gas fields was studied.

Research methodology and materials. To solve this problem, published and stock materials on geology, oil and gas potential and geophysical fields obtained in different periods were used. The geological and lithological-stratigraphic description of the section of the study area is given using materials [12,13].

The Ferghana depression, which has a common northeastern strike, is limited from the northwest and southeast by deep faults of a reverse fault type. Paleozoic and early mesozoic formations are thrown into younger formations (see fig. 2). The amplitude of faults varies from 200 m to 1.5 -2 km or more. The thickness of the mesozoic and cenozoic sediments in the central part of the depression reaches 9, sometimes 10 km (see fig. 2).

Within the Ferghana Depression, many oil and gas fields have been discovered. In fig. 4 is a schematic map of their location. Their highest density is observed in the southern and southeastern parts of the basin. However, their sizes are different, and the conditions for the placement of deposits are different.

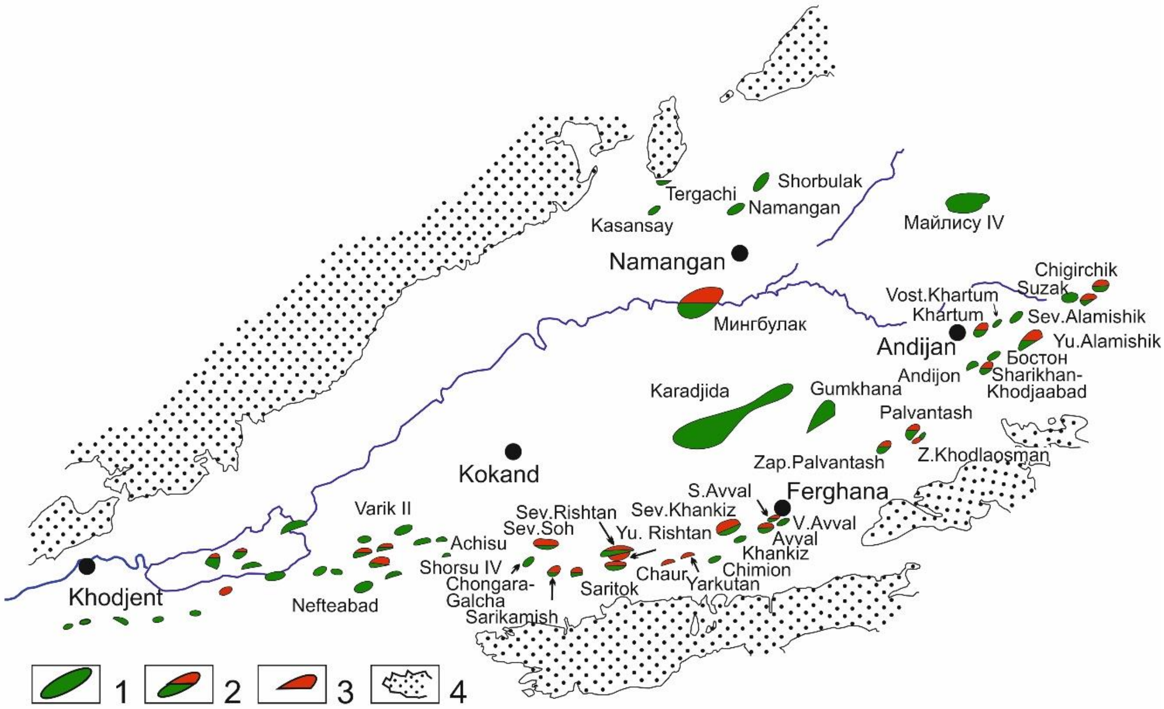

Fig. 4. Schematic map of the location of oil and gas deposits in the Ferghana Depression. Deposits: 1 - oil, 2 – oil-gas, 3 - gas; 4 - exits to the surface of the pre-Mesozoic formations.

There are types of traps in the form of anticlinal folds, tectonically and lithologically shielded reservoirs. In most cases, deposits are multi-tiered, multi-storey in nature (Fig. 5). Productive horizons are unevenly distributed over the section, deformed, broken by intense neotectonic movements, deposits are confined to opposite wings, shifted relative to each other along the surfaces of the shifter, mainly in the form of uplift.

