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Hydrodynamic features of oil and gas bearing deposits of the southern areas of Ob-Irtysh interfluves

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Abstract. The results of study of hydrogeological conditions of oil and gas bearing deposit of the southern areas of Ob-Irtysh interfluves (southern regions of West Siberian basin) are presented. The hydrodynamic field is characterized by direct dependence and the presence of normal and increased pressure (formation anomalous pressure factor not exceed 1.13) is common in Apt-Alb-Cenomanian, Neokomian, Jurassic and pre-Jurassic complexes. The results of study of the reservoir properties and hydrodynamic conditions indicated that the elision water exchange play the dominant role in the modern hydrogeological structure formation. Two types of water drive system is established: elisional (lithostatical and termodehydrational) in the inner areas (southern part of Koltogor-Nyurol trench, Nyurol megadepression, Verkhnevasyuganskaya anteclise and other structures) and infiltrational within the territory of Barabinsk-Pikhtovskaya monocline. Elisional system is replaced by the elisional-termodehydrational at the depth 2.0-2.2 km. Large piezo maximum zones (southern part of Koltogor-Nyurol trench and Nyurol megadepression) become the inner regions of water pressure generation (the inner feed areas) with the maximal degree of hydrogeological closure of the interior. The region of piezo minima, tracing the structures of the Barabinsk-Pikhtovskaya megamonocline, relates to the external feed area. The hydrodynamic model of the southern areas of Ob-Irtysh interfluves is building for the first time and allow to predict the pressure change trends in the areas with poorly provided with the actual data.

Keywords: elision water exchange, hydrodynamic field, stratal pressure, inter-layer flows, West Siberian sedimentary basin, Ob-Irtysh interfluve

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Introduction

The structure of the hydrodynamic field of oil and gas bearing basins is taking its shape for a long time and is closely connected with the geological history, with the processes leading to consolidation of sedimentary rocks accompanied by the formation of elision water-pressure systems (Kartsev, Abukova, Abramova, 2015) and, as a consequence, by the appearance of increased and anomalously high formational pressure in the hydrogeological section. Since the beginning of prospect works for oil and gas in West Siberia, enormous factual material depicting the structure of the hydrodynamic field has been accumulated. Hydrodynamic studies of the West Siberian sedimentary basin (WSSB) have been carried out by B.L. Aleksandrov, G.D. Ginsburg, A.E. Gurevich, V.I. Dyunin, A.P. Kamenev, V.N. Kortsenshtein, N.M. Kruglikov, B.F. Mavritskiy, V.M. Matusevich, A.D. Nazarov, V.V. Nelyubin, D.A. Novikov, O.V. Ravdonikas, A.D. Reznik, (Kortsenshtein, 1977; Kruglikov, Yakovlev, 1981; Kruglikov et al., 1985; Matusevich, Bakuev, 1986; Aleksandrov, 1987; Shvartsev, Novikov, 1999; Shvartsev, Novikov, 2004; Nazarov, 2004; Matusevich et al., 2005; Dyunin, Korzun, 2005; Novikov, Lepokurov, 2005; Novikov, 2014; Novikov, Sukhorukova, 2015; Novikov, 2017; Novikov, 2017; Novikov, 2018; Novikov et al, 2018; Novikov, 2019). Due to a sharp reduction of exploration work in early 90-es of the past century, the flow of reliable geological and geophysical information had stopped almost completely.

Investigation of the hydrodynamics of the WSSB is of great fundamental and theoretical interest, first of

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all, from the viewpoint of solving theoretical problems considering the mechanisms of the formation of oil and gas deposits, substantiation of an optimal complex of hydrogeological criteria for the evaluation of the oil and gas bearing potential at the regional, zonal and local levels. Second, this is also important for the design of the development of hydrocarbon pools, for the prediction of complications connected with hole making, compilation of hydrodynamic models and recommendations concerning the operation of the systems maintaining the formational pressure, solving the tasks connected with the optimization of waterflooding of the deposits, hydrogeological substantiation of the objects of technical water supply to the fields, utilization of industrial waste waters and bottom water.

Materials and methods

According to the administrative division, the region under investigation is situated in the northern territories of the Norosibirsk Region and the adjacent territories of the Tomsk and Omsk Regions (Fig. 1). According to the oil-and-gas related geological zoning of the West Siberian province, the major part of the territory under investigation is situated within the boundaries of the Kaymys and Vasyugan oil and gas bearing regions.

The best studies reservoirs are Upper Jurassic ones (Yu$_1$ horizon), because they are the main object of development at the territory under investigation. According to the accepted hydrogeological stratification of the WSSB (Nudner, 1970; Kruglikov et al., 1985), five water-bearing complexes are distinguished within the lower hydrogeological stage in the region under study (Nazarov, 2004; Novikov et al., 2018; Sadykova et al., 2019). They are reliably isolated from the zone of active water exchange by the regional Turonian-Oligocene aquiclude (from top to bottom): Aptian-Albian-Senomanian, Neocomian, Upper Jurassic, Lower and Middle Jurassic, and pre-Jurassic. A specific feature of the geological structure is extremely high degree of nonuniformity and fragmentariness of the occurrence of Lower Jurassic sediments.

The evolution of any sedimentary basin, post-sedimentation transformations of water-embedding rocks starting from the silt stage in the early diagenesis and finishing with metamorphism stage, as a rule, is accompanied by the formation of elision water-pressure systems (Kartsev, Abukova, Abramova, 2015). An elision geostatic water-pressure system is understood as a system of hydrogeological basins confined to the sagging region of the earth's crust composed of a thick stratum

