ISSN 2411-3336; e-ISSN 2541-9404

JOURNAL OF MINING INSTITUTE
Zapiski Gornogo instituta
Journal homepage: pmi.spmi.ru




*Research article*

# $M_1$ formation tectono-structural features and gas-oil potential within Archinskaya area Paleozoic basement (Western Siberia)

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***How to cite this article*:** Belozerov V.B., Korovin M.O. $M_1$ formation tectono-structural features and gas-oil potential within Archinskaya area Paleozoic basement (Western Siberia). Journal of Mining Institute. 2024. Vol. 268, p. 520-534.

***Abstract.*** Western Siberian Plate basement oil and gas potential evaluation largely depends on structural and stratigraphic complex architecture representation. New modern procedures for seismic data processing, detailed Paleozoic deposits stratigraphic studies and expanded geophysical well logging significantly change the representation of the basement rocks fold-block structure and previously developed hydrocarbon reservoirs models. Detailed studies conducted within the Archinskii uplift showed that Paleozoic sediments form a contrasting folded structure complicated by block tectonics. The significant block displacements amplitude determines the lithological and stratigraphic basement rocks erosional-tectonic surface, while the identified stratigraphic blocks control the oil productivity distribution within the Archinskaya area. The filtration-capacity heterogeneity folded structure of the Paleozoic sediments is reflected in the distribution of hydrocarbon saturation in the well section, forming independent gas, oil, and oil-water zones for the development process. The relationship between anticlinal structural forms of basement rocks to lowered, and synclinal to elevated blocks, determines the necessity to conduct exploration prospecting within younger stratigraphic blocks when assessing the deep Paleozoic oil and gas potential.

***Keywords*:** pre-Jurassic sedimentary complex; basement rocks; seismic exploration; oil and gas potential; reflective horizon; structural forms

***Received: 21.11.2022*** ***Accepted: 02.05.2024*** ***Online: 18.07.2024*** ***Published: 26.08.2024***

**Introduction.** Due to original data interpretation ambiguity, different authors note differences in Western Siberian basement tectonic development features interpretation not only in individual parts structure analysis case, but also from the general approach that involves plate tectonics or geosynclinal concept usage. From the standpoint of plate tectonics, the Paleozoic stage of transformation is described in the published literature within the framework of the entire Western Siberian Plate (WSP) [1-3], its individual parts [4-6], adjacent territories [7, 8], and global reconstructions [9-11], where generalized schemes of tectonic transformations are presented without territorial individual parts geological structure emphasis, which does not allow data usage in specific local areas detailed study purposes.

Tectonic and subsurface composition maps (small and large scale) are created on the basis of all accumulated geological and geophysical data, reflecting the features of its tectonic development during the Paleozoic era as a whole for WSP [12-14], its individual parts [15-17] and in relation to oil and gas content [18, 19], is interpreted within the geosynclinal concept framework.

The latest researches following WSP basement geotectonic zonation with deep wells data support [20] reveal corrections to previously presented tectonic zoning schemes and pay attention to modern researchers controversial innovations opposing their predecessors – A.P.Karpinsky, V.A.Obruchev, A.D.Arkhangelsky, N.S.Shatsky. In their understanding, “new proposals should be based on previous tectonic schemes with a reasoned indication of any changes”.



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Structural-facial zones through cross-sections formation structure favors the Western Siberia geosynclinal development in the Paleozoic era[1] (Fig.1). According to the geostructure zones and types of their formation series proposed by V.E.Khain, structural-facies blocks are referred to geosyncline (zones 3-7, 10). The basement of the section is composed of spilite-keratophyre, clayey-siliceous, jasper formations (basalt-andesites, clayey-siliceous schists, jasper) and has Ordovician – Silurian period of accumulation. Carbonate-terrigenous formation including magmatic (basalts, andesites) and effusive rocks is placed above the previous strata (Devonian – lower Carboniferous). Limnic coal-bearing formation represented by interbedding of bituminous shales, sandstones and conglomerates finishes the cross-section (Middle Carboniferous – Permian).

Within the miogeosyncline uniting the structural-facial blocks 1, 2, 13, 15-20, the base of the sections (Ordovician) is composed of aspidine formation (metamorphosed argillites and phyllitized schists). Further (Silurian – Lower Carboniferous) follows the terrigenous-carbonate formation (interbedding of limestones, dolomitized limestones, dolomites, sandstones, argillites with the inclusion of basalts, tuffs and effusives). The sections are completed (Middle Carboniferous – Permian) with continental grayish-colored coarse-grained formation consisting of interbedding of argillites, bituminous argillites, aleuropelites, sandstones, and conglomerates. For the sections of the geosyncline and miogeosyncline, numerous stratigraphic discrepancies of various age ranges are characteristic.

The article [20], in which comprehensive biochronological and geochronological materials on the pre-Jurassic basement of Western Siberia are generalized and a comparison of geological information with seismic survey data is carried out, confirms the geosynclinal model of the formation of Paleozoic deposits of the WSP. Based on the results of the studies, the authors identify the Ural-Altai region with a basement age of 250 million years. The geotectonic zoning of this region into Uralides and Altaids is well consistent with the formation division of this territory into eugeosyncline and miogeosyncline (Fig.1). Since the geostructural zones of the WSP basement are a continuation of the tectonic structures of its framing, it is possible to compare the history of their development. As the basis of the history of the development of geostructural zones, the diagram of geosynclinal, orogenic, platform and rift stages of development proposed by V.V.Belousov [21] is accepted, according to which in the west of the WSP, Hercynides of the Urals are distinguished, in the south – Caledonides and Hercynides of Northern Kazakhstan, in the south-east – Salairides and Hercynides of Western Sayans, and in the east – Baikalides of the Siberian Platform (Fig.1, *a*).

In comparing the geostructural zones of the initial stage of the tectonic development, the Uralides can be attributed to the eugeosyncline, while the Altaids can be attributed to the miogeosyncline. The presented comparisons are well consistent with the studies of V.S.Surkov et al. [13, 15], who refer the geosynclinal complexes of the Urals (Uralides) to the eugeosyncline and the Central West Siberian (Altaids) to the miogeosyncline. It is also noted that the Ural folded system developed according to an inherited scheme, where the main folded structures are represented by anticlinoria and synclinoria of the inherited type, and the Central West Siberian system was formed according to an inverted scheme. Its main structures are inverted anticlinoria, which arose in place of slate geosynclinal depressions. Examples of paleogeomorphological analysis of Paleozoic complex deposits and related oil and gas content are presented in works [22, 23], and issues of development of the identified oil-prospective objects are discussed in studies [24, 25].