There is some regularity in the location of deposits depending on their type: oil, oil and gas or gas. The largest oil fields of Karajida and Gumkhana are located in the middle part of the basin - in the Central Ferghana graben synclinal (see fig. 4). On this site, the most submerged part of the paleozoic basement and the maximum thickness of the neogene-quaternary sediments are noted (see fig. 3). We have performed the collection and analysis of available materials for all currently known fields with the compilation of a data catalog, indicating the stratigraphic position of the deposits, the type of trap structure, type of deposits, lithology of the rocks, their reservoir properties, effective volume and reservoir thickness, volume contours hypsometric position. Based on these data, a diagram of the oil and gas content of the Mesozoic and Cenozoic sediments in the form of a lithologic-stratigraphic column with the application of productive horizons of the studied deposits is compiled.

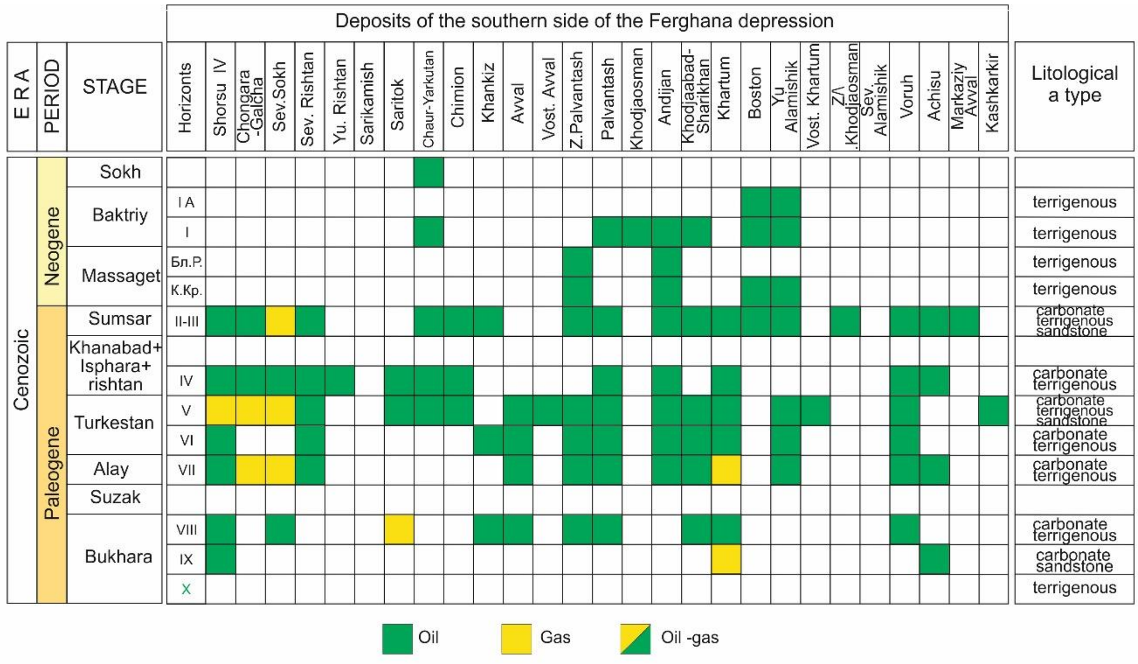

Fig. 5. Oil and gas potential diagram of the Cenozoic sediments of the southeastern side of the Ferghana depression.
The color of the Square indicates the type of Deposit: green - oil, yellow - gas, yellow-green - oil and gas.

A fragment of such a diagram of the oil and gas potential of the southeastern side of the Ferghana Depression for Cenozoic sediments is shown in Figure 5. As can be seen from the diagram, Neogene terrigenous deposits in the areas of Palvantash, West Palvantash, Andijan, Khojaabad-Sharikhan, Boston and South Alamyshik, Chaur, are productive for oil. Yarkutan, (see Fig. 5). Their oil productivity has also been established for Mesozoic deposits. In addition to these areas in the Mesozoic sediments, oil deposits were discovered in the areas of Shorsu IV, Northern Rishtan, Khankyz, Western Palvantash, and Varukh. Gas deposits in the Mesozoic deposits were mainly recorded in the areas of Shorsu IV, Chongara-Galcha, Northern Sokh, Khartoum (see Fig. 5).