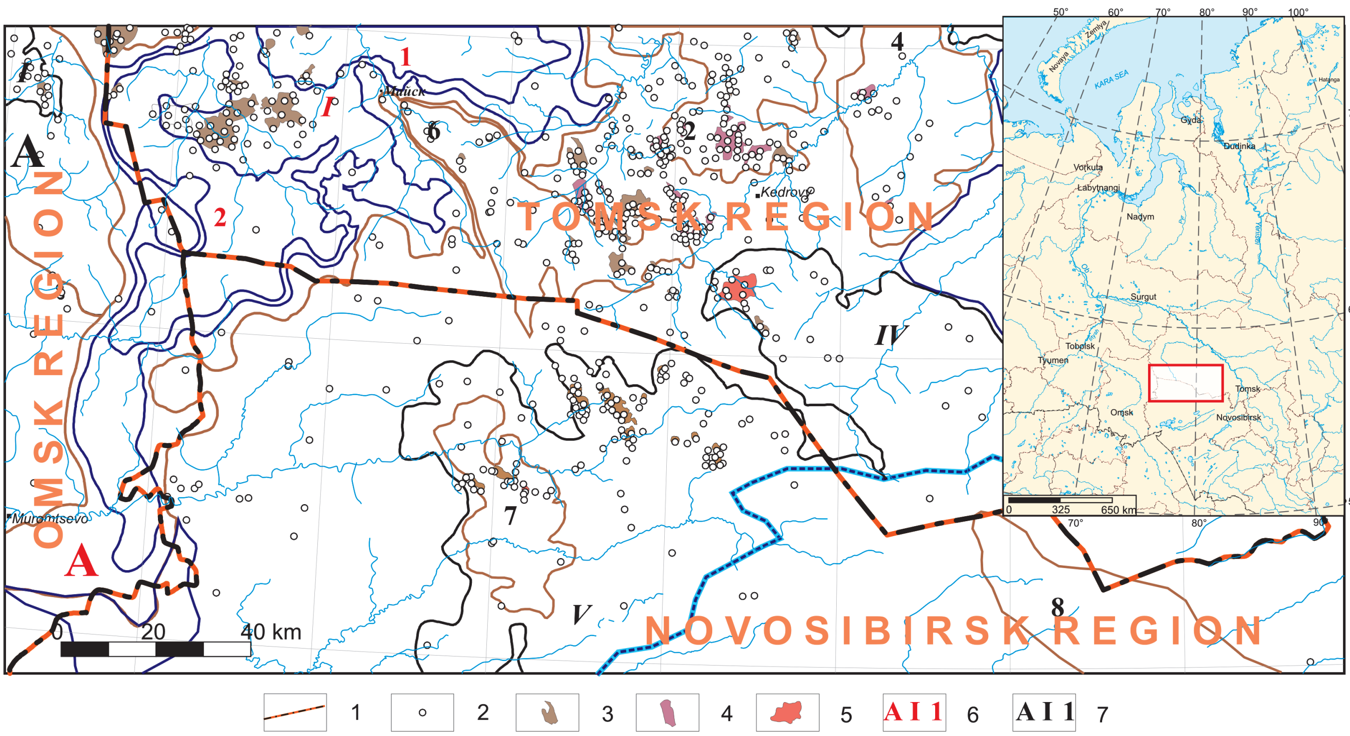

Fig. 1. Location of the studied area within West Siberia: 1 – administrative boundaries, 2 – fields: 3 – oil, 4 – oil-gas-condensate, 5 – gas-condensate and condensate; Tectonic elements: 6 – Negative; 7 – Positive. Names of tectonic elements are given on the map (Kontorovich et al., 2001): Negative: A – Koltogor-Nyurol Trench, I – Nyurol megadepression, 1– Centralno-Nyurol mezodepression, 2 – Yuzhno-Nyurol mesodepression, 3 – Bakchar mesodepression, 5 – Kyshtov inclined mesodownfold; Positive: A – Verkhnevasyuganskaya anteclise, I – Verkhnedemyansky megaswell, II – Parabelskiy inclined megaswell, IV – Kalgachsky inclined megaswell, V – Mezhovsky structural megaforeland, 1 – Kolpashevsky mezoswell, 2 – Pudinskoe dome-shaped mezouplift, 4 – Goreloyarskoe dome-shaped mezouplift, 6 – Lavrovskii inclined mezoswell, 7 – Western Mezhovsky dome-shaped mezouplift, 8 – Verkhneshegarsky mezobulge.

of sedimentary formations in which the feed region is the deepest submerged part of the collector stratum, so that water entering it moves towards the bed rise to the discharge regions. The main form of energy is the potential energy of the elastic deformation of the liquid accumulated in collectors as a result of consolidation of the deposits and pressing waters out of them. Several kinds of the systems are distinguished: 1) systems in which water pressure arises mainly as a result of water pressing from clay into the collectors; these systems are characteristic of relatively young sediments, mainly of the Mezo- and Cenozoic age, at a depth of 2.5-3.5 km; 2) systems in which the source of pressure is mainly solidification of the collectors themselves; these systems are characteristic of relatively ancient sediments. An elision thermohydration system is understood as a system of hydrogeological basins in which water pressure arises as a consequence of the excess amount of liquid during thermal dehydration of minerals, that is, water pressure is controlled by the geotemperature field; thermodehydration of the minerals is accompanied by the release of chemically bound water into the free phase, which leads to groundwater freshening in the deep parts of the hydrogeological basin (Kartsev, Abukova, Abramova, 2015).

Under the action of mechanical forces and physicochemical processes, the porosity of sedimentary rocks decreases, and they get consolidated. The major factor of consolidation is gravity, that is, the weight of the overlapping sediments, which increases with an increase in the thickness of the sedimentary cover (Vassoyevich, 1960). Because of this, the degree of consolidation of clay rocks is determined mainly by the geostatic pressure, while their physical properties depend on the depth of submergence or on the load value. In addition to the load, the value of sand rock consolidation is affected by physicochemical processes leading to the dissolution of the contiguous fragmental grains at their contacts. Two kinds of consolidation are distinguished: elastic and plastic (Levorsen, 1970). The rocks subjected to elastic deformation recover their initial volume and porosity in full or partially after the pressure is removed. However, if the rocks were subjected to plastic deformation, their initial volume and porosity are not recovered, even in part (Alekseev et al., 1982). Fragile deformations (cataclasis) of fragmental grains also occur in the sediments under consideration and cause a substantial increase in rock permeability (Antonellini et al., 1994). Gravitational corrosion of grains is also observed (Simanovich, 1978).

The present investigation is based on generalization and analysis of the whole factual material available till the present moment (the published and collected data) since the start of exploration work in the region (since 1950-es). The data include the results of tests of more than 445 objects, 217 wells, 84 exploration areas, including 368 measurements of formational pressure and the characteristics of more than 2400 inflows, as well as the data obtained in the laboratory core studies (more than 3400 samples). At the basis of structural layout made at the Trofimuk Institute of Petroleum Geology and Geophysics of the Siberian Branch of the Russian Academy of Sciences, the dependencies of formational pressure on depth, the grid models (Grid) of the distribution of formational pressure in the roof of 7 stratigraphic levels were built with the help of software packages GridBuilder, GridMaster and Surfer: Talitskaya series ($₽_1$); Kuznetsovskaya series (K_2); Senomanial horizon (K_2); Alym horizon (K_1); Bezhenovskiy horizon (J_3); U-10 bed (J_2); Pre-Jurassic complexes (T-Pz).

The next stage was correction of the plotted maps taking into account actual measurements of formational pressures in wells. The final stage was the development of a conceptual 3D model characterizing the distribution of formational pressures within the boundaries of the oil and gas bearing deposits in the southern regions of the Ob-Irtysh interfluve.

Results of investigation and discussion

The change of the porosity and permeability characteristics (PPC) of the rocks with the depth of their occurrence will be considered. In general, the porosity of sandstone and siltstone in oil and gas bearing sediments varies within a broad range from 0.70 to 43.5 %, regularly decreasing from the Aptian-Albian-Senomanian complex to the Lower Jurassic reservoirs (Table 1). It was established that the rocks dominating in the section are sand-siltstone with the porosity 10-20 %. The intervals with PPC increased up to 15-18 % were detected in the lower part of the sedimentary cover at the background of not very high porosity (Fig. 2).

