Structure of the hydrogeological field of the Krasnoleninsky arch

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Abstract: The study is devoted to the problem of formation of the hydrogeological field of the deep oil and gas bearing horizons of the Krasnoleninsky Arch. Analysis of seismic data shows the presence of a large concentration of discontinuous violations, which can be traced from the basement and have a different penetration depth in the sedimentary cover. It is shown that significant fluctuations in the parameters of the composition of groundwater and hydrostatic pressure at the depth of the Lower-Middle Jurassic hydrogeological complex are associated with the receipt of deep high-temperature fluids from discontinuous disturbances that are formed under the influence of neotectonic processes. The pressure deficit can reach 9 MPa, an average of 1.6 MPa, and fluctuations in mineralization values range from 3 g/l to 12 g/l. Data have been obtained indicating the dependence of the occurrence of hydrocarbonate-sodium type waters with low mineralization from the position of faults (this type of water is found in samples taken from wells located at a distance of no more than 3 km from the recorded rupture violation). Chlorcalcium type, according to V.A. Sulin, with mineralization normal for these depths is determined in samples taken also from the Lower-Middle Jurassic complex, but from wells located at a distance of more than 2.5-3 km from the revealed disruption. Evidence of the deep fluids' effect on the complex rocks are provided (the presence of such authigenic minerals as pyrite, siderite, dickite, carbonates, and kaolinite in rocks of the complex).

1. Introduction
The relevant task of modern oil and gas hydrogeology is the development of a methodology for studying the hydrogeology of the deep oil and gas bearing horizons of the West Siberian megabasin, the development of more effective practical recommendations for carrying out work on maintaining reservoir pressure (reducing the amount of calcite deposits, etc.) and calculating underground water reserves. Since almost all aspects of groundwater formation at the depths of the Mesozoic basin of Western Siberia are directly related to the development of the doctrine of naftidogenesis. The study of the mechanisms of groundwater movement at the depths of oil and gas bearing horizons is one of the urgent problems of modern oil and gas hydrogeology. V.M. Matusevich, A.A. Kartsev, S.B. Vagin, V.I. Dyunin and many others considered these issues for the conditions of Western Siberia. The most important aspects of oil and gas hydrogeology abroad are studied by Toth J. [1, 2] who considered water-pressure systems and their role in the formation of hydrocarbon reserves, the mechanisms of groundwater movement and hydrocarbon accumulation in the case of Alberta in Canada. The complexity of the problem lies in the fact that we can judge the patterns of motion based on indirect information only, by combining data on lithology, petrography, tectonics, geohydrotemperature conditions and hydrogeology. For each field, such an analysis should be carried out individually.
The basic hydrogeological data obtained during the work on the calculation of groundwater reserves for the purpose of maintaining reservoir pressure or works for the utilization of industrial effluents involves determining the macro- and micro-component composition of water samples, measuring the reservoir pressure and temperatures. There are often situations when the data in wells located close enough to each other (even within 5-10 km) is several times different. For example, within the Lower-Middle Jurassic hydrogeological complex in the Talinskoye oilfield, samples were obtained with a salinity of 3 g/l and 12 g/l under the same paleohydrogeological conditions for the formation of the complex. Also, reservoir pressures within a single hydrogeological complex in one exploration area can vary significantly (from over hydrostatic to lower hydrostatic). This kind of data that are "knocked out" of the general picture because of the absence of complex analysis are most often rejected, sometimes despite their frequent occurrence. On the example of the results described below, we wanted to show that this is not always correct.

First of all, it is necessary to understand that studies of hydrogeological conditions at the depths of oil and gas bearing horizons should be carried out taking into account the fact that the formation of deep fluids is often accompanied by phase transitions in the fluid-rock system, which leads to a significant change in the filtration-capacitive properties of fluid-bearing rocks, change in chemical and gas composition of fluids, etc. [3]

2. Research
On the example of the Krasnoleninsky arch, we carried out a comprehensive analysis of information on hydrogeological conditions (hydrogeochemistry, geohydrology, hydrogeodynamics) and geological structure, structure of the basement, the presence of faults, autogenic processing of rocks.

The main provisions, based on which the analysis was performed, are as follows:

1) The Krasnoleninsky arch refers to an elution lithostatic water-pressure system according to the classification of water-pressure systems by A.A. Kartsev, S.B. Vagin [4] with the additions of V.M. Matusevich and O.V. Bakuev [5]. Elision is the process of squeezing buried waters from clay rocks to sandy as the sedimentary basin is filled and the geostatic load increases - is considered one of the main processes that determined the structure of the hydrogeological field of the research area. According to this theory, the elision waters create superhydrostatic pressures and contribute to the formation of the hydrocarbonate-sodium type of waters by V.A. Sulin;

2) Three hydrogeological basins are distinguished in the section: Cenozoic, Mesozoic and Paleozoic and, respectively, seven hydrogeological complexes: Oligocene-Quaternary, Turonian-Oligocene, Aptian-Albian-Cenomanian, Neocomian, Upper Jurassic, Lower-Middle Jurassic, Triassic-Palaeozoic (Matusevich, 1998). A feature of the geological structure of the research area is the completely clay composition of the Neocomian complex with a capacity of more than 750 m, which led to the attribution of the Krasnoleninsky arch area to an elision water-pressure system. The tracking in the study area of three megacyclites should also be noted: the Triassic-Aptian, Aptian-Oligocene and Oligocene-Quaternary;

3) The object of research is the Lower-Middle Jurassic hydrogeological complex within the fields of the Krasnoleninsky Arch, composed of an uneven alternation of sandstones, siltstones with interlayers of argillite-like clays;

4) Analysis of seismic data shows the presence of a large concentration of faults that start from the foundation and have a different penetration depth into the sedimentary cover.