According to Uzbekgeofizika JSC, the majority (about 70%) of the oil and gas deposits of the Ferghana Depression are in the Sumsar, Turkestan and Alai layers of the Paleogene. Deposits of the field are discovered on the northern side in the areas of Namangan, Tergachi, Mailisay, Mailisu-IV, Izbaskent. All these data on oil and gas content were used in comparison with geophysical materials, in particular with anomalies of the gravitational field. For the Ferghana Depression, the most complete summary of gravimetric materials, with a historical overview and the determination of the contribution of researchers to the formation of the “database”, is given in [14,15].

The possibility of using gravimetric surveys to study the structure of various deep horizons is determined by the density properties of rocks. The geological section of the Mesozoic-Cenozoic of the described territory according to the density properties of rocks in [14] is divided into four groups: light (2.34-2.36 g/cm^2), medium density (2.38 - 2.47 g/cm^2), increased (2.48 - 2.49 g/cm^2)

and heavy (2.53 g/cm^2 and above). For Paleozoic rocks, the density values were 2.62–2.63 g/cm^2 and up to 2.67 g/cm^2 for metamorphic schists, dolomites, and diabases. These density data were necessary to calculate the reduced values of the anomalies - Bouguer and Faya.Without dwelling on the description of these cartographic materials, we give a generalized diagram of the elements of the gravitational field (Fig. 6), compiled by us using published materials. As you can see, in the gravitational field of the Ferghana Depression, the largest zone of the regional maximum is noted, which practically covers the southwestern and central parts.

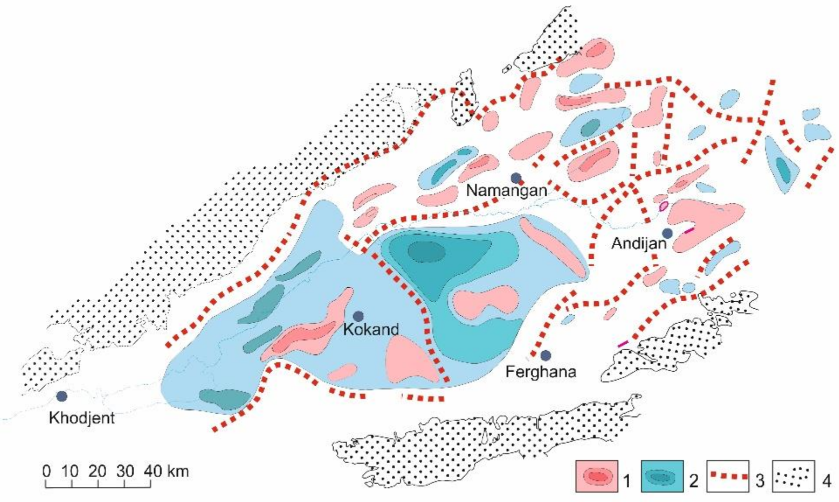

Fig. 6. Schematic map of the elements of the gravitational field, without the influence of the latest deposits (compiled using materials [Zunnunov et al, 1973]).
1 - local zones of maximum; 2 - regional and local zones of minimum; 3 –high-gradient zones of the gravitational field; 4 - outputs of pre-Mesozoic formations

The zone of regional minimum falls to the central part (between the large cities of Kokand, Fergana, Andijan, Namangan). Here, the largest minimum band has a west-north-west strike and is separated from the south-western half by a zone of increased gradient of north-west strike. This gradient zone is called the Kokand gravity stage. In addition, the largest gravitational steps are also Andijan, Namangan, North and South Ferghana. All of them have a northeastern strike.

In Fig. 7 shows a diagram of the isolines of the deep gravity anomalies in the Fai reduction averaged by the “sliding window” method with a step of 20x20 km. The same anomalies averaged with a step of 40x40 km are shown in Fig. 8.