Cumulative plots depicting the dependencies between the porosity of sandstone, siltstone, clay/argillite and the depth of their occurrence according to the results of petrophysical core studies are presented in Fig. 2a, b and c. One can see that the porosity of both the former and the latter decreases with depth. This dependence is also characteristic of permeability (Table 1). The rate of rock consolidation is relatively high for the depth of burial down to 1000-1500 m, and slows down with an increase in the depth (Burst, 1969; Perry, Hower, 1972; Alekseev et al., 1982; Magara, 1982; Dyunin, Korzun, 2005). Water abundance of the Mesozoic sediments also decreases regularly with an increase in the depth of the objects under investigation.

For instance, the average water flow rate in the Cretaceous complexes is 27-78 m^3/day, while in the Jurassic complexes it is 9-48 m^3/day. The highest collector characteristics are exhibited by weakly

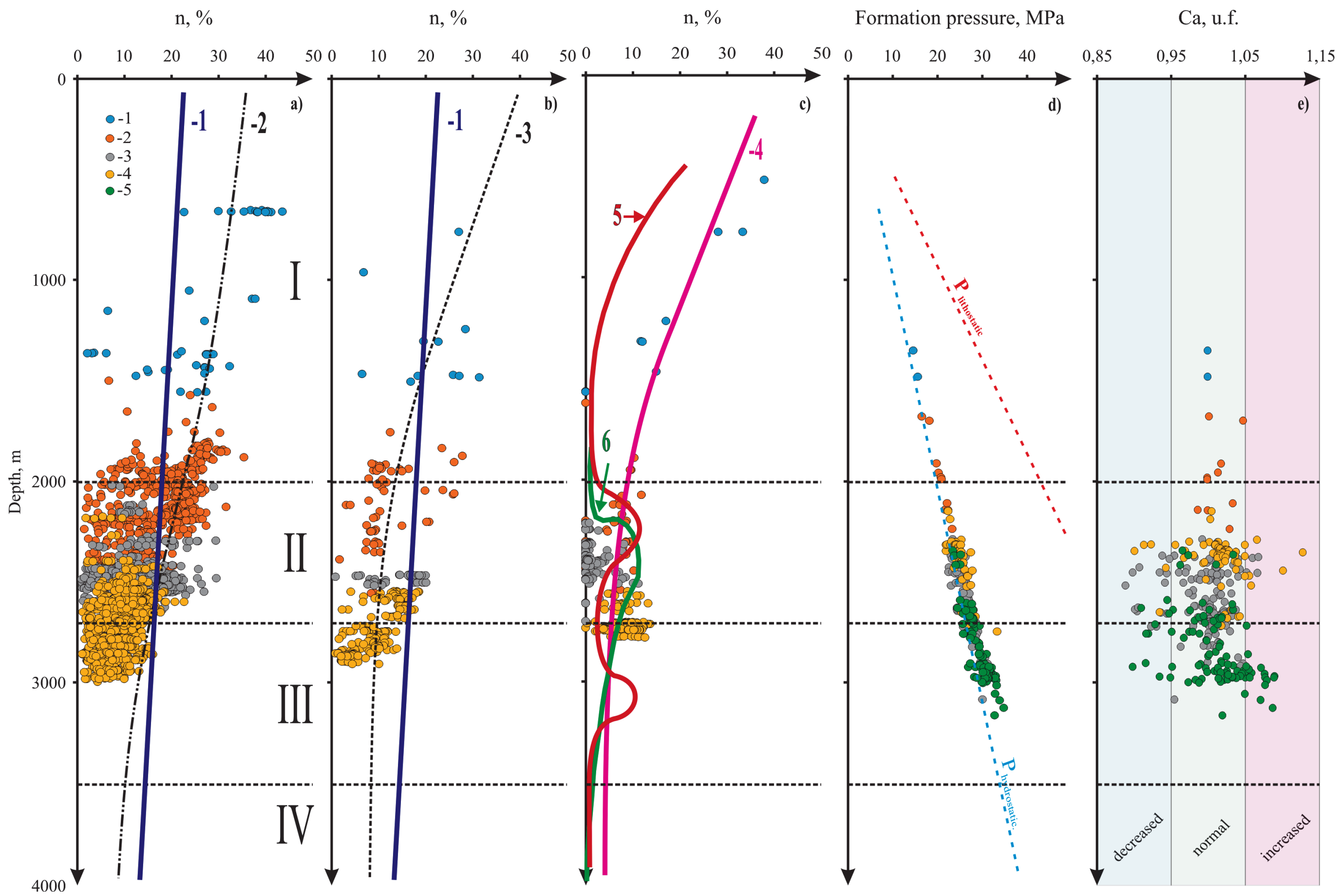

Fig. 2. Depthwise variation of filtration-capacity properties of rocks and hydrodynamic parameters of the sedimentary cover of WSSB. (a) Porosity of sandstones and siltstones – variation trends: (1) global (Ehrenberg, Nadeau, 2005), (2) in sandstones from central sectors of WSSB (Alekseev et al., 1982), (3) in siltstones from the above sectors (Alekseev et al., 1982); (b) porosity of clays and mudstones in central sectors of WSSB: (4) according to (Alekseev et al., 1982); Plots showing water release from the consolidating clays: (5) according to (Burst, 1969); (6) according to (Perry, Hower, 1972). Stages of sediment dehydration: (I) expulsion of free water, (II) expulsion of interlayer water (50 %) at a depth of 2.0-2.7 km (initial stage), (III) expulsion of the next portion (25 %) of interlayer water at a depth of 2.7-3.5 km (intermediate stage); (IV) expulsion of the last (25 %) water interlayer at a depth of more than 3.5 km (final stage); (c) formation pressure – aquifer complexes: (1) Aptian-Albian-Cenomanian, (2) Neocomian, (3) Upper Jurassic, (4) Lower-Middle Jurassic, (5) pre-Jurassic.

