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Research Article

Hydrogeology of the Lower-Middle Jurassic Complex of the Talinskoye Oil Field Located in West Siberia

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ABSTRACT.

The article discusses thehydrogeologic conditions of the Talinskoye oil field located in the west of the Khanty-MansiyskDistrict of West Siberia. There are more than 5,400 wells within the field, which made it possible to collect representative hydrogeochemical materials, as well as to analyze numerous values of observed reservoirpressure. The authors address the Lower-Middle Jurassic aquifer system, which is characterized by the most contrasting conditions and lies above the Paleozoic rocks. The mineralization variation interval ranges widely from 2-3 g/l to 14-16 g/l. Water contains a large amount of hydrocarbonate ions which are of the sodium bicarbonate type according to Sulin. Within the field, the authors identified areas with low mineralization and analyzed the dependence of low-mineralized water distribution on the basement roof temperature, reservoirpressure, the location of ruptures in the basement and the ingress of water "squeezed" from clay rocks (elision water). It was perceived that low hydrostatic pressures, the formation of which is associated with the earth crust stretching processes, prevail in the field. The pressure deficit in the research area reaches 5-9 MPa, averaging 1.6 MPa. The authors believe that hydrogeological conditions correspond to the model of conjugate descending-ascending mass transfer.

Keywords: Lower-Middle Jurassic hydrogeological complex, Groundwater mineralization,Reservoir pressure, West-Siberian megabasin, Basement,Hydrocarbonate-chloride sodium ion-salt composition.

INTRODUCTION

The hydrogeodynamic and hydrogeochemical conditions of the Lower-Middle Jurassic complex were analyzed using the example of the Talinskoye oil field located in the Khanty-MansiyskDistrict in the Tyumen Region in the west of West Siberia. This field was chosen due to the presence of sufficient actual hydrogeochemical material, numerous reports on testing wells before the start of operation, and a large amount of published materials on metasomatism of Jurassic sediments within this field. To date, more than 5,400 wells have been drilled here. The field has the largest area of more than 160 km, which allows for the conclusion about regional hydrogeological patterns of the research area.

The field under consideration is located in the west of the West-Siberian megabasin (WSMB). Hydrogeological stratification has the form of three hydrogeological basins (Paleozoic, Mesozoic and Cainozoic) and seven independent hydrogeological complexes (HC): Oligocene-Quaternary, Turon-Oligocene, Apt-Alb-Cenomanian, Neocomian, Upper, Lower and Middle Jurassic, and Trias-Paleozoic.

METHODS

According to modern data, geological stratification and hydrogeological conditions within the Talinskoye oil field were described. The Lower-Middle Jurassic complex under study was thoroughly decomposed into formations. The authors analyzed the paleogeographic situation in the Early-Middle Jurassic in order to identify the predominant composition of sedimentation water and its mineralization. The geological structure was analyzed in regard to determining the extent of elision water entering the reservoirs. This type of water is released from clay sediments in the case of increasing geostatic load with the accumulation of deposits due to compression of clay rocks. To reveal the influence of deep fluids entering Jurassic reservoirs from the basement, a schematic map of reduced reservoirpressures (including water density) of the Lower-Middle Jurassic complex was drawn up. In this scheme, areas with mineralization significantly less than the background one (2-3 g/l, when the background one is 8-9 g/l) are highlighted, and these areas are overlaid on the schematic map of reservoirpressures with faults and intrusive bodies in the sedimentary cover basement. The data described was analyzedand combined, taking into account temperatures of the basement roof, which made it possible to determine the main reasons for the heterogeneity of hydrogeological conditions of the Lower-Middle Jurassic complex of the Talinskoye oil field.

RESULTS AND DISCUSSION

The features of the formation of groundwater in the area of the Talinskoye field are associated with its unique geological structure: 1) close proximity to the East-Ural marginal suture with numerous ruptures, which caused the reservoir-block structure and the specificity of the chemical composition and hydrogeodynamic conditions of the Lower-Middle Jurassic hydrogeological complex; 2) presence of a thick (up to 800 m) stratum of exceptionally clayey deposits of the Frolovskformation in the composition of Cretaceoussediments, which caused elision water exchange [1].

According to the results of the first paleohydrogeological studies of WSMB [2, 3], the most extensive redistribution of substance in the west of WSMB is associated with elision water exchange caused by squeezing the natural water buried with deposits (mainly clayey) into reservoir rocks due to increasing geostatic load from overlying sediments. Currently, taking into account the latest data on thehydrogeochemistry, geophysics, geotemperatures, reservoirpressures, mineral composition and hydrothermal processing of rocks, one should also speak about the influence of deep fluids (probably coming from the basement during periods of tectonic activity) on the composition of reservoirwater.