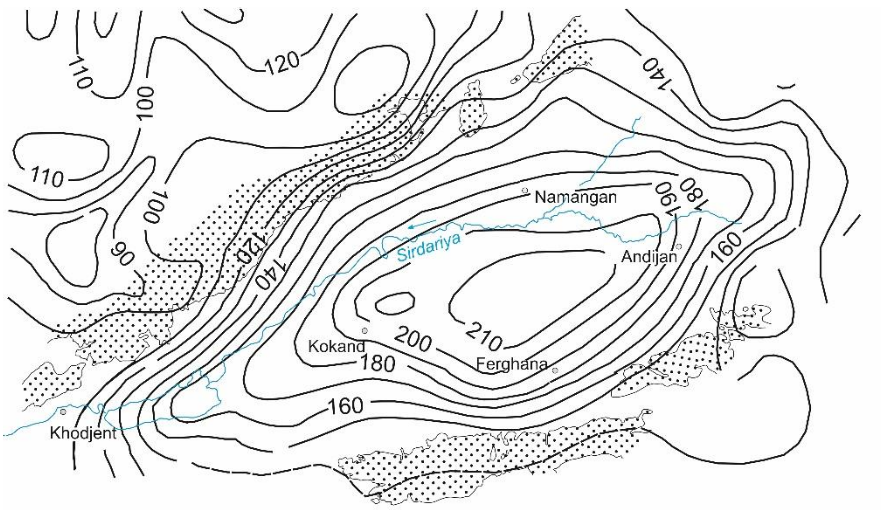

Fig. 7. The contours of the deep gravity anomalies (in Mgl), adjusted for the height of the observation points (in Faya reduction), averaged by the "sliding window" method with a step of 20x20 km [Zunnunov et al., 1973].

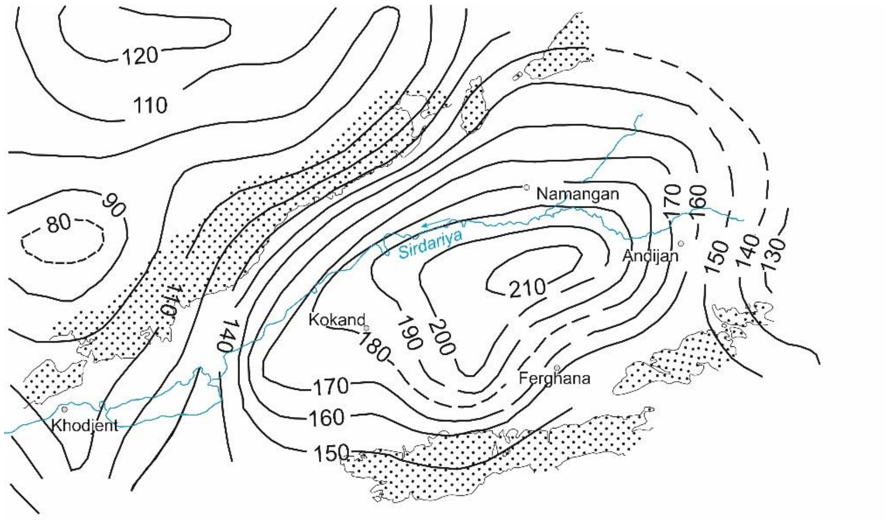

Fig. 8. The contours of the deep gravity anomalies (in Mgl), adjusted for the height of the observation points (in Faya reduction), averaged by the "sliding window" method with a step of 40x40 km [Zunnunov et al., 1973].

The following features are noted in these schematic maps: the regional maximum of the values of the anomalies, which are caused by the density inhomogeneities of the deep layers, up to the lower crust and upper mantle, fall to the central part of the depression; the positions of the large Kokand gravity stage, and other stages in the northwestern and southeastern outskirts are preserved.

The study of the dependence of field indicators and geological and geophysical data was carried out on the basis of identifying qualitative and quantitative relationships based on visual comparison of cartographic materials on the studied factors and the analyzed characteristics with each other, as well as a statement of quantitative data of the studied attribute on various gradations of factors with the preparation of correlation tables as well as performing analysis of variance. At the same time, recommendations for observing the requirements for performing statistical analysis in the papers [16,17].

Comparison and selection of data was carried out using the ArcGis software-integrated environment, deposits were recorded that fall into zones with different values of the gravity field anomaly of various levels of generalization, and also fall into zones with a maximum, minima, and zones of high contrast. All data were presented in tabular form and used for analysis of variance (by qualitative and quantitative characteristics). The technique and technique of analysis of variance is described in [16,17]. Analysis of variance allows, together with the study of the nature of the dependence, to quantitatively assess the degree of connection (or "force of influence") between the factor of the gravitational field and the studied attribute - the effective volume of the field. As an indicator of the size of the reservoir, the effective volume was used, which, due to known circumstances, is presented in the form of a conditional dimensionless coefficient proportional to it.