AS	n, %	P, μm^2	Pf, MPa	Ca, u.f.	Q_{water}, m^3/day
I	2.1-43.5 25.6(65)	2.0×10^{-3}-7.9 1.51(29)	14.6-15.6 15.1 (2)	1.00-1.00 1.00 (2)	7.0-864 78.2 (25)
II	1.5-35.4 17.1(668)	8.2×10^{-6}-5.6 0.17(440)	16.4-23.3 20.6 (10)	0.99-1.05 1.01 (10)	5.0-550.0 27.3 (159)
III	0.6-29.5 13.2(1166)	1.9×10^{-7}-1.8 0.04(799)	21.2-28.5 25.1 (104)	0.90-1.13 1.02 (104)	3.0-760 48.5 (166)
IV	0.3-22.7 8.6(973)	0.9×10^{-5}-0.14 2.0×10^{-3} (490)	22.5-31.1 26.6 (150)	0.89-1.07 1.00 (150)	3.0-256 9.1 (376)
V	-	-	23.4-44.2 29.5 (102)	0.90-1.09 1.01 (102)	3.0-1148 32.4 (335)

Table 1. Characterization of the hydrodynamics parameters along with the porosity and permeability characteristics of the oil and gas bearing deposits in the southern regions of the Ob-Irtysh interfluve. AS – aquifer system: I – Apt-Alb-Cenomanian; II – Neocomian; III – Upper Jurassic; IV – Lower Middle Jurassic; V – pre-Jurassic; n – porosity; P – permeability; Ca – anomaly coefficient of formation pressure = Pf/Pn, where Pf – formation pressure, Pn – normal hydrostatic pressure; the numerator shows the minimum and maximum values, the denominator shows the average (number of measurements); Q_{water} – rate of flow; "-" – lack of data.

cemented sands and sandstone of the Aptian-Albian-Senomanian water-bearing complex (horizon PK). Their porosity reaches 43.5 %, permeability is up to 7.9 μm^2, with the average value 1.5 μm^2.

This allows obtaining inflow up to 600-800 m^3/day and more. Because of this, in the majority of cases the groundwaters of the Aptian-Albian-Senomanian complex of West Siberia are used in the development of hydrocarbon deposits as the source for the operation of the systems maintaining the formation pressure (Novikov, 2005). Though the water-bearing horizons of the Neocomian water-bearing complex exhibit high PPC, they are affected by consolidation processes to a higher extent than overlying sediments. The sediments of the complex include permeable layers of A and B groups with the porosity within the range 1.5-35.4 %, permeability varying within the range $8.2 \cdot 10^{-6}$-5.6 μm^2, average water discharge reaching 27.3 m^3/day. Lower lying Jurassic water-bearing horizons include permeable layers of the J ground (J_1 in the Upper Jurassic and J_2-J_{17} in the Lower Jurassic). The porosity of the reservoirs varies within the range from 0.3 to 29.5 % with deterioration of the collector properties with depth. Permeability varies within a broader range: $1.9 \cdot 10^{-7}$-1.8 μm^2, that is, by a factor of several million. Water influx in wells decreases with depth while the PPC worsens. It should be stressed that Pre-Jurassic complexes (Triassic and older sediments) are only poorly hydrogeologically studied in the southern regions of the Ob-Irtysh interfluve. Water discharge varies during the tests of Pre-Jurassic objects from 3.0 to 1148 m^3/day (in idle objects it varies from 0.01), with the average value equal to 32.4 m^3/day, which is connected with the change of the pore-type collector for a cavernous, fractured and so on (Novikov et al., 2018).

The features of the structure and the extent of WSSB investigation over depth allow us at present to distinguish the Mesozoic-Cenozoic water-pressure system with characteristic water-embedding and waterproof complexes. Triassic and Paleozoic formations are penetrated by an insignificant number of wells at a relatively small depth, and their hydrogeological disintegration is impossible. The most essential hydrodynamic feature of the southern regions of the Ob-Irtysh interfluve is the manifestation of increased formational pressure in the Jurassic reservoirs starting from the depth of 2300-2350 m (Fig. 2 d, e). In general, the region under investigation is characterized by the direct hydrodynamic zoning and the development of normal and increased formational pressure; the coefficient of anomality (Ca) varies from 1.0 in Cretaceous water-bearing aquifers to 1.13 in the Jurassic ones (Fig. 2 d, e). Water-bearing complexes characterized by the hydrodynamic data to the smallest extent are the Aptian-Albian-Senomanian and Neocomian ones. It was established on the basis constructions and the available data for the Aptian-Albian-Senomanian complex that the formational pressure changes from several units to 15.6 MPa (1557-1626 m in the Mirnaya 410 well), Ca is 1.00. In general, an increase in the formational pressure is observed in the western direction (Fig. 3a). Formational pressure varying from 16.4 to 23.3 MPa was detected in the Neocomian water-bearing complex (2332-2374 m in the Bergulskaya 2 well 2), and Ca varies from 0.99 to 1.05, with the average value equal to 1.01. The largest values of formational pressure were detected in the south-western and north-western parts of the region under investigation in the southern part of the Koltogor-Nyurol trench and in the Nyurol megadepression, while the smallest ones were detected at the Verkhneshegar ledge in the south-east (Fig. 3b). Formation pressure in the Upper Jurassic water-bearing complex varies from 21.2 to 28.5 MPa (2774-2778 m in the Vostochno-Moiseevskaya 1 well), Ca changes within the range 0.90-1.13 (the Rakitinskaya 7 well, 2467-2485 m), the average value being 1.02. It was established that the formational pressure in the Upper Jurassic complex increases from the south-east (the Barabinsk-Pikhtovskaya monocline) to the north-west, to the structures of the Nyurol mega-depression (Fig. 4).

The Lower- and Middle-Jurassic water-bearing complex is characterized by the hydrodynamic materials to the highest extent. The measured formational pressure in it reaches 31.1 MPa within the range of 3006-3053 m in the Yuzhno-Tabagan 135 well. The Ca values in it are somewhat lower than in the Upper Jurassic water-bearing complex and vary from 0.89 to 1.07. An increase in the formational pressure with an increase in the depth towards the north-western and western directions is established. Increased pressure was also established in the Bakchar depression (Fig. 3 c). Formational pressure in the Pre-Jurassic sediments varies from 23.4 to 44.2 MPa (4520-4530 m, the Urmanskaya 6 well), Cavaries from 0.90 to 1.09, and the average value is 1.01. In general, the distribution of formational pressure in Pre-Jurassic sediments is similar to that in the overlying Lower and Middle Jurassic complex. The highest values were established in the north-western part of the region, and in the Bakchar depression, while the lowest value was detected in the south-east within the boundaries of the Barabinsk-Pikhtovskaya monocline (Fig. 3 d).