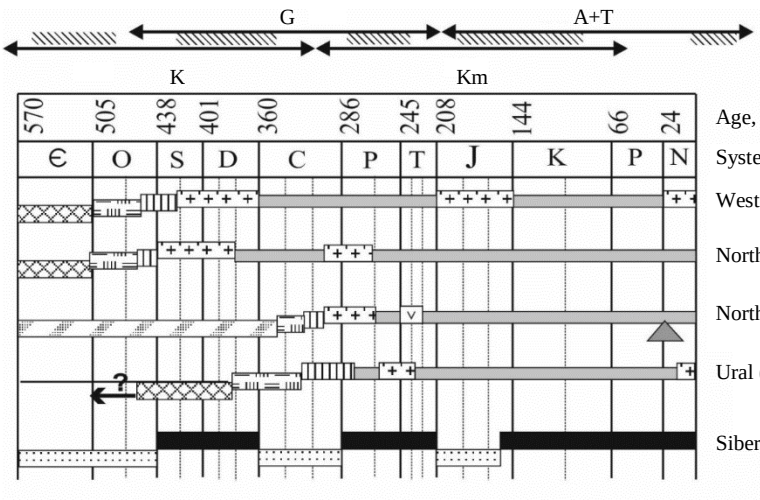
[1] Decisions of the Interdepartmental Meeting on the consideration and adoption of the regional stratigraphic scheme of the Paleozoic formations of the West Siberian Plain. Ed. by V.I.Krasnov. Novosibirsk: SNIIGGiMS, 1999, p. 79.



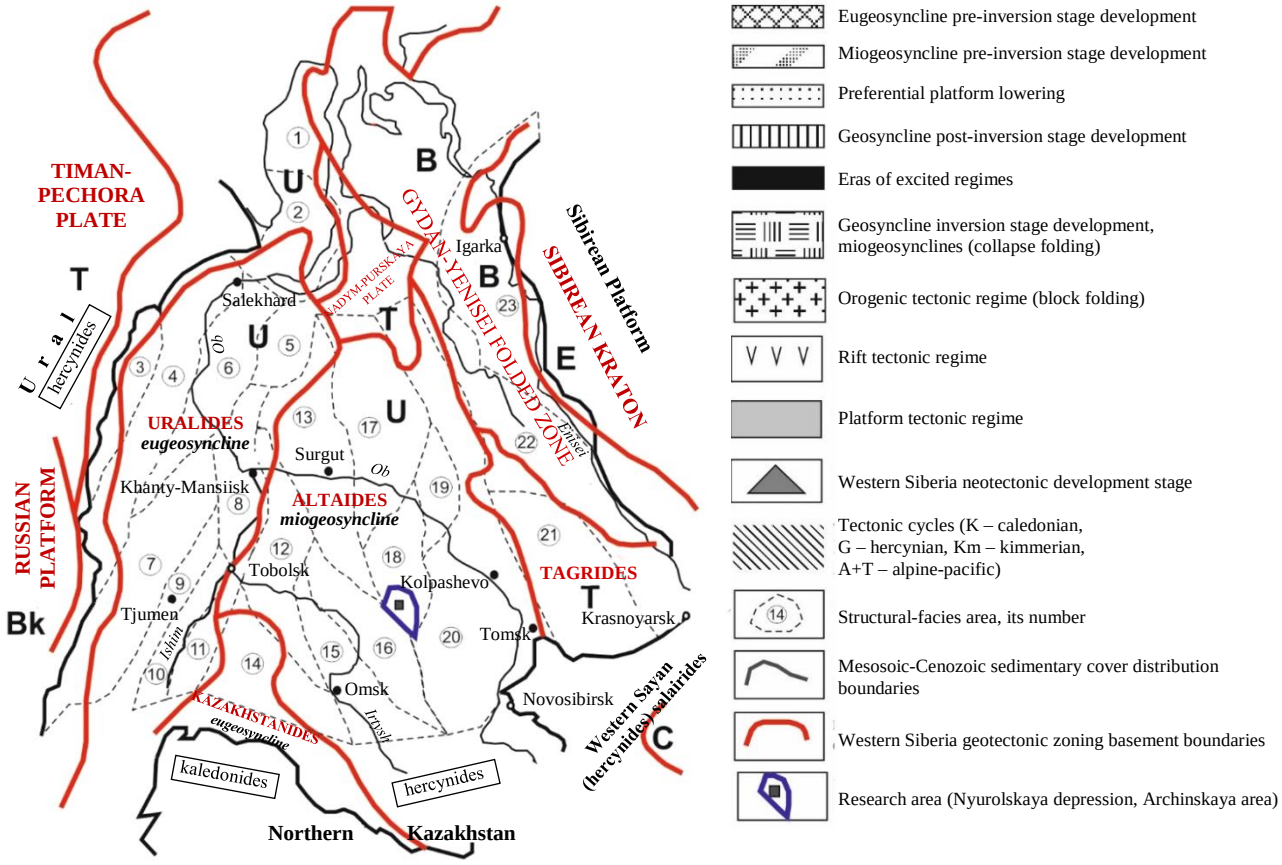
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*a*




*b*




E – engidinides (2,515 bil years)
B – baikalides (625 mln years)
C – salairides (400 mln years)
Bk – baikalides (2,61 bil years)
T – timanides (500 mln years)
U – uralides (250 mln years)

Fig.1. West Siberian geosyneclise: stages of tectonic development (*a*) [20] and tectonic zoning scheme (*b*) [21]

Structural-facial regions: 1 – Bavonenkovskii; 2 – Novoportovskii; 3 – Tagilskii; 4 – Berezovo-Sartyninskii; 5 – Yarudeyskii; 6 – Sherkalinskii; 7 – Shaimskii; 8 – Krasnoleninskii; 9 – Tyumenskii; 10 – Kosolapovskii; 11 – Uvatskii; 12 – Salymskii; 13 – Ust-Balykskii; 14 – Ishimskii; 15 – Tevrizskii; 16 – Tuysko-Barabinskii; 17 – Varieganskii; 18 – Nyurolskii; 19 – Nikolskii; 20 – Kolpashevskii; 21 – Vezdekhodnii; 22 – Tyyskii; 23 – Ermakovskii


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According to the presented geotectonic model of the development of the southeastern part of the WSP (Fig.1, *b*), in the Paleozoic-Mesozoic era, the following manifestations occurred on the considered territory:

- miogeosynclinal stage of development (Cambrian, Ordovician – Middle Carboniferous);
- folding and inversion (upper Carboniferous – lower Middle Carboniferous);
- orogenic phase folding (Upper Carboniferous – Lower Permian);
- rifting stage (Lower Triassic);
- platform (Jurassic – Paleogene) and neotectonic (end of Paleogene) stages of tectonic development.