To determine the influence of a factor on the indicator under study, three types of variance are calculated [16]: C_x - “factorial” (or organized), C_z - “random”, C_y - “general”. If necessary, variants can be calculated (or unit variances of individual members of the sample) defined by the expressions:

for factorial

$$\sigma_x^2 = C_x/(r-1) \tag{1}$$

and for unorganized influences

$$\sigma_z^2 = C_z/(N-r)\,, \tag{2}$$

where N - the total number of values in all gradations of the sample, r is the quantity of gradations of the factor.

The main idea of analysis of variance is to compare the "factorial" and "random" variances. If the difference between factorial (C_x) and random (C_z dispersion is significant (with high probability), then a conclusion is made about the strong influence of the factor on the studied trait. Then the difference between the mean values (M_{mi})) for the sample groups by the studied factor will be significant.

The force of influence of the factor η_x^2 and its error in determining $m_{\eta_x^2}$ are calculated by formulas (3) and (4):

$$\eta_x^2 = \frac{C_x}{C_y} \tag{3}$$

$$m_{\eta_x^2} = (1-\eta_x^2)\frac{r-1}{N-r} \tag{4}$$

Here $r-1=\nu_1$ is the first degree of freedom taking into account the number of gradations of the factor, and $N-r=\nu_2$ is the second degree of freedom for the entire sample size.

The total degree of freedom ν_o is determined as the sum of the first and second. These data are used to extract the calculated standard values of the Fisher criterion for three thresholds of probabilistic forecasts ($\beta_1 = 0{,}95$; $\beta_2 = 0{,}99$; $\beta_2 = 0{,}999$) [16].

The reliability of the influence (Φ) is determined on the basis of expression (5) as the ratio of the influence force (η_x^2) to the error of its determination ($m_{\eta_x^2}$), the value of which is compared with the standard values (t_{st} and F_{st}) of the Fisher criterion, calculated for three thresholds of probability of reliable forecasts ($\beta_1 = 0{,}95$; $\beta_2 = 0{,}99$; $\beta_2 = 0{,}999$) [16].

$$\Phi = \frac{\eta_x^2}{m_{\eta_x^2}} \geq t_{st}\ (or\ F_{st})\ \{\ \beta_1,\ \beta_2\,,\ \beta_3\ \} \tag{5}$$

The standard values of the Fisher criterion for the indicated thresholds of probabilistic forecasts are given in the literature on mathematical statistics [16, p. 346].

In the formation of the dispersion complex, qualitative and quantitative data were used: selected from the map of gravitational anomalies (see Fig. 6), maps of local anomalies (not shown here), deep anomalies averaged over 20 × 20 km sites (see Fig. 7) and 40x40 km (see Fig. 8) and field layouts (see Fig. 4).

The statistical material participating in the calculations was divided into appropriate gradations (or groups) from 3 to 6 intervals of the analyzed indicator (factor). Due to the cumbersomeness of the tables with the initial data, they are not presented here. Note that the number of deposits ranged from 30 to 62, depending on the presence or absence of data.

Analysis of variance was carried out for three types of data: 1) for all fields (oil, oil and gas and gas), 2) only for oil fields, 3) only for oil and gas. For gas fields, the sampling was insufficient and did not provide a condition for representativeness.

Results and comparative analysis. The following tables summarize the results of a variance analysis of the effect of the deep anomaly of the gravitational field in the Fai reduction on the effective volume of deposits. An analysis was carried out for two versions of the maps obtained with averaging at a site of 20x20 km and 40x40 km and for three variants of fields: all oil and oil and gas (Table 1, Table 2); only for oil (Table 3), only for oil and gas (Table 4).

As can be seen from the Table 1 and Table 2 indicators of influence were found to be almost equal to 0.44 and 0.45. This means that, out of the total amount of acting factors, the influence of the deep-seated anomaly factor in the Fai reduction is 44-45%. The calculated values of the criterion of reliability of influence according to Fisher (F) amounted to 3.91 in the first case and 5.04 in the second. When comparing the calculated values of the Fisher criterion with the standard values for the indicated degrees of freedom [16], the calculated ones were higher than the standard values at the second level of the probability threshold of error-free forecasts 0.99 - 3.5 and 3.7, respectively. This indicates that the influence is not only significant, but also significant with a probability of 0.99. The share of the influence of the analyzed factor on effective volumes: separately for oil fields is 42% (Table 3), and separately for oil and gas - 62% (Table 4).