Results of the investigation of porosity and permeability, as well as the hydrodynamic characteristics of collectors in the hydrogeological section point to the dominating role of elision water exchange

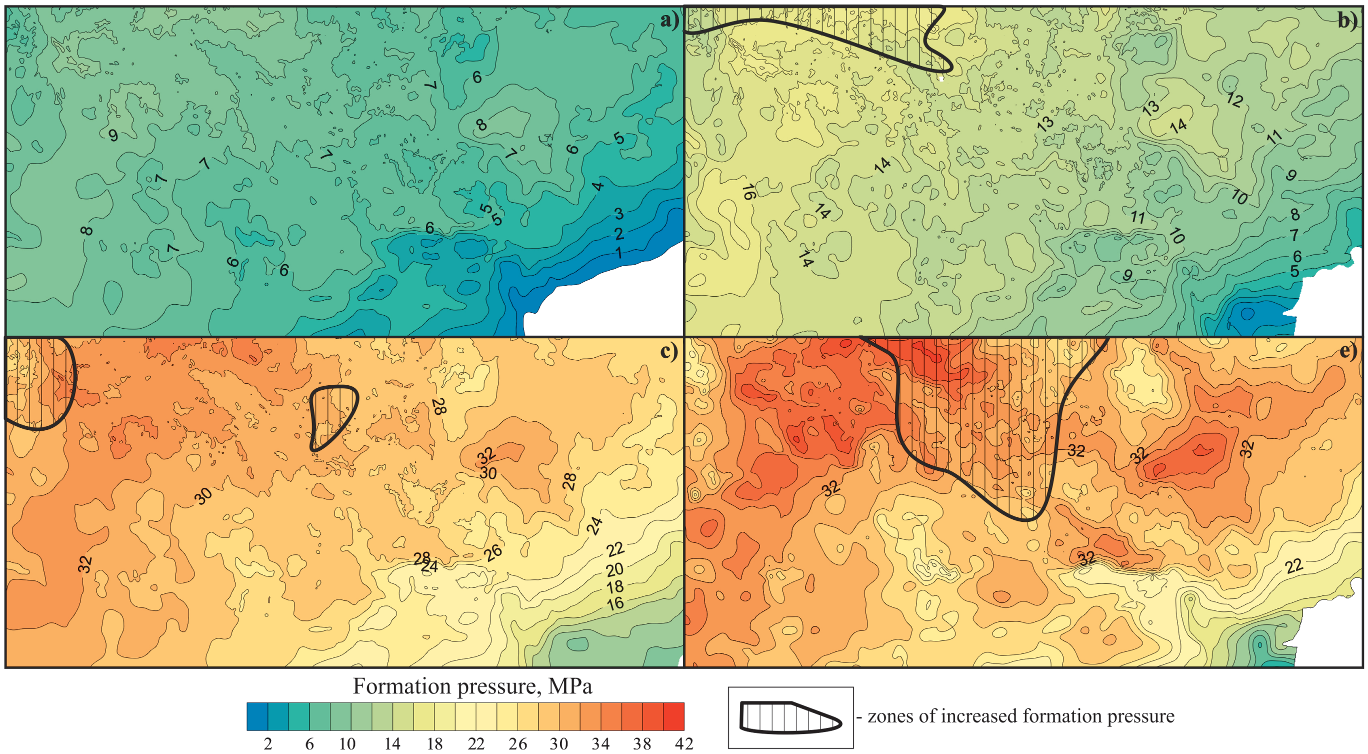

Рис. 3. Stresses in the hydrodynamic field of the Aptian-Alb-Cenomanian (a), Neocomian (b), Lower Middle Jurassic (c) and pre-Jurassic (d) aquifers complexes

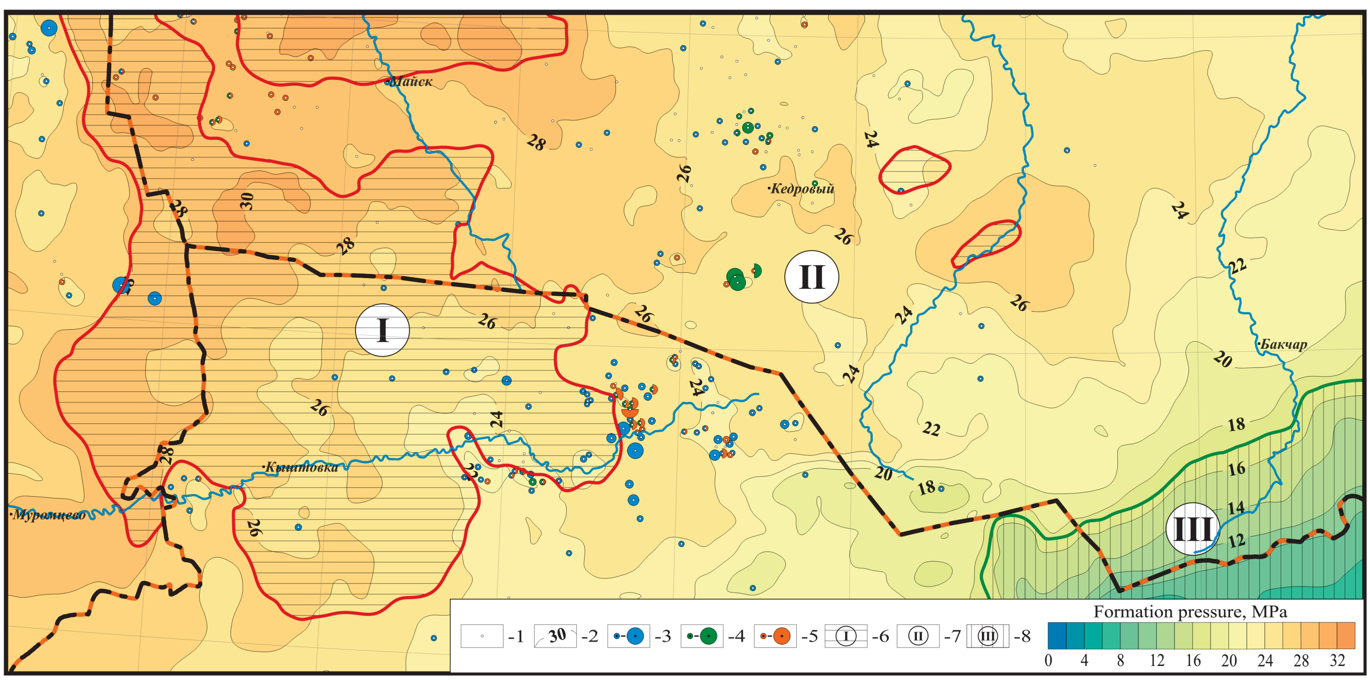

Fig. 4. Map of reservoir pressure of the Upper Jurassic aquifer with elements of regionalization of water-pressure systems. 1 – wells; 2 – isobars, MPa; Flow rates: 3 – water (from 3 to 1100 m³/day), 4 – gas (1-450 thousand m³/day), 5 – oil (from 0.1 to 450 m³/day); zones of development of water-pressure systems: 6 – elision thermal-dehydrational; 7 – elision lithostatical; 8 – infiltrational.

in the formation of the modern structure of the hydrodynamic field. Two types of natural water-pressure systems were established: elision-based (lithostatic and thermodehydrational) in the internal regions (the southern part of the Koltogor-Nyurol trench, the Nyurol megadepression, Verkhnevasyuganskaya anticline and other structures) and infiltration-based, within the structures of the Barabinsk-Pikhtovskaya monocline (Fig. 4). The elision lithostatic system starts to attain the features of elision thermodehydrational one from the depth of about 2.0-2.2 km. Vast zones of piezo-maxima (southern part of the Koltogor-Nyurol trench and the Nyurol megadepression) at the present stage of the development of the water-pressure system of the region under investigation became the internal areas of water-head generation (the internal catchment areas) with the maximal degree of the hydrogeological closure of the interior. The region of piezo-minima tracing the structures of the Barabinsk-Pikhtovskaya megamonocline relates to the external catchment area.