The miogeosynclinal stage of tectonic development included the accumulation of terrigenous-carbonate (Larinskaya, Mezovskaya silurian series) and carbonate (Armychevskaya, Nadezhdinskaya, Gerasimovskaya, Luginetskaya Devonian series) formations, with subordinate inclusion of effusive and intrusive rocks. Folding, which deformed the earlier formed sedimentary rock complex under the action of compressive forces, was formed under compression, while all other tectonic transformations were characterized by stretching in conditions of domed uplift (inversion, orogenesis, rifting, neotectonics) or subsidence (platform stage).

In the conditions of inversion and orogenesis, magmatic, effusive (Peshekhodnaya series of Upper Carboniferous – Lower Permian) thicknesses were formed, and in the conditions of denudational activity, terrigenous (Kievskaya, Chkalovskaya, Omelichskaya, Archinskaya Lower-Upper Permian series) formations were formed. On the rift stage of development, terrigenous-effusive (smolyanaya, middle layer of Lower-Middle Triassic) and terrigenous (Strezhevaya Triassic series) formations were deposited.

**Methodology.** The determining factors of the formation of the tectonic heterogeneity of the basement rocks of the Nyurolskaya depression, within which the Archinskii uplift is located (Fig.1, *b*), the phases of folding, orogenesis (Fig.2, *a*) and rifting (Fig.2, *b*) manifested in the Carboniferous, Permian and Triassic on the considered territory can be identified. The folded structure of the Paleozoic complex within the considered areas (Solonovskaya and Severo-Ostaninskaya [26, 27]) is justified by age determinations of its upper part and elements of the bedding of rocks based on paleomagnetic research results.

At the Severo-Ostaninskaya area, in the core of a synclinal fold of northwest orientation, identified by measurements of the angles of inclination of basement rocks by paleomagnetic research data in wells 15, 7 and 3, carbonate deposits of Middle Devonian were exposed. Outside the identified synclinal fold, the Paleozoic basement top is represented by clayey-siliceous formations of Lower-Middle Carboniferous in wells 6 and 13. During folding, the previously formed sedimentary layer was transformed into a folded system, within which zones of destruction and thrust slips were formed at the boundaries of synclinal and anticlinal uplifts [28]. Subsequently, during the orogenic stage, there were inversion transformations between introgeosynclinal and introgeoanticlinal geostructures controlling carbonate shelf (introgeoanticline) and clayey depression (introgeosyncline) types of sedimentation [13]. As a result of inversion transformations, the Nyurolskaya depression, being an introgeoanticlinal shelf zone of the miogeosynclinal stage of development, was transformed into an intermountain basin during the orogenic phase of folding [13, 14]. In the post-orogenic stage, the mountain system was subjected to erosion, as a result of which intermountain basins were filled with sedimentary formations of Permian (Kievskaya, Chkalovskaya, Omelichskaya, Archinskaya series).

The initial stage of rifting, associated with the formation of a dome uplift within the miogeosynclinal zone [14], along with the activation of magmatic activity predetermined the intense manifestation of block tectonics along previously created zones of destruction in the wing parts of folds. As a result of the dome stretching process, a contrasting grabens-horst relief was formed, in which grabens were represented by anticlinal, and horsts synclinal folds of the basement. Further, the folded-block heterogeneity of the Paleozoic in the Triassic and Lower Jurassic was subjected to intense erosional-denudational processes with the formation of weathering crust and zones of hypergenic top part basement rocks transformation.


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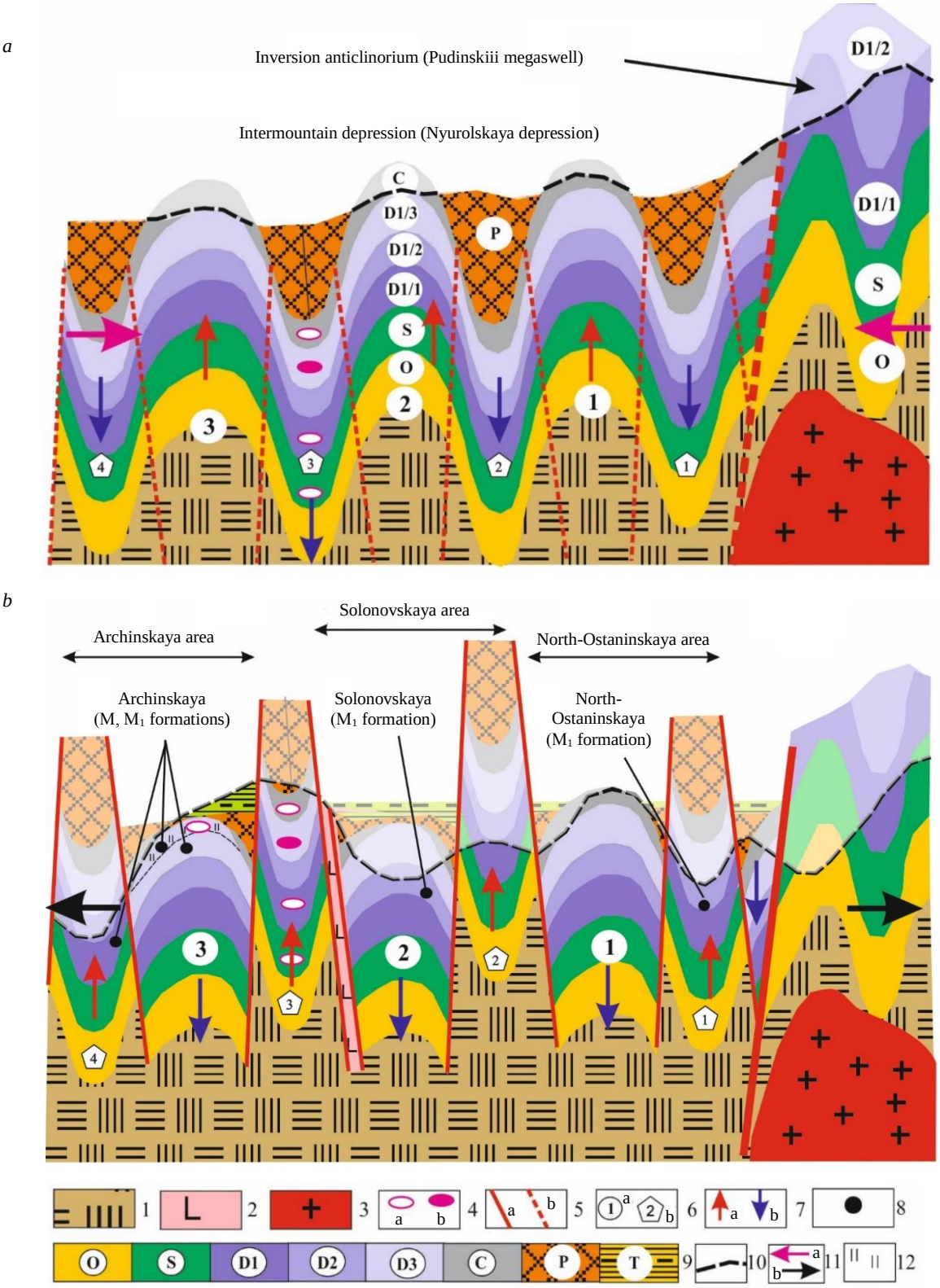