If we take into account that the used data of gravitational anomalies are formed due to density inhomogeneities of the lower levels of the crust and upper mantle, then the results indicate a significant influence on the formation of the size of oil and gas deposits of deep subcrustal processes that create the corresponding gravitational effects. Known published works on the problem of reflecting the features of the deep structure of the subsoil in the nature of the gravitational field. Such characteristic deep-seated objects of the Ferghana Depression include the roof of the Pre-Mesozoic basement, “the relief of which is clearly reflected in the morphology of the gravitational field” [14, p. 50].

Table 1.

The results of the analysis of variance of the influence of the deep anomaly (Δg_F) with averaging of 20x20 km on the effective volume of oil and gas deposits

Type of dispersion	dispersion	Degrees of freedom (ν_1, ν_2, ν_o)	Variance (σ_x^2, σ_z^2)
Factorial (***C_x***)	6046	6	1008
Random (***C_z***)	7731	31	258
General (***C_y***)	13777	37	

Index of the influence of the depth anomaly factor: 0**.44**
Reliability of influence according to the standard Fisher Criterion **F=3.91**
Standard Fisher test values for thresholds
probabilities 0.95; 0.99; 0.999: **2.4 – 3.5 – 5.1.**
The influence of the organized factor of deep anomaly is **44%**
Confidence limits of the general indicator: **0.07-0.71** (from 7 to 71 %)

Table 2.

The results of the analysis of variance of the influence of the deep anomaly (Δg_F) with averaging 40x40 km on the effective volume of oil and gas deposits

Type of dispersion	Dispersion	Degrees of freedom (ν_1, ν_2, ν_o)	Variance (σ_x^2, σ_z^2)
Factorial (***C****x*)	6167	5	1233
Random (***C****z*)	7591	31	245
General (***C****y*)	13758	36	

Index of the influence of the depth anomaly factor: **0.45**
Reliability of influence according to the standard Fisher Criterion **F=5.04**
Standard Fisher test values for thresholds probabilities 0.95; 0,99; 0.999: **2.5– 3.7 – 5.5.**
The influence of the deep anomaly factor is **45%**
Confidence limits of the general indicator: **0.23-0.67 (23-67%)**

The large gravitational steps noted in the Ferghana Depression (for example: Kokand, north-north-western strike) have a deep nature and can be associated not only with large flexural elements of the basement. This may be evidenced by the fact that this gradient zone manifested itself at all levels of the transformation of the gravitational field with analytical continuation into the upper half-space at high altitudes (8.12.15 km) and averaging of the field with large windows (30x30, 42x42, 48x48 km) [14].

An analysis of the influence of gravitational anomalies on the location and effective volume of oil and gas deposits was carried out by us based on local anomalies of the gravitational field formed from density inhomogeneities of the lower horizons of the Mesozoic complex and the Paleozoic basement [14].

In these schemes, frequent alternation of the zones of maxima and minima of the southeast and northeast strike is noted, there are separate local gradient zones. Within the Ferghana Depression, at different depth levels up to 30 km in the middle and upper parts of the crust [18], volumes were distinguished that differ in various petrophysical indices (Fig. 9). When comparing it with tectonic elements in some high-density geoblocks: for example, Kokand and Andijan, the author notes their association with different tectonic structures, and associates their nature with “relicts of mantle diapirs of plumes)” [18].

It is assumed in the work that they can be represented by tectonic-magmatic formations of the main composition, which include subalkaline basaltoids, gabbroids, and dolerites with a density of 2.8 to 3.0 *g/cm^3*. Various processes are involved in the formation of density inhomogeneities of these deep levels. Among them, a special place is occupied by the processes of plume tectonics - one of the constituent parts of the “triad of modern geodynamics” [19].

Table 3.