It was demonstrated (Burst, 1969; Perry, Hower, 1972) that dehydration starts from the depth of about 2 km (wringing of interfacial water) with clayey minerals; this process includes several stages (Fig. 2 c). D.B. Shaw calculated the depth and temperature of clay dehydration for more than 2000 deposits in the USA; he established that the depth of dehydration varies within the range 1280-4850 m, and temperature varies within the range 83-111°C (Shaw, Weaver, 1965).

So broad depth range is first of all due to different values of the thermal flux at the deposits under investigation. Taking into account the results of geothermal studies of the sedimentary cover of West Siberia carried out by G.D. Ginsburg, A.D. Duchkov, Yu.G. Zimin, A.E. Kontorovich, V.A. Koshlyak, N.M. Kruglikov, A.R. Kurchikov, B.F. Mavritskiy, I.I. Nesterov, B.P. Stavitskiy, E.E. Fotiadi, G.A Cheremenskiy (Mavritskiy, 1960; Stavitskiy, 1964; Zimin et al., 1967; Fotiadi et al., 1969; Surkov et al., 1972; Nesterov et al., 1980; Kurchikov, 1981; Stavitskiy et al., 1981; Kurchikov, Stavitskiy, 1985; Kurchikov, Stavitskiy, 1986; Kurchikov, Stavitskiy, 1987; Nesterov et al., 1988; Duchkov et al., 1990; Kurchikov, 1992) and the results of our studies of the southern regions of the Ob-Irtysh interfluve, Fore-Yenisei sedimentary basin etc. (Novikov, 2011; Dultsev, Novikov, 2017; Novikov et al., 2018), we may assume that the elision geostatic (lithostatic) system within the region under investigation takes on the features of thermodehydrational system from the depth of about 2.0-2.2 km because the formational temperature exceeds 100°C.

To summarize, the detailed analysis of the available data allowed us to complied for the first time a conceptual 3D model characterizing the distribution of formational pressures within the boundaries of oil and gas bearing sediments in the southern regions of the Ob-Irtysh interfluve. The model allows predicting the constraint of the hydrodynamic field for the structures poorly provided by factual data, which is especially relevant for designing deep-hole drilling in the region (Fig. 5).

Conclusion

Water-pressure systems of the Cretaceous and Jurassic complexes in the southern regions of the Ob-Irtysh interfluve including the productive layers traced over a substantial territory are isolated from each other

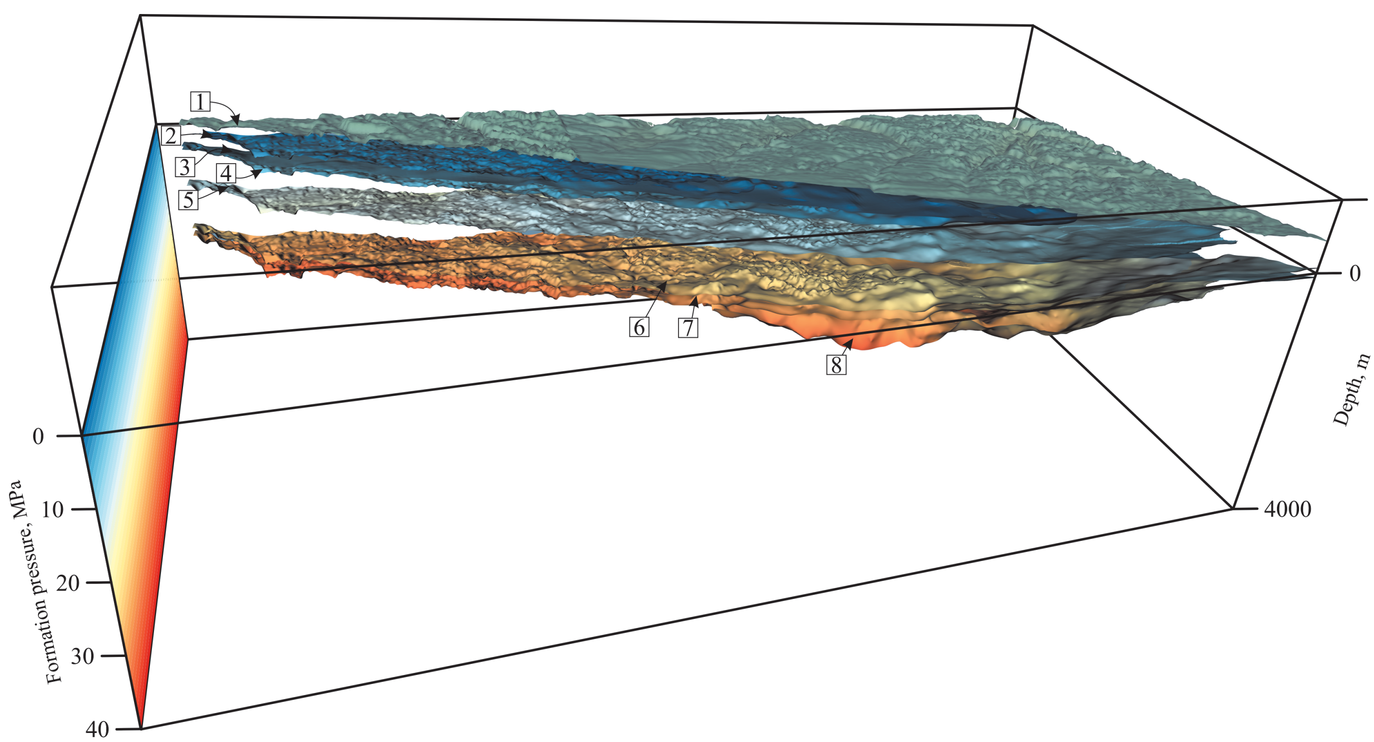

Fig. 5. Model of reservoir pressure distribution in oil and gas bearing deposits of the southern regions of the Ob-Irtysh interfluve. 1 – day surface; top of: 2 – Talitsky suite (P_1); 3 – Kuznetsovskaya suite (K_2); 4 – Cenomanian horizon (K_2); 5 – Alym horizon (K_1); 6 – Bazhenov formation (J_3); 7 – layer U-10 (J_2); 8 – pre-Jurassic deposits (T-Pz).

with reliable fluid-seal rocks. The isolated structure is disturbed only at local regions: in the systems of faults, tectonic disturbances and stratigraphic breaks. Hydrodynamic conditions change substantially even within one complex in which hydrodynamically isolated blocks are distinguished.