The Lower-Middle Jurassic HC includes sediments of the Tyumen (YuK_{2-3}, YuK_{5-6}, YuK_{7-9}) and Sherkalin (YuK_{10}, YuK_{11}) formations. Hydrogeodynamic and hydrogeochemical conditions were analyzed using the example of the Sherkalinformation. Its thickness within the field reaches 125 m; the roof of sediments is traced at depths of up to 2,745 m. The first unit of theformation corresponds to the bed YuK_{11} and is composed of quartz gravelites and coarse-grained sandstones with layers of mudstone-like clays. At the top of the unit, there are Radom mudstone-like clays. The section between the beds YuK_{11} and YuK_{10} are Togur clays. The bed YuK_{11} consists of quartz sandstones and gravelites with clay interlayers.

Based on the analysis of paleogeographic situations in the research area, one can assume that the magnitude of groundwater mineralization in the Lower-Middle Jurassic did not exceed 10 g/l – the maximum mineralization of hydrocarbonate and sulphate water types formed in continental conditions.

At present, underground water of the Lower-Middle Jurassic HC hasa bicarbonate-sodium chloride or sodium chloride composition. The type of water according to Sulin is sodium bicarbonate. For this type of water, rNa/rCl is greater than 1 and $(rNa-rCl)/rSO_4$ is greater than 1, where r indicates the measurement unit of mg equivalent/l. The mineralization variation interval ranges widely from 2-3 g/l to 14-16 g/l, while in the complex under consideration there is classical hydrogeochemical zonality, despite the general inversion hydrogeochemical zonality from the Apt-Alb-Cenomanian to the Lower-Middle Jurassic HC.

Mineralization, as noted above, in the Lower-Middle Jurassic HC increases with depth, although some wells in sediments of the Sherkalinformation Yu_{11} contain water with mineralization of 2.4-5.3 g/l. The background modern groundwater mineralization of the Lower-Middle Jurassic HC in the research area is 8-9 g/l; the maximum values reach 15-16 g/l. The latter values exceed the background ones, but in general are normal for these depths and quite common. Their formation is explained by the known processes of interaction in the "water – rock" system. Water-dissolved gases are of the methane type (according to Zorkin) with a methane concentration of 85-95%.

Regionally, in the direction of the North-Sosvinsky arch, and also to the east of the research area, there is a change in the groundwater type to potassium chloride according to Sulin due to an increase in reservoir rock thickness and the absence of the thickest clay rocks, which are the main "source" of elision water [4-6]. Elision water exchange in the research area was significant. Water was squeezed out down from the Neocomian and Upper Jurassic clays to Jurassic reservoir rocks, as well as to the east. Calculations of the number of cycles of elision water exchange are not given in this article due to the impossibility of reliable estimation of the "effective" thickness of clays from which the water was squeezed out. Squeezing out the elision water from the central part of a thick clayey bed (Frolovskformation), considered in this case, is difficult. A similar situation develops during the emigration of bitumoids from thick layers of mudstones, as noted by Kontorovich [5]. In the central part of the thick clayey bed, the composition of bitumoids is closer to primary, autochthonous. Probably, sedimentation water of central parts of clayey layers remains the closest in composition to sedimentation water originally buried with sediments, despite the increased geostatic load. The thickness of the Frolovskformation (Neocomian HC), covering the Jurassic sediments within the field, reaches 800 m.

When assessing the extent of elision water entering the Lower-Middle Jurassic HC, it was conditionally assumed that its volume is approximately the same per unit area of distribution within the field.

Researchers who dealt with the problem of elision process agree that when squeezed, water is desalinized, its mineralization decreases and chemical activity increases. There is a clear correlation between the clay content and the mineralization of squeezed water: with an increase in clay content, the mineralization of squeezed water decreases, all else being equal.