The results of the analysis of variance of the influence of the deep anomaly (Δg_F) with averaging 40x40 km on the effective volume of oil deposits

Type of dispersion	Dispersion	Degrees of freedom (ν_1, ν_2, ν_o)	Variance (σ_x^2, σ_z^2)
Factorial (***C****x*)	4188	2	2094
Random (***C****z*)	5678	15	379
General (***C****y*)	9866	17	

Index of the influence of the depth anomaly factor: **0.42**
Reliability of influence according to the standard Fisher criterion **F=5.53**
Standard Fisher test values for thresholds probabilities 0.95; 0.99; 0.999: **3.7 – 6.4 – 11.3**.
The influence of the deep anomaly factor is **42%**
Confidence limits of the general indicator: **0.16-0.69 (от 16 до 69** %)

Table 4.

Results of a variance analysis of the influence of the deep anomaly (Δg_F) with averaging 40x40 km on the effective volume of oil and gas deposits

Type of dispersion	Dispersion	Degrees of freedom (ν_1, ν_2, ν_0)	Variance (σ_x^2, σ_z^2)
Factorial (C_x)	2343	4	586
Random (C_z)	1415	14	101
General (C_y)	3757	18	

Index of the influence of the depth anomaly factor: **0.62**
Reliability of influence according to the standard Fisher Criterion **F=5.80**
Standard Fisher test values for thresholds probabilities 0.95; 0.99; 0.999: **3.1 – 5.0 – 8.6.**
The influence of the deep anomaly factor is **62%**
Confidence limits of the general indicator: **0.29-0.96 (29-96%)**

Based on modeling the mechanisms of granite gneiss diapirism in the continental crust [20,21] quantitative estimates of the parameters of the maximum level of penetration of diapir bodies - reaching the middle parts of the cortex were determined.

It was also noted that diapirs can easily transport large magma masses through the mantle and lower-middle crust with viscoplastic properties, not necessarily with increasing temperatures until the host rocks melt. Such an introduction of the mantle substance, which occurs upward vertically, and also has a lateral effect, leads to the formation of inhomogeneities differing in viscous and density parameters from the environment. It was noted that at a rise rate in the crust of the order of 19 mm / year, the substance remains in a viscoplastic, subsolidus state, rising and spreading forms a dome shape due to pressure from the molten material of the diapir core [21].

Thus, among the main factors determining the genesis of density inhomogeneities in the lower and middle parts of the crust are mantle intrusions. The essence and features of mantle intrusions based on modeling over the past decades have been successfully studied at the SB RAS [19]. Data were obtained on the formation of various objects in the lower and middle parts of the crust, due to the breakthrough of mantle material in areas with different thicknesses of the continental crust. All these data allow us to identify the material composition of decompressed blocks of deep levels of the crust of the Ferghana depression with rocks of magmatic origin with a density of 2.48 to 2.6 g/cm^3. In the geological and geophysical model of the deep section of the Ferghana Depression, pronounced differentiation of the density of the layers of the earth's crust at depths of 20-25 km (2.90-2.95 g/cm^3), 10-20 km (2.85-2.90 g/cm^3), 5-10 km (2.80 -2.85 g/cm^3), 0-5 km (2.40-2.65 g/cm^3) [22]. In this model, the discontinuous elements of the lower deep levels are displayed in the form of fault faults, which change the angle of inclination to vertical upstream [22].