The hydrodynamic field of the region under investigation is characterized by the direct hydrodynamic zoning and the development of normal and increased formational pressure (Ca up to 1.13) in the Pre-Jurassic, Jurassic and Cretaceous water-bearing complexes. Results of the investigation of reservoir porosity and permeability, and the hydrodynamic characteristics of collectors in the hydrogeological section point to the dominating role of elision water exchange in the formation of the modern structure of the hydrodynamic field. Two types of natural water-pressure systems are revealed: elision-based (lithostatic and thermodehydrational) in the internal regions (the southern part of the Koltogor-Nyurol trench, Nyurol megadepression, Verkhnevasyuganskaya anteclise and other structures) and infiltration-based within the structures of the Barabinsk-Pikhtovskaya monocline.

The elision-based lithostatic system starts to retain the features of the elision-based thermodehydrational system from the depth of about 2.0-2.2 km. Vast zones of piezo-maxima (the southern part of the Koltogor-Nyurol trench and the Nyurol megadepression) at the present stage of the development of the water-pressure system became the internal regions of the generation of water head (internal catchment regions) with the maximal degree of the hydrogeological closure of the interior. The region of piezo-minima tracing the structures of the Barabinsk-Pikhtovskaya mega-monocline relates to the external catchment region.

The hydrodynamic model of oil and gas bearing sediments in the southern regions of the Ob-Irtysh interfluve allowing predictions of the trends of formational pressure changes in the structures poorly provided by the factual data has been compiled for the first time.

Acknowledgements

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References

Aleksandrov B.L. (1987). Abnormally high reservoir pressure in oil and gas basins. Moscow: Nedra, 216 p. (In Russ.)

Alekseev G.I., Andreev V.N., Gorelov A.A., Kazmin L.L. (1982). Methods for studying the compaction of terrigenous rocks during paleogeological reconstructions. Moscow: Nauka, 144 p. (In Russ.)

Antonellini M.A., Aydin A., Pollard D.A. (1994). Microctructure of deformation bands in porous sandstones at Arches National Park, Utah. *J. Struct. Geol.,* 16, pp. 941-959. https://doi.org/10.1016/0191-8141(94)90077-9

Burst J.F. (1969). Diagenesis of Gulf Coast Clayey Sediments and Its Possible Relation to Petroleum Migration. *AAPG Bull.*, 53(1), pp. 73-93. https://doi.org/10.1306/5D25C595-16C1-11D7-8645000102C1865D

Duchkov A.D., Galushkin Yu.I., Smirnov L.V., Sokolova L.S. (1990). Evolution of the temperature field of the sedimentary cover of the northern West Siberian Plate. *Russian Geology and Geophysics*, 10, pp. 51-60.

Dultsev F.F., Novikov D.A. (2017). Geothermal zonality of Fore-Yenisei sedimentary basin. *Bulletin of the Tomsk Polytechnic University, Geo Assets Engineering*, 328(11), pp. 6-15.

Dyunin V.I., Korzun V.I. (2005). Hydrogeodynamics of oil and gas basins. Moscow: Nauchnyy mir, 524 p. (In Russ.)

Fotiadi E.E., Moiseyenko U.I., Sokolova L.S. (1969). About the thermal field of the West Siberian plate. *Doklady AN SSSR*, 189(2), pp. 385-388. (In Russ.)

Kartsev A.A., Abukova L.A., Abramova O.P. (2015). Dictionary of oil and gas hydrogeology. Moscow: GEOS, 304 p. (In Russ.)

Kontorovich V.A., Belyayev S.Yu., Kontorovich A.E., Krasavchikov V.O., Kontorovich A.A., Suprunenko O.I. (2001). Tectonic structure and history of evolution of the West Siberian geosyneclise in the Mesozoic and Cenozoic. *Russian Geology and Geophysics*, 42(11-12), pp. 1832-1845.

Kortsenshteyn V.N. (1977). Water pressure systems of the largest gas and gas condensate fields of the USSR. Moscow: Nedra, 247 p. (In Russ.)

Kruglikov N.M., Nelyubin V.V., Yakovlev O.N. (1985). Hydrogeology of the West Siberian oil and gas basin and features of the formation of hydrocarbon deposits. Leningrad: Nedra, 279 p. (In Russ.)

Kruglikov N.M., Yakovlev O.N. (1981). Questions of groundwater dynamics in the north of Western Siberia. *Hydrogeological conditions of petroleum potential of some regions of the USSR*, pp. 78-100. (In Russ.)

Kurchikov A.R. (1981). The hydrodynamic nature of the geothermal anomaly in the Salym and Krasnolensky regions of Western Siberia. *Trudy ZapSibNIGNI*, 164, pp. 38-47. (In Russ.)

Kurchikov A.R. (1992). Hydrogeothermal criteria of petroleum potential. Moscow: Nedra, 231 p. (In Russ.)

Kurchikov A.R., Stavitskiy B.P. (1980). Features of change with the depth of thermal conductivity of sedimentary rocks of Western Siberia. *Trudy ZapSibNIGNI*, 48, pp. 11-15. (In Russ.)

Kurchikov A.R., Stavitskiy B.P. (1985). Geothermy of Western Siberia. *Trudy ZapSibNIGNI*, 200, pp.75-90. (In Russ.)

Kurchikov A.R., Stavitskiy B.P. (1986). Determination of the deep heat flow in complex geothermal conditions. *Izv. AN SSSR. Ser. Geol.*, 11, pp. 121-127. (In Russ.)

Kurchikov A.R., Stavitskiy B.P. (1987). Geothermy of oil and gas regions of Western Siberia. Moscow: Nedra, 134 pp. (In Russ.)

Levorsen A.I. (1970). Geology of oil and gas. Moscow: Mir, 639 p. (In Russ.)

Magara K. (1982). Rock compaction and fluid migration. Applied Petroleum Geology. Moscow: Nedra, 296 p. (In Russ.)

Matusevich V.M., Bakuyev O.V. (1986). Geodynamics of water-pressure systems of the West Siberian oil and gas megabasin. *Sovetskaya geologiya*, 2, pp. 117-122. (In Russ.)

Matusevich V.M., Rylkov A.V., Ushatinskiy I.N. (2005). Geofluid systems and oil and gas problems of the West Siberian megabasin. Tyumen: TyumGNGU, 225 p. (In Russ.)

Mavritskiy B.F. (1960). Geothermal zonality of the West Siberian artesian basin. *Izv. AN SSSR. Ser. Geol.*, 3, pp. 72-83. (In Russ.)

Nazarov A.D. (2004). Oil and gas hydrogeochemistry of the south-eastern part of the West Siberian oil and gas province. Moscow: Ideya-Press, 288 p. (In Russ.)

Nesterov I.I., Kurchikov A.R., Stavitski·y B.P. (1988). The main features of the geothermal field of Western Siberia. Neftegeological interpretations of the thermal regime of the bowels of Western Siberia. *Trudy ZapSibNIGNI*, pp. 5-23. (In Russ.)

Nesterov I.I., Stavitskiy B.P., Kurchikov A.R. (1980). On the degree of disturbance of the thermal regime of the subsoil for the Late Quaternary time (according to data on Western Siberia). *Doklady AN SSSR*, 250(2), pp. 418-421. (In Russ.)