Fig.2. Scheme of tectonic transformations of miogeosynclinal-orogenic (*a*) and riftogenic (*b*) stages of development of the southeastern part of the Nyurol depression

1 – folded previous stage of tectonic development basement; 2 – effusive formations of Triassic rifting; 3 – granite batholiths; 4 – tuffs (a) and basalts (b) in sedimentary rocks; 5 – tectonic disturbances (a) and destruction zones (b); 6 – anticlinal (a) and synclinal (b) folds; 7 – ascending (a) and descending (b) tectonic movements; 8 – tectono-stratigraphic association of hydrocarbon deposits; 9 – sedimentary formations of the miogeosynclinal stage (Ordovician, Silurian, Lower, Middle and Upper Devonian, Carboniferous), post-orogenic (Permian) and rift (Triassic); 10 – erosion surface; 11 – horizontal compression stresses of the shear folding phase in the Middle-Upper Carboniferous (a), horizontal tension stresses of the Triassic rifting phase (b); 12 – weathering crust


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It should be taken into account that the oil and gas content of the considered Paleozoic complex may be associated with the weathering crust of basement rocks, which come to the erosional-tectonic surface (M horizon), the basement rocks top part (layer $M_1$ horizon), and deeper horizons ($M_2$, $M_3$ horizons). The formation of reservoirs in the deeper parts of the Paleozoic carbonate complex section is due to the manifestation of hydrothermal processes and the formation of weathering crust during the miogeosynclinal stage of tectonic development of the considered territory.

Within Archinskaya area, M horizon weathering crust is represented by bauxites formed as a result of hypergenic processing of basic effusives, and the native Paleozoic deposits are organogenic limestones. The genetic relationship of the weathering crust with the basement rocks top part allows combining layers M and $M_1$ into an oil and gas-bearing horizon of the contact zone (OGBZ), however, the spatial development of these layers is often not hereditary in nature. The geological structure and oil and gas content of the Archinskaya area are considered in a number of publications, where the main focus is on the study of the reservoir structure [29-31], the peculiarities of the geological structure of the hydrocarbon deposit [32-34] and its development [35] and less attention is paid to the tectonic features of the formation of basement rocks. The role of folded-block tectonics in the structure of Paleozoic deposits can be assessed using examples of seismic surveys performed within the Urmansko-Archinskaya area (Fig.3, *a*) and lithological-stratigraphic analysis of rocks in deep wells of the Kalinovaya area (Fig.4).

The poststack processing of 3D seismic data conducted in 2014 by OOO Slavneft-NPC on the Urmansko-Archinskaya area [34] clearly shows the contrasting, folded-block structure of the basement (see Fig.3, *a*). If we consider the F3 deep Paleozoic reflecting horizon as a stratigraphic boundary along the seismic profile 01, we can note that the vertical stratigraphic displacement of the block boundaries along tectonic disruption N 7 is about 1000 m.

The reversible nature of the tectonic movements of the miogeosynclinal-orogenic and rifting stages of development within the Archinskii-Urmanskii uplift (see Fig.2) can be explained by Fig.3, a, where well U03 is located in the zone of an anticlinal fold, and well U06 is in the zone of a synclinal fold of the paleozoic complex. Top Paleozoic deposits within Upper Devonian age in well U03 indicates that during the rifting stage, the anticlinal block had a tendency to submerge, and the Lower Devonian age of the basement top in well U06 indicates the upward movement of the synclinal fold block. Similar tectonic dislocation trends are also observed along seismic profile 02 (Fig.3, *b*), the analysis of which is presented in article [36].

Similar results are observed in the distribution of age determinations of rocks in deep wells of Kalinovaya area [37]. Thus, on the profile of wells K06-K04-K07 there is a sequential shift of the stratigraphic boundary between the Upper and Middle Devonian by 440 and 640 m respectively. (Fig.4, *a*). Even more significant vertical displacements are noted between wells K07 and K05, where the boundary between the Middle and Upper Devonian in well K07 is distinguished at an absolute mark of –4000 m, while the lower boundary between the Middle and Lower Devonian in well K05 is located at an absolute mark of –3000 m. If we take into account that in the Nurolskaya depression, the stratigraphic thicknesses exposed by deep wells are up to 500 m for the Lower Devonian, 1000 m for the Middle Devonian, and 2000 m for the Upper Devonian, then one can assume significant scales of vertical displacements of basement blocks.

Considering the correspondence of the basement folding in the Archinsko-Urmanskaya area to the features of vertical displacements of tectonic blocks (see Fig.3, *a*), it can be noted that anticlinal folds identified on the seismic section correspond to lowered blocks of the basement, while synclinal ones correspond to raised ones, which is due to the peculiarities of their vertical displacement as a result of domed stretching during the initial stage of rifting. This is also confirmed by the determination of the age of the top rocks of the basement in the drilled wells of the Archinsko-Urmanskaya area [38]. Within the synclinal folds, Lower Devonian rocks emerge on the erosion-tectonic surface (Archinskaya area, well A05, Urmanskaya area, well U06), and zones of anticlinal uplifts