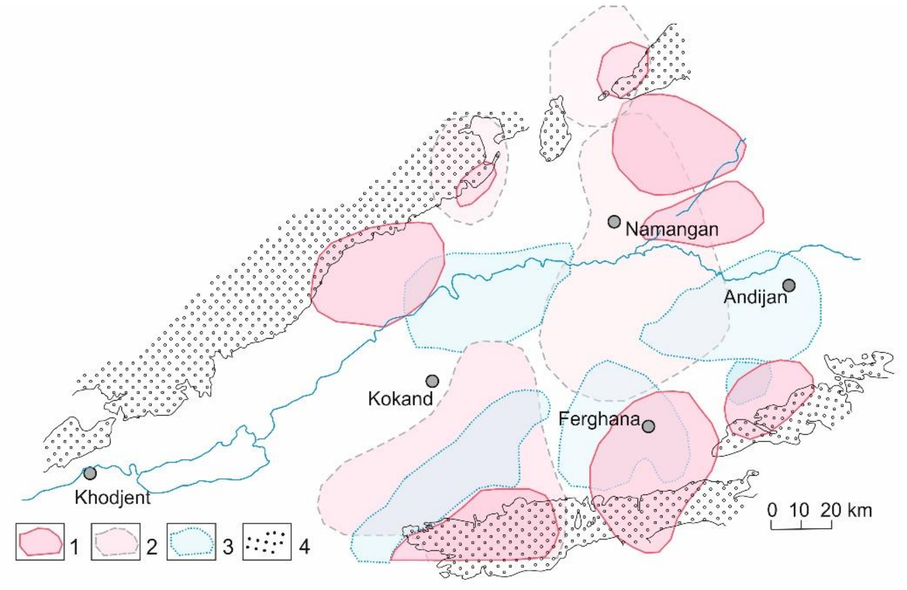

Fig. 9. Geoblocks with anomalous petrophysical parameters of the Ferghana Basin (compiled using materials [Mordvintsev, 2010]).
1 - increased density, average depth of coverage (up to 30 km), 2 - deeper;

When comparing the position of geoblocks with oil and gas fields, it was noted that within the South Board they "gravitate to contact zones between bodies with contrasting density properties" [18]. In addition, in a number of cases, the confinement of deposits to the boundaries of blocks with high and low density characteristics was noted. The data on the deep structure of the crust and upper mantle described in [23] for the Asian continent also indicate the vertical and horizontal distribution of volumes with anisotropic properties. These volumes differ in speed characteristics (waves SV and SH), which allows us to judge the density heterogeneity of the deep levels of the lower crust and deeper parts. Vertical anisotropy was observed to depths of about 250 km, with maxima from the depth interval from the bottom of the earth's crust to 150 km [24].

With a length of about 200 km, it has a sub-latitudinal strike, consistent with the general strike of the main structures of the region. The fact that they are under a common regional stress field does not exclude the possible existence of a similar zone of lateral plastic flow in the lower part of the Earth's Crust of the Ferghana depression. In a sense, this is also indicated by the location of the decompressed blocks noted above in the middle and lower parts of the Earth's Crust [18]. The involvement of other geophysical data, along with the anomalies of the gravitational field, is also of great importance, since when obtaining a quantitatively reasonable estimate of the reliability of their influence on the studied dependence, it can be used as a reliable search criterion.

Unlike other indicators of non-physical content, these criteria also contain genetic traits. Unfortunately, to date, many of the materials on the density inhomogeneities of depression have not participated in the analysis of variance. But these studies are ongoing. And according to the data that we recruited for local anomalies associated with the upper sections of the geological section of the basin, analysis of variance showed that, although the influence of local anomalies of the gravitational field on the location and effective volume of deposits is statistically significant, the reliability is low. Therefore, the degree of influence of density inhomogeneities of the upper and middle horizons remains unclear. Apparently, more detailed studies are needed here. However, the established reliable and significant relationship between the influence of gravitational anomalies of a deep nature can already be used to solve the search problems of oil and gas geology.

Conclusion. Thus, on the basis of the study, the following conclusions can be drawn:

The influence of the deep anomaly factor in the Fai reduction on the value of the effective volume of the field is 44-45%. The calculated values of the criterion of reliability of influence according to Fisher (F) amounted to 3.91 in the first case and 5.04 in the second. When comparing with the standard values of the Fisher criterion for the indicated degrees of freedom, the calculated values turned out to be higher than the standard ones for the second threshold of probability of error-free forecasts 0.99 - 3.5 and 3.7, respectively. This indicates that the influence is not only significant, but also significant, with a probability of 0.99.

The share of the influence of the analyzed factor of the deep anomaly of the gravitational field on the effective volume of oil fields is 42%, and on oil and gas - 62% of the total amount of influencing factors. When these results are extended to the general population, it turns out that for oil fields the strength of influence varies from 16 to 69%, and for oil and gas fields - 29 - 96%. The power of influence is very significant.

Dispersion analysis of data on local gravity anomalies associated with the upper sections of the geological section of the basin showed that their influence on the location and effective volume of deposits is significant, but the reliability is low. The degree of influence on them remains unclear.

The obtained quantitative data indicate a significant influence of deep subcrustal processes that create the corresponding gravitational effects on the formation of sizes and distribution of oil and gas deposits in the Ferghana Depression. The obtained dependencies and quantitative estimates are of great scientific and applied value for the development of methods for forecasting and prospecting for oil and gas.

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