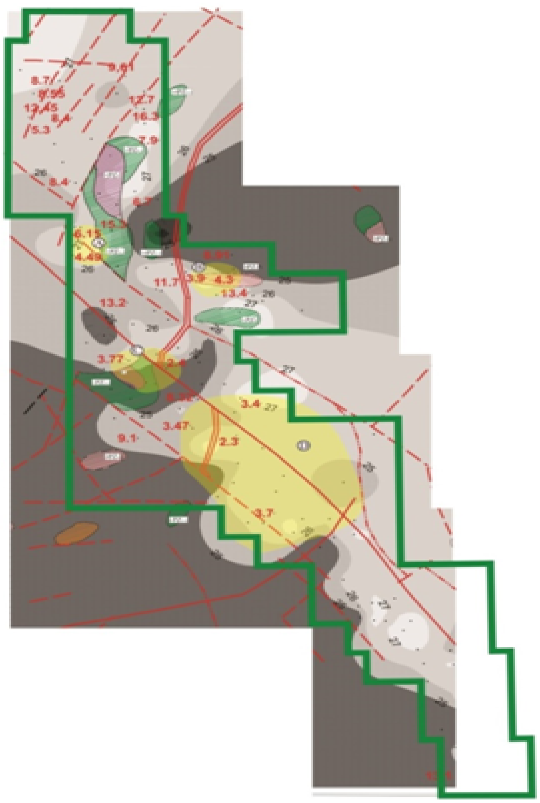
The paper by Flerova [7] gives results of pressing solutions from clay sediments of West Siberia according to the method of Kryukov. The composition of pore solutions was studied in two areas of the central part of WSMB; the samples were taken from depths of 1,600-1,900 m and 2,200-2,400 m. It was determined that the total mineralization of squeezed pore solutions ranges from 5.3 to 11 g/l. If one applies the results obtained by this author to the object of research – the Talinskoye field – and assumes that buried sedimentation water of the Lower-Middle Jurassic complex and elision water with a mineralization of 5.3-11 g/l are mixed, the occurrence of anomalies in areas with a groundwater mineralization of 2-3 g/l has no explanation if analyzed only with regard to elision water exchange. These anomalies could have been formed during the ingress of high-temperature deep fluids, probably fresh or ultra-fresh, through vertical channels of migration.

Anomalies of chemical composition have a direct genetic relationship with the structure of hydrogeodynamic field. Fig. 1 shows a schematic map of the basement structure with superimposed anomalies of chemical composition. Areas with a recorded significant decrease in mineralization relative to the background value (8-9 g/l) are marked as separate zones (letters: A, B, C, D were used for description). The schematic map does not show the most typical values of groundwater mineralization.

The structure of hydrogeodynamic field is extremely non-uniform, and pre-hydrostatic pressures are mainly observed. The pressure deficit in the research area reaches 5-9 MPa [1], averaging 1.6 MPa. At the same time, there are areas with super-hydrostatic reservoir pressures (SHRP). The excess of conditional hydrostatic pressure reaches 1 MPa; the average value is 0.5 MPa. Magnitudes of the excess or deficit of reservoirpressure is given relative to the conditional hydrostatic pressure at 2,700 m.

The chemical composition anomaly A is confined to the northern part of the field, the excess of conditional hydrostatic pressure here is 0.77 MPa. Groundwater is characterized by very low mineralization of 4.5-6.1 g/l. The current temperature of the basement roof is on average 100 °C. In this area, there is a major fault of north-eastern orientation.

The chemical composition anomaly B is confined to the area where the SHRP of 27.6 MPa was recorded. Water mineralization is 3.9-4.3 g/l. At the same time, there is an intrusive body of Paleozoic age, consisting of diorites and tonalites, in this area. The current temperature of the basement roof in this area is 100-105 °C, reaching 110 °C. Probably, this is an area of ascending migration, ingress of deep fluids during periods of tectonic movements.



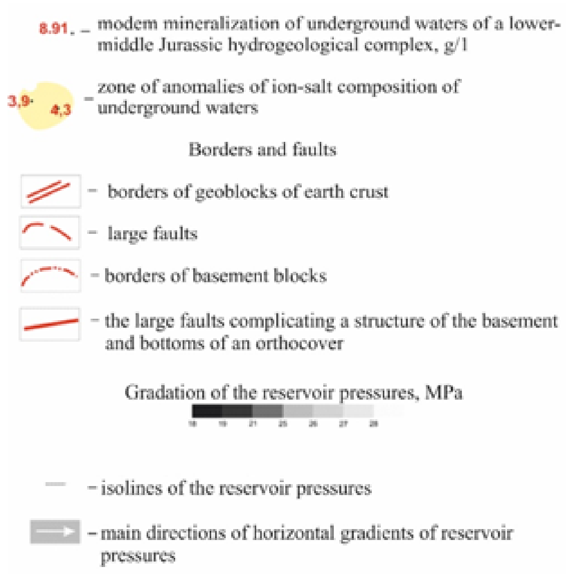


Fig. 1 Schematic map of the mentioned Lower Jurassic sediments of the Talinskoye field with anomalies of the ion-salt composition of groundwater.

The chemical composition anomaly C is confined to the area where pressures are low hydrostatic and vary from 21 to 25.5 MPa. Water mineralization is very low and amounts to 2.4-3.7 g/l. This is the area of the border between the East-Ural fore deep and the Trans-Ural geoblock of a major fault.