3. Results and discussion
As it was mentioned above, the research area refers to the Krasnoleninsky arch. In particular, the lower-middle Jurassic hydrogeological complex of the Talinskoye oil field was considered in the most detail. The area is characterized by the development of a large number of disruptive violations. In case they had no effect on the hydrogeochemical, hydrogeodynamic and hydrogeothermal conditions, proceeding from the paleohydrogeological conditions in the Lower-Middle Jurassic complex, the
chloralkalcalcium type of waters would be widely distributed, according to V.A. Sulin, with mineralization of 15-20 g/l and higher. The hydrogeodynamic field would be homogeneous and would be characterized by the development of normal and superhydrostatic pressures.

But the picture of the hydrogeological field is quite different. The hydrocarbonate-sodium type of water (according to V.A. Sulin) is widespread, the mineralization varies from 2 g/l to 16 g/l. Ion-salt composition - hydrocarbonate-chloride sodium.

The hydrodynamic field is extremely inhomogeneous, the areas of the pre-hydrostatic pressures alternate with the areas of superhydrostatic ones. The pressure deficit can reach 9 MPa, with an average of 1.6 MPa. Areas with superhydrostatic pressures (SHSP) are fixed locally. For the Talinskoye oil field (as for other Krasnoleninsky arch fields), the development of such conditions when vertical fluid migration prevails over the lateral one, since the pressure drops in the section exceed those on the laterals by 1-2 MPa, is the most possible [6].

We believe that it is possible to explain such contrasting conditions from the position of the geodynamic concept in modern hydrogeology [7], according to which, underground waters form, move, and also transform their composition under the conditions of functioning of geofluidal systems (GFS). V.M. Matusevich and his co-authors interpret the concept of GFS as a complex block structure, where the elements are structural-lithological blocks and their boundary zones [7]. In our opinion, at the present stage of the development of the West Siberian geosyncline, these zones, which are represented by discontinuous disturbances, places of increased or decreased permeability of rocks (barriers), determine the directions of movement of the underground fluids at the depths of the aquifers of the Jurassic and older ages of the Krasnoleninsky arch. Similar conditions are described by P.W. Huntoon [8] for the Wyoming Artesian Basin.

Fig. 1 shows the seismic picture of the lower part of the Mesozoic hydrogeological basin [9] and indicates the hydrogeochemical characteristics of water samples taken from appropriate exploratory wells. Hydrocarbonate-sodium type of waters with low salinity is recorded near the disruption of disturbance (no more than 3 km). Chlorcalcium type, according to V.A. Sulin, with mineralization normal for these depths is determined in samples taken also from the Lower-Middle Jurassic complex, but from wells located at a distance of more than 2.5-3 km from the revealed disruption. The obtained data are summarized in Table 1.

The foundation of the sedimentary cover in this region is complicated by numerous intrusive bodies of the Paleozoic age, represented by gabbro, gabbro-diorites, serpentinites. These bodies are located at the intersection of large faults, which are the boundaries of geoblocks. In these zones, increase in basement temperatures from 110 °C to 145 °C is fixed. Disruptive disturbances are a kind of "roots", which can also be traced in the form of boundary zones between structural-lithological blocks (Figure 1). We believe that the reduced mineralization and the hydrocarbonate-sodium type of water are the result of the penetration of deep high-temperature fluids through these zones, which diluted stratal sedimentary waters. In the study area, there are no brines, so, most likely, deep fluids have a low salinity.
Figure 1. Seismic profile of the lower part of the Mesozoic hydrogeological basin.

This is confirmed by several facts below. For example, the coefficient B/Br presented in Table 1 (a value of up to 2.2, an average of 1.5), which indicates the genesis of deep waters. Values of B/Br - coefficients approaching 1, or exceeding these values, should indicate a sharp increase in the temperature of the feed solution, i.e. on the arrival of deep fluids [10]. A detailed explanation of this phenomenon is given in the articles of V.A. Vsevolozhsky and T.A. Kireeva.

Table 1. Generalized hydrogeological characteristics.

| Index                          | Fracture zone                        | No faults and fracture |
|-------------------------------|--------------------------------------|------------------------|
| Reservoir pressure, MPa       | 22 - 27                              | 25 - 27                |
| Water type according to V.A. Sulin | Hydrocarbonate-sodium               | Hydrocarbonate-sodium, sometimes chloralcium |
| Mineralization, g/l           | 3 - 15, 9                            | 5 - 18                 |
| basement roof temperature, °C | 100-145                              | 93 - 140               |
| B/Br                          | 0.34 – 2.2                           | 0.19 – 0.63            |
| SiO₂, mg/l                    | 4 - 28                               | 7 - 99                 |
| I, mg/l                       | 1.7 – 6.1                            | 2.6 – 15.2             |
| rNa/rCl                       | 0.87 – 2.46                          | 0.96 – 1.96            |
| Formula of ionic-salt         | (Na+K)95 Ca3 Mg2                     | (Na+K)96 Ca3 Mg1       |
Numerous studies of products of hydrothermal activity have also been carried out in the area of work [11], such authigenic minerals as pyrite, siderite, dickite, carbonates, kaolinite, etc. were found. Zubkov M.Yu. [6], on the basis of reconstructions of the mechanism of formation of secondary porosity and collectors in the Jurassic sediments of the Talinsky field of the Krasnoleninsky arch, showed a sequence of hydrothermal mineral formation. The author provides numerous evidences of hydrothermal processing of rocks due to the introduction of deep fluids, conditionally calling them hydrothermal He notes that the separation of various types of hydrothermal minerals occurs repeatedly, which is determined by the thermodynamic conditions and composition of the hydrothermal fluid. The same