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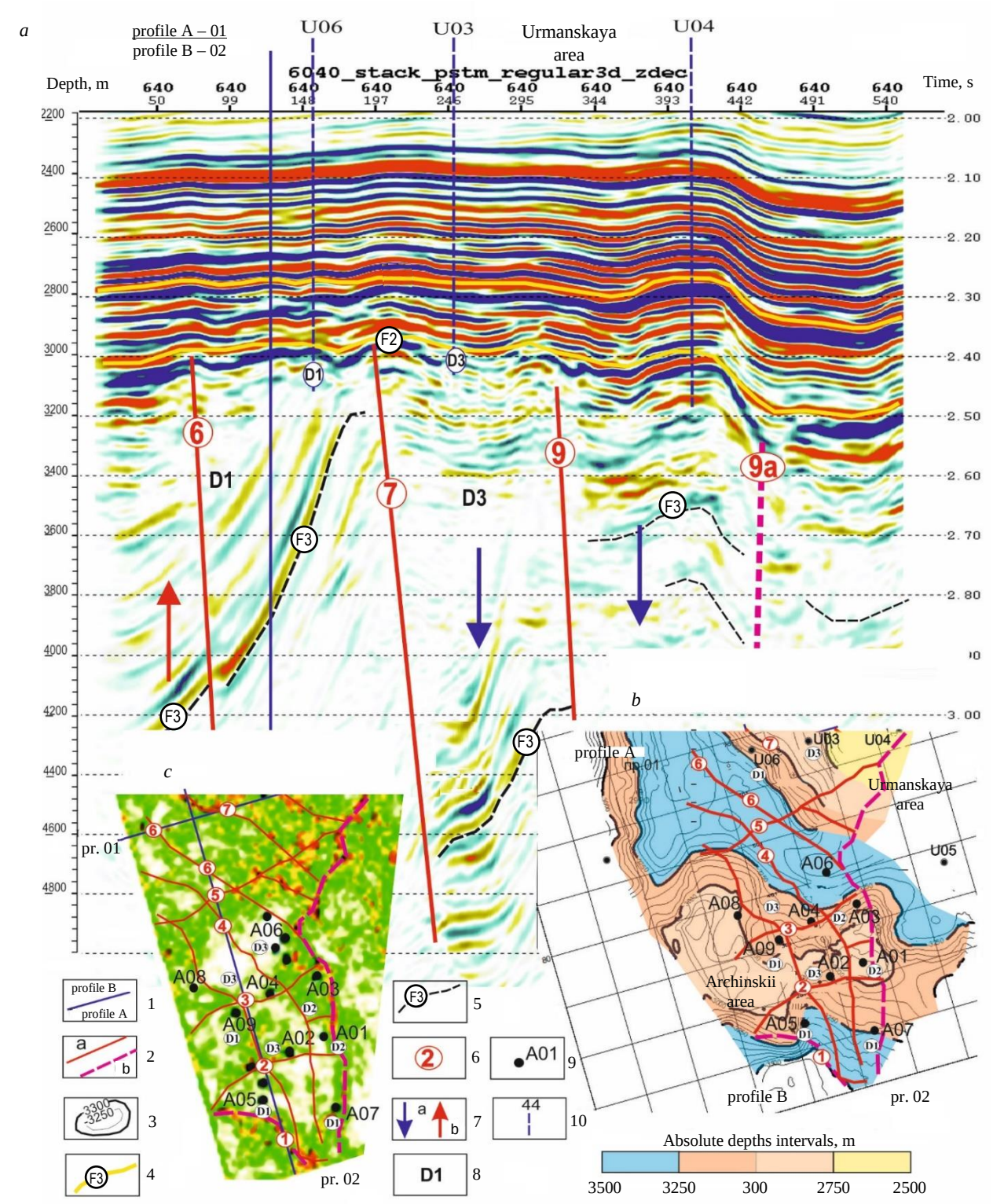



Fig.3. Folded basement block structure of the Urmano-Archinskaya area according to 3D seismic data (*a*, *c*) and a structural diagram for the reflecting horizon F3 without taking into account the influence of tectonic disturbances (*b*)

*a* – structural-block interpretation of the basement along seismic profile A;
*b* – schematic structural map of the deep Paleozoic along the F3 reflecting horizon without taking into account displacement along tectonic blocks;
*c* – basement block heterogeneity according to seismic profiles, incoherence maps and Paleozoic top age determination;
1 – seismic profiles of 3D survey; 2 – tectonic disturbances according to 3D seismic data (a) and associated with processes Triassic rifting (b);
3 – isohypses of the conditional reflecting horizon F3 without taking into account vertical displacements along tectonic violations; 4 – basement top reflecting seismic horizon (F2); 5 – predicted distribution of seismic boundaries Paleozoic basement; 6 – number of tectonic fault identified by seismic exploration; 7 – basement blocks vertical movements, ascending (b) and descending (a); 8 – top rocks formation age; 9 – well, its number;
10 – wells located on the seismic profile line


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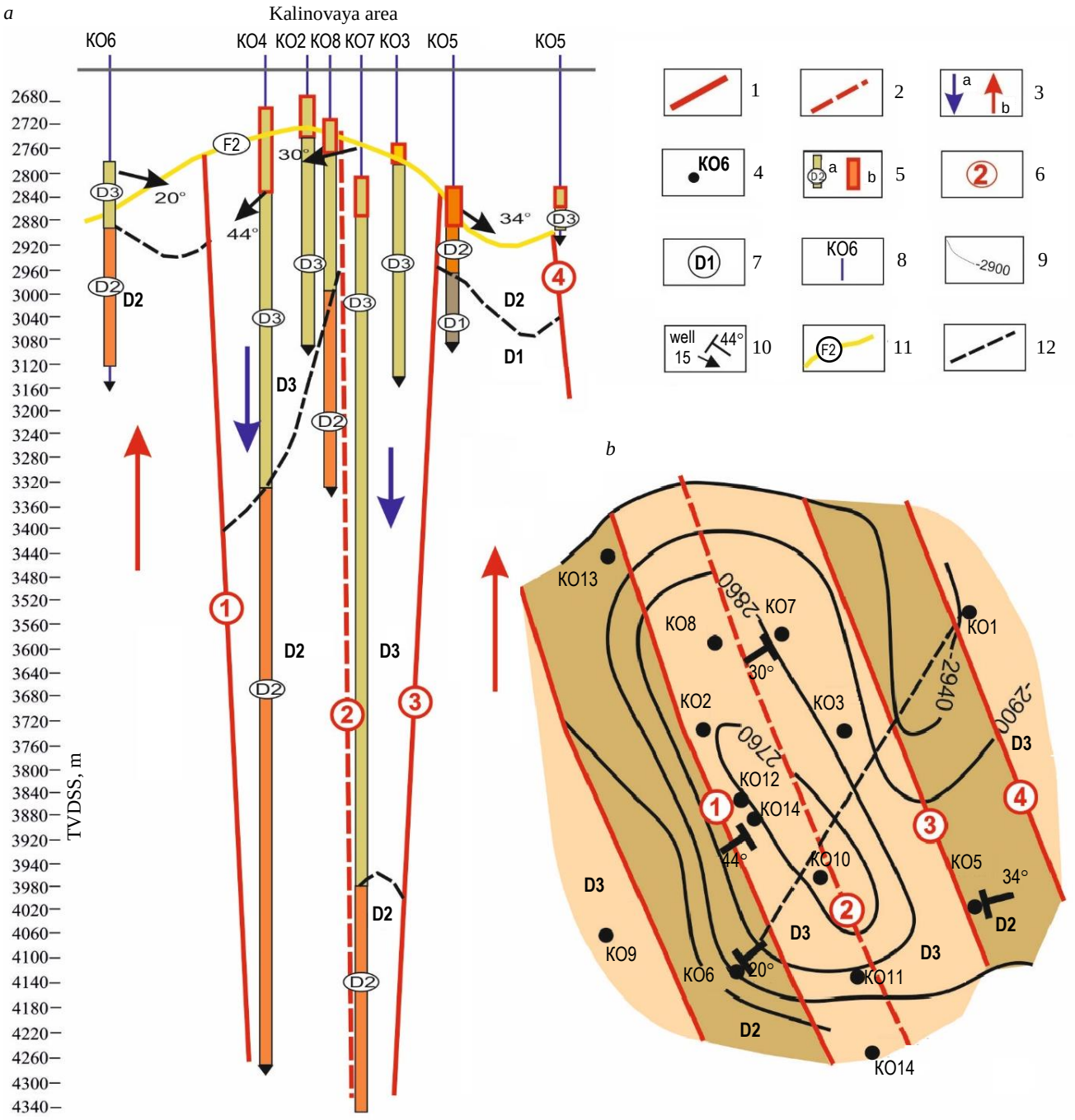