The current temperature of the basement roof is 100 °C. Decreased mineralization may be associated with the "suction" of elision water from overlying reservoir rocks through vertical migration channels. During periods of tectonic activity, intrusions of low-mineralized deep fluids could also occur here.

To the south-east of the chemical composition anomaly C, the anomaly D is highlighted. The reservoirpressures here are mainly low hydrostatic, the pressure deficit reaches 4.5 MPa. There are localareas with SHRP, where the excess of the conditional hydrostatic pressure reaches 0.92 MPa. The average pressure in the area is 26.5 MPa.

Groundwater mineralization here is 2.3-3.7 g/l. In this area, large faults of north-east orientation are recorded in the basement, between which the border of geoblocks passes. In the same area, elevated basement roof temperatures exceeding 110 °C are observed, which, together with a heterogeneous hydrogeochemical field, unequivocally indicate a complex hydrogeodynamic situation and divergent flows of reservoirfluids.

The current structure of the hydrogeodynamic field of the Lower-Middle Jurassic HC within the Talinskoye oil field is characterized by contrast and, despite the ingress of a large amount of elision water during the filling of the West-Siberian geosyneclise, the prevalence of pre-hydrostatic pressures as a result of the development of the earth crust stretching processes. The dependence of the formation of hydrogeochemical anomalies (areas with low mineralization) on the position of faults, basement roof temperatures, and values of reservoirpressures corresponds to the model of conjugate descending-ascending mass transfer [1, 8]. At this stage of development of the hydrogeological field, new portions of elision water probably do not flow, but the water that was previously squeezed out and mixed with sedimentation water interacts with deep fluids. These complex mixing processes occur primarily due to the presence of ruptures, which, according to seismic surveys, are sometimes recorded from the basement to the Apt-Alb-Cenomanian sediments and above.

Ingress of deep fluids is a periodic, pulsating phenomenon, determined by geodynamic processes in WSMB [9]. The scale of ingress of deep fluids into lower parts of the section is confirmed by the wide development of authigenic mineral formation processes.

CONCLUSION

In the authors' opinion, the contrast of hydrogeochemical and hydrogeodynamic conditions can be explained using an integrated approach, taking into account the history of groundwater formation in the area. The data obtained in recent years leads to the necessity of combining elements which, at first glance, belong to opposing points of view on the features of groundwater formation in deep oil and gas bearing horizons, primarily with anomalously low mineralization. The paper by Vsevolozhsky and Kireyeva [10] combines theories of inversion water formation and considers them in the form of three general groups. These are the elision-dehydration hypothesis of inversion water formation; the hypothesis explaining the inversion water formation by the entry of deep fluids containing CO_2into the sedimentation salt water of lower parts of artesian basins; the theory of the origin of inversion water by distillation and condensation of steam-gas mixtures. The wide distribution of water with low inversion mineralization has been found in many parts of West Siberia. Such areas often correlate with complex structures of hydrogeodynamic and hydrogeothermal fields. Using the example of the considered hydrogeological conditions of the Talinskoye field, one cannot deny the dilution of the originally buried sedimentation water with both elision and deep fluids. At the present stage of development of WSMB, complex aqueous solutions were formed in the Lower-Middle Jurassic HC (under the conditions of a closed hydrogeological system due to the presence of the Neocomian Frolovsk formation), which are the result of the mixing up of natural water of different genesis and age.

Dyunin, Tóth, and other researchers note [6, 9, 11-13] that the methodology for studying the underground water of deep horizons is poorly developed due to the large complexity of the research object: multidirectionality and diversification of processes occurring in the water-rock system at great depths, extreme unevenness of groundwater exploration, significant complexity of equations describing elastically deformable media in which deep fluids are formed. But the work of hydrogeologists in this area is extremely important [3, 14] as a task of not only basic, but also applied science, since the gradual solution of the inversion water formation issues will entail the understanding of many processes associated with the formation and destruction of hydrocarbon deposits, which occur in the aquatic environment.

During hydrogeological studies carried out within the framework of works on maintenance of reservoirpressure, disposal of commercial and waste water, monitoring of the geological environment at hydrocarbon fields, etc., the analyses of samples with low values are considered to be faulty in the overwhelming majority of cases. Faults during the selection of deep groundwater samples, of course, may have place for a variety of reasons [13, 15-18]. But the results of the authors' research show that rejection should be made taking into account many factors, since low mineralization can be the result of dilution of originally buried sedimentation water with elision water, low-mineralized high-temperature deep fluids, the ingress of which occurred during sedimentation. This is confirmed by the combination of structural plans, tectonic maps with hydrogeochemical, hydrogeodynamic, paleohydrogeological and hydrogeochemical maps.

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