Novikov D.A. (2005). Groundwater geochemistry of the Apt-Alb-Cenomanian hydrogeological complex of the Nadym-Tazovsky interfluve. *Otechestvennaya geologiya*, 3, pp. 73-82. (In Russ.)

Novikov D.A. (2011). Vertical geothermal zonality at the north areas of Western Siberia and the Kara sea area. *Proc. VII Int. Sci. Congress "GEO-Siberia-2011"*, 2(2), pp.57-61. (In Russ.)

Novikov D.A. (2014). Hydrodynamics of oil and gas deposits of the neocom transition region from the West Siberian artesian basin to Khatanga. *Geologiya, geofizika i razrabotka neftyanykh i gazovykh mestorozhdeniy = Geology, Geophysics and Development of Oil and Gas Fields*, 2, pp. 24-33. (In Russ.)

Novikov D.A. (2017). Hydrogeochemistry of the Arctic areas of Siberian petroleum basins. *Petroleum Exploration and Development*, 44(5), pp. 780-788. https://doi.org/10.1016/S1876-3804(17)30088-5

Novikov D.A. (2017). Hydrogeological conditions for the presence of oil and gas in the western segment of the Yenisei-Khatanga regional trough. *Geodynamics and Tectonophysics*, 8(4), pp. 881-901. https://doi.org/10.5800/GT-2017-8-4-0322 (In Russ.)

Novikov D.A. (2019). Role of elisional water exchange in the hydrodynamic field formation in the Yamal-Kara Depression. *Lithology and Mineral Resources*, 54(3), pp. 236-247. DOI https://doi.org/10.1134/S0024490219030076

Novikov D.A. (2018). On the vertical hydrodynamic zonality of the Yamalo-Kara Depression (northern regions of Western Siberia). *Izvestiya Vuzov. Neft i gaz = Oil and Gas Studies*, 1, pp. 35-42. https://doi.org/10.31660/0445-0108-2018-1-35-42 (In Russ.)

Novikov D.A., Dultsev F.F., Chernykh A.V. (2018). Abnormally high formation pressures in jurassic-cretaceous reservoirs of Arctic regions of Western Siberia. *IOP Conference Series: Earth and Environmental Science*, 193(1), 012050. DOI https://doi.org/10.1088/1755-1315/193/1/012050

Novikov D.A., Lepokurov A.V. (2005). Hydrogeological conditions of petroleum potential deposits on the structures in the southern part of Yamalo-Karskoye depression. *Geologiya nefti i gaza = Oil And Gas Geology,* 5, pp. 21-30. (In Russ.)

Novikov D.A., Ryzhkova S.V., Dultsev F.F., Chernykh A.V. (2018). On the geothermal zonality of oil and gas deposits of the north-western regions of the Novosibirsk region. *Izvestiya Vuzov. Neft i gaz = Oil and Gas Studies*, 5, pp. 69-76. DOI: https://doi.org/10.31660/0445-0108-2018-5-69-76 (In Russ.)

Novikov D.A., Ryzhkova S.V., Dultsev F.F., Chernykh A.V., Ses K.V., Efimtsev N.A., Shokhin A.E. (2018). Oil and gas hydrogeochemistry of the prejurassic deposits in the southern areas of Obirtysh interfluves. *Bulletin of the Tomsk Polytechnic University, Geo Assets Engineering*, 329(12), pp. 39-54. DOI https://doi.org/10.18799/24131830/2018/12/19 (In Russ.)

Novikov D.A., Sukhorukova A.F. (2015). Hydrogeology of the northwestern margin of the West Siberian Artesian Basin. *Arabian Journal of Geosciences*, 8(10), pp. 8703-8719. DOI https://doi.org/10.1007/s12517-015-1832-5

Nudner V.A. (1970). Hydrogeology of the USSR. V. XVI: West Siberian Plain (Tyumen, Omsk, Novosibirsk and Tomsk Regions). Moscow: Nedra, 368 p. (In Russ.)

Perry E.A., Hower J. (1972). Late-stage dehydration in deeply buried politic sediments. *AAPG Bull.*, 56(10), pp. 2013-2021. https://doi.org/10.1306/819A41A8-16C5-11D7-8645000102C1865D

Sadykova Ya.V., Fomin M.A., Glazunova A.S., Dultsev F.F., Ses K.V., Chernykh A.V. (2019). To the nature of the hydrochemical anomalies in mezhovksky oiland gas-bearing region (Tomsk and Novosibirsk regions). *Geologiya, geofizika i razrabotka neftyanykh i gazovykh mestorozhdeniy = Geology, Geophysics and Development of Oil and Gas Fields*, 1, pp. 45-54. DOI https://doi.org/10.30713/2413-5011-2019-1-45-54 (In Russ.)

Shaw D.B., Weaver C.E. (1965). The mineralogical composition of shales. *Journal of Sediment. Res.*, 35(1), pp. 213-222. https://doi.org/10.1306/74D71221-2B21-11D7-8648000102C1865D

Shvartsev S.L., Novikov D.A. (1999). Hydrogeological conditions of Kharampur megawall. *Izvestiya Vuzov. Neft i gaz = Oil and Gas Studies*, 3, pp. 21-29. (In Russ.)

Shvartsev S.L., Novikov D.A. (2004). The nature of vertical hydrogeochemical zoning of petroleum deposits (exemplified by the Nadym-Taz interfluve, West Siberia). *Geologiya i Geofizika*, 45(8), pp. 1008-1020. (In Russ.)

Simanovich I.M. (1978). Quartz of sand rocks. Moscow: Nedra, 152 p. (In Russ.)

Stavitskiy B.P. (1964). Geothermal conditions of the West Siberian Lowland. *Geologiya SSSR*, XLIV (II), pp. 205-209. (In Russ.)

Stavitskiy B.P., Kurchikov A.R., Belkina B.V., Bulgakova N.E., Kudryavyy S.V. (1981). Thermal regime of the Western Siberia interior. Knowledge and features. *Trudy ZapSibNIGNI*, 164, pp. 18-37. (In Russ.)

Surkov V.S., Romenko V.I., Zhero O.G. (1972). Geothermal characteristics of the platform cover of the central part of the West Siberian plate and its connection with the geological structure of the basement. *Trudy SNIIGGIMSa*, 156, pp. 101-109. (In Russ.)

Vassoyevich N.B. (1960). Experience in building a typical gravitational compaction curve of clay sediments. *Novosti neftyanoy tekhniki. Geologiya*, 4, pp. 11-15. (In Russ.)

Zimin Yu.G., Kontorovich A.E., Shvydkova L.I. (1967). Geothermal characteristics of the Mesozoic deposits of the West Siberian oil and gas basin. *Russian Geology and Geophysics*, 5, pp. 3-13. (In Russ.)

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