Fig.4. Stratigraphic section (*a*) and geological map of the basement (*b*) of the Kalinovaya area

1 – tectonic disturbances separating various stratigraphic blocks; 2 – tectonic disturbances within homogeneous stratigraphic blocks; 3 – immersion (a) and uplift (b) of large basement blocks; 4 – determination of the age of basement rocks from the well section (a) and weathering crust intervals (b); 5 – number of tectonic disturbance; 6 – age of basement rocks according to drilled wells; 7 – seismic isohypses of reflecting horizon F2 (top of basement rocks); 8 – azimuth and dip angle of layering in Paleozoic deposits according to oriented core data; 9 – basement top reflecting seismic horizon (F2); 10 – well, its number; 11 – wells located on the profile line; 12 – geological section line

are characterized by Upper Devonian rocks (Archinskaya area, well A04 and Urmanskaya area, wells U01 and U02). This is not contradicted by the stratigraphic division of the sections and the determinations of the fall in the layering of the basement rocks based on oriented core data in the wells of the Kalinovaya area [39]. Thus, the distribution of azimuths and bedding dip angles in wells K06 (NE – 70°), K04 (SW – 48°), K07 (SW – 60°), K05 (E – 60°) of the Kalinovaya area (Fig.4, *b*) indicates the presence of an anticlinal Paleozoic folds in a stratigraphically lowered basement block (Fig.4, *a*).



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Taking into account the spatial location of conventionally identified reflecting horizons F3, F4 of the Paleozoic complex of the Archinskaya area [36] and the stratigraphic division of the well sections, an attempt was made to reconstruct the Paleozoic structural form before the manifestation of tectonic disturbances, which caused significant vertical movements of the basement blocks. The results of the performed reconstruction are presented (see Fig.3, *b*), in accordance from which, within the Archinskaya area in the basement section, fragments of two synclinal and one anticlinal folds of northwestern orientation can be distinguished. Tectonic disturbances according to the results of work [36] and Fig.3, a were identified at the boundary of the morphological "break" of the Paleozoic reflecting horizons in accordance with the stratigraphic upper part basement rocks heterogeneity in the wells, the results of well testing and interpretation of the seismic attribute of incoherence (Fig.3, *c*). The reconstruction of the folded system of the deep Paleozoic shown in Fig.3, *b* takes into account the basement blocks vertical movements. Taking into account the difficulty of identifying a reflective horizon of the same age in the considered set of reflecting boundaries of the Paleozoic, the map presented in Fig.4, *c*, showing the general trends in the structural plan of the analyzed deposits, is conditional. According to the results of the completed constructions, the anticlinal fold of the Archinskii uplift is not rectilinear and is complicated by bending deformations.

The presented reconstruction is in good agreement with the dip and strike data of the Devonian layering according to the azimuthal electrical microimager (FMI) data in production wells A11, A14, A13, A10, A12 (Fig.5, *a*). As follows from the figure, the analyzed wells were drilled on the southeastern slope of a bending anticlinal structure within the Archinskii uplift. The dip azimuths reflect the morphological features of the structure of the fold in the area of its bend (well A12) and the plunging wing (wells A11, A14, A13, A10). Angles of incidence naturally increase from the axial part of the fold in wells A14 and A11, where they vary from 10 to 36°, and in the direction of the slope in wells A12, A13, A10 with dip angles of 38-74°.

The blocky, layered-folded heterogeneity of Paleozoic deposits also affects the distribution of oil and gas content in the basement rocks of the Archinskaya area, where, based on the results of exploratory drilling in the oil and gas bearing horizon of the contact zone, represented by bauxites of the weathering crust of formation M and organogenic limestones of formation $M_1$, a massive gas-oil deposit was identified. A qualitative characteristic of the filtration-capacity model of the $M_1$ formation of the Archinskii uplift is given in [40], according to which the reservoir in the field is represented by cavernous-porous-fractured limestones, where porosity according to well logging reaches 9.4-29 %, and permeability from 0.24 up to $8.4 \cdot 10^{-3}$ μm$^2$. Pores in limestones are connected with biovoids (amphiporous limestones) and intercrystalline pores in areas of calcite decrystallization. Cracks in limestones are of catagenetic and tectonic origin. Catagenetic cracks (microcracks) are represented by stylolite sutures, oriented along the rock layering and filled with clay-organic material, and tectonic cracks (macrocracks) form systems of subparallel and intersecting cracks of different generations. In impermeable limestone varieties, the crack space is completely filled with calcite.

Cavities in the rock are usually unevenly distributed and range in size from 1 mm to 10-15 mm. The shape of the caverns is irregularly rounded, the walls are sinuous, sometimes encrusted with dolomite crystals, which are associated with bitumen admixtures. Low core removal from Paleozoic sediments in prospecting and exploration wells in the Archinskaya area does not allow for a correct assessment of the filtration and reservoir characteristics of carbonate rocks. An assessment of reservoir properties, carried out on dense carbonate varieties in wells A07 and A06, indicates that with a porosity of 0.2-0.3 % the rock is not permeable. When testing such intervals at dynamic levels of 770-850 m, insignificant (0.18-0.14 m$^3$/day) oil or water flow rates are obtained. Porosity and



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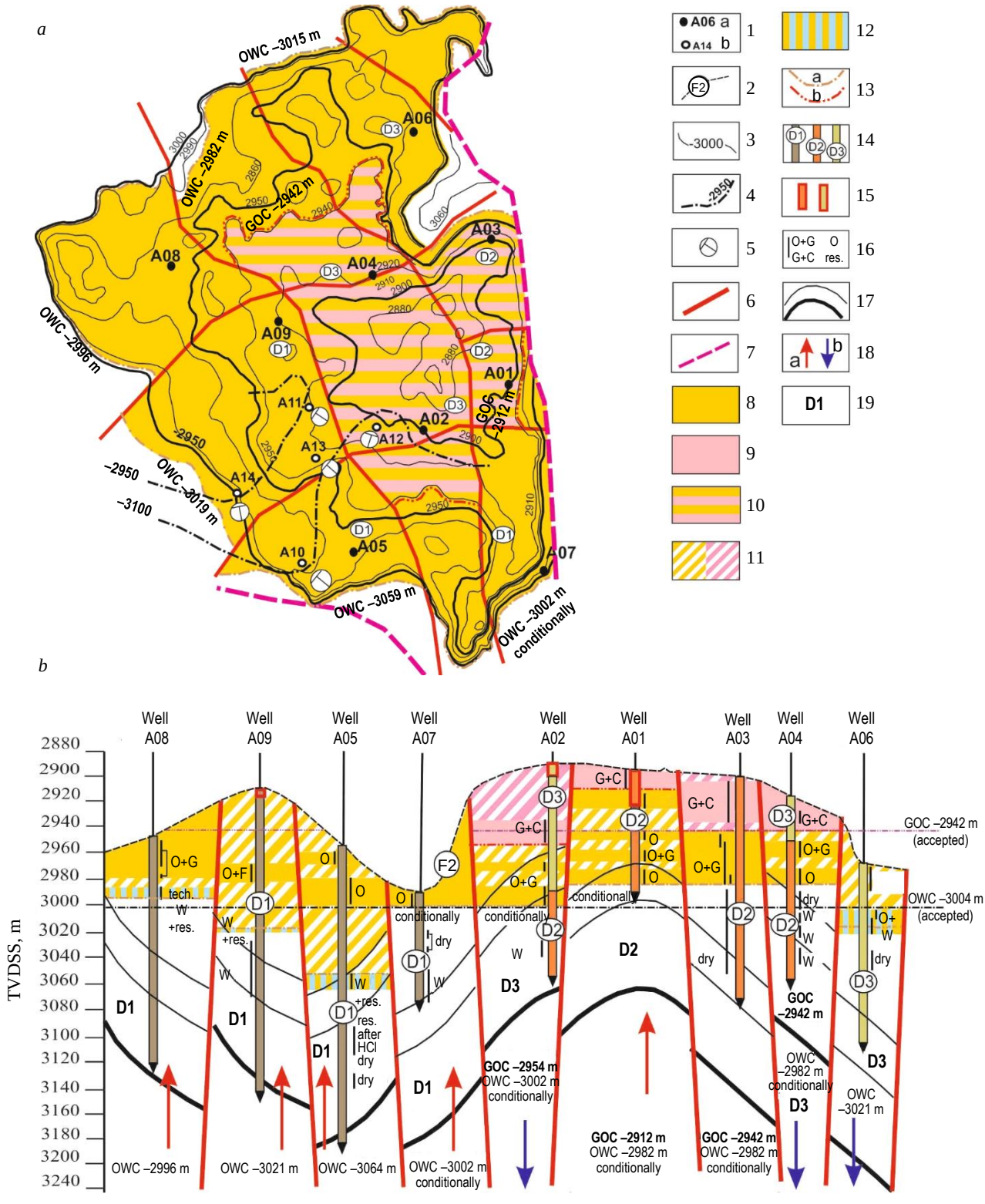



Fig.5. Distribution of oil and gas content for the $M_1$ horizon of the Archinskaya area in plan (*a*) and section (*b*)

1 – prospecting (a) and production (b) well, its number; 2 – basement top; 3 – seismic isohypses of reflecting horizon F2 (basement top); 4 – conditional isohypses of the Paleozoic fold along the reflecting horizon F3; 5 – azimuths of dip and strike in the layering of basement rocks according to FMI data; 6 – tectonic disturbances of different stratigraphic blocks; 7 – tectonic disturbances associated with the processes of Triassic rifting; 8 – oil deposit; 9 – gas condensate deposit; 10 – oil deposit with a gas "cap"; 11 – forecast intervals of oil and gas content within the block; 12 – water-oil saturation of a layered reservoir; 13 – water-oil (a) and gas-oil (b) contacts; 14 – intervals for determining age in well cores; 15 – deposits of weathering crust; 16 – sampling interval and its result (G+C – gas and condensate, O – oil, O+G – oil and gas, res. – oil film, O+F – oil and filtrate; 17 – folded structure of the basement; 18 – basement blocks vertical movements (a) and downwards (b); 19 – basement blocks age;



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permeability properties of replacement dolomites are more significant. Thus, in wells A01 and A02 with a porosity of 1-4 %, the permeability reaches 20-30·$10^{-3}$ μ$m^2$. Oil flow rates from such intervals on a 4 mm choke range from 14 to 19 $m^3$/day. The most permeable intervals, where oil flow rates on an 8 mm choke can be 109 $m^3$/day (well A08), have not been characterized by core, but they are recorded at drilling by absorption of drilling fluid and "failure" of the tool.

In accordance with the existing concepts of the geological structure of the productive reservoir [34] the gas-oil (GOC) and water-oil (OWC) contacts of the $M_1$ reservoir within the field in the Archinskaya area are highlighted, respectively, at absolute levels –2942 m and –3004 m (Fig.5, *b*). The results obtained during prospecting, exploration and production drilling are largely contradictory and indicate a more complex distribution of hydrocarbons in the section and area, which may be associated with both the block heterogeneity of the basement and the layered-folded heterogeneity of the rocks composing it. According to seismic geological interpretation, well testing results and stratigraphic studies performed within the field in the Archinskaya area, a number of independent oil and gas bearing blocks are identified (Fig.5). Based on the phase distribution of hydrocarbons in well sections, the oil and gas bearing zone can be geographically divided into oil zone, which includes the western group of blocks, and gas and oil zone, characteristic of the tectonic blocks of the central and eastern part of the field (Fig.5, *b*).

In the western group of Lower Devonian blocks (wells A08, A09, A05), where dark gray to black marls with lenses of bioclastic limestones of the Armichevskaya (well A09) and gray, cream, globoid limestones of the Nadezhdenskii (well A05) formations were exposed, differences are noted both in terms of the level of determined OWC and in terms of oil flow rates within the considered tectonic blocks. The highest elevations of the OWC (–2996 m) correspond to the northern one, and the lowest (–3064 m) to the southern blocks. In accordance with the well tests, oil flow rates within the northern and southern blocks ranged from 108.6 (well A08, 8 mm choke) to 74 $m^3$/day (well A05, 3.2 mm choke), and when testing the oil part formation $M_1$ of the central block in well A09, overflows of oil and drilling fluid filtrate were obtained with a flow rate of 2.1 $m^3$/day.

The central group of Upper Devonian blocks is lithologically characterized by oolitic-clotted-detrital, algal-foraminiferal limestones with interlayers of calcareous mudstones of the Luginets Formation. Based on the results of OWC wells testing, the identified hydrocarbon deposits of the central and northern blocks of the group under consideration were conditionally accepted at levels of –3002 m (well A02) and –2989.2 m (well A04). Differences in the distribution of GOC elevations in the central (GOC – 2954 m) and northern (GOC – 2942 m) blocks indicate their hydrodynamic isolation. For the southern block, due to the lack of deep drilling data, a forecast of possible localization zones of gas and oil deposits is presented.

The oil and gas potential of the eastern part of the Archinskoe field is associated with a group of blocks of different stratigraphic affiliation. The Upper Devonian northern block (well A06) is represented by sediments of the Luginetskaya Formation. The two central Middle Devonian blocks (wells A03, A01) are composed of brown, dark gray, biomorphic, stromatoporo-coral, brachiopod limestones of the Gerasimov Formation. In the southern Lower Devonian block (well A07), Nadezhdenskii formation limestones were exposed.

Based on the test results, the OWC for the northern block in well 06 was determined at –3015 m. For the remaining blocks it is conditionally accepted at levels of –2982 m (wells A01, A03) and –3002 m (well A7). When testing wells, the lowest oil flow rates of 0.18 $m^3$/day at a dynamic level of –850 m were noted in well A07 of the southern Lower Devonian block.

For gas deposits of the central blocks, the highest elevation of the GOC – 2912 m was determined in well A01. In well A03, GOC is identified at an elevation of –2942 m. In the northern block, well A06, drilled on the northeastern flank of the structure, did not reveal a gas deposit. However, the high


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gas factor (167 $m^3/m^3$) when testing the lower perforation intervals suggests the possibility of its presence in the hypsometrically elevated zone. Within the southern Lower Devonian block (well A07), taking into account the lack of gas content in similar stratigraphic blocks in the western part of the field, the presence of a gas deposit is not predicted.

Paleozoic sediments complex lithological sections interlayering, complicated by fracturing, forms the contrasting, layered, filtration-capacitive heterogeneity of the $M_1$ formation, which is manifested both during drilling and testing of the productive reservoir. If there are interlayers of cavernous-fractured limestone in the section, during the drilling process, the absorption of drilling fluid is observed until the complete loss of circulation, which was revealed during the drilling of well A03 and described in [36], and during testing, different flow rates of fluid inflow are recorded when testing different intervals of formation perforation. An example is well A01, where four intervals were tested in the oil part of the $M_1$ formation (Fig.5). In the intervals of oil inflows, flow rates ranged from 0.082 to 0.7 $m^3$/day at dynamic levels of 1219-895 m, and in the intervals of gas-oil inflows on a 4-mm choke, oil inflows of 14.2-3.14 $m^3$/day and gas inflows of 23.4-16.6 thousand $m^3$/day were obtained. An example of the heterogeneous structure of permeable layers within the gas-oil part of the $M_1$ formation of well A03 is presented in the section in Fig.5.

According to the oil genetic type analysis in well A06, the source of its generation was Devonian sediments [41, 42]. The folded structure of the observed layered heterogeneity of the sections of the Paleozoic basement is reflected in the development features. Taking into account the significant inclination angles of the layered heterogeneity, especially on the wing parts of the Paleozoic structure, in these areas it is most rational to drill horizontal wells in the top of the formation with the shaft oriented to the cross of the strike of the Paleozoic fold. In this case, the well will penetrate the maximum number of productive layers, increasing the area coverage of the deposit at the maximum distance from the OWC boundary. In the crest of the Paleozoic fold it is possible to drill directional wells.

**Results and discussion.** The data obtained indicate the presence of territorially isolated hydrocarbon deposits within the Paleozoic basement identified blocks of the Archinskaya area (Fig.5). This increases the prospects for oil-bearing hydrocarbon deposits in tectonically screened traps that are not associated with structural forms of erosion-tectonic surfaces of Paleozoic formations, where individual stratigraphic blocks are independent prospecting objects for hydrocarbon deposits.

Thus, an anticlinal fold identified according to seismic data along the reflecting horizon F3 to the west of the Archa uplift can be an object for searching for hydrocarbon deposits in the deep Paleozoic horizons (see Fig.3, *b*). In addition, it is necessary to take into account that the presence of impermeable layers in the section of the basement rocks, taking into account its folded structure, requires a revision of the concepts of the “massive” type of hydrocarbon deposits in the deposits of the Paleozoic basement to “massively layered”. This provides the basis for a more rational design of the operating stock of horizontal and directional wells.

Based on the characteristics of the tectonic development of the analyzed territory and the results of interpretation of seismic data, hydrocarbon deposits of structural type in deep-lying Paleozoic reservoirs will be confined to younger stratigraphic blocks that control the anticlinal uplifts of the folded basement system.

Taking into account the complex tectono-stratigraphic conditions for the formation of hydrocarbon deposits in the sediments of the Paleozoic basement of the WSP, with an integrated approach to identifying oil-promising objects, it is necessary to use data from high-precision magnetic surveys [26] and electromagnetic sounding [43], which have proven themselves well at the stage of exploratory drilling within Western Siberia.



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**Conclusion.** Analysis of the structure of Paleozoic basement deposits within the Archinskaya area based on new data on the processing of seismic information, stratigraphic knowledge of the strata in question and the results of production drilling allows us to draw the following conclusions.

• The sedimentary complex under consideration is represented by a folded structure, complicated by contrasting block movements, as follows from the interpretation of seismic sections and top rocks age formation determination (see Fig.3). In contrast to the accepted uniform of a massive deposit as a whole for the field [34] the identified blocks control the spatial distribution of hydrocarbons and are independent objects for the search for hydrocarbon deposits and their further development, and the conditional OWC levels determined for a number of blocks indicate a possible increase in hydrocarbon reserves within their boundaries (Fig.5).

• Synclinal folds of basement rocks correspond to uplifted, and anticlinal folds to submerged tectonic blocks, which predetermines the search for hydrocarbon deposits of the "structural" type in deep Paleozoic deposits within younger stratigraphic blocks. An example is well U04 of the Urmanskaya area (Fig.3, *b*) located in the crest part of the Paleozoic fold, but outside the outlining isohypsum of the Urman uplift, where an industrial oil deposit was discovered in the $M_2$ horizon, which lies 95 m below the basement top. Within the Archinskaya area, the prospects for the deep Paleozoic can be associated with the western flank of the uplift, where a contrasting anticlinal Paleozoic fold stands out (Fig.3, *b*).

• The folded-layered structure of the reservoir of the $M_1$ formation, which is heterogeneous in lithological composition and porosity and permeability properties, requires a revision of the concepts of the "massive" type of hydrocarbon deposits in the deposits of the Paleozoic basement to "massive-layered". This gives grounds for a more rational design of the operational stock of horizontal and inclined wells, placing the first within the wing wells, and the second in the crest parts of the Paleozoic fold.

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*The authors declare no conflict of interests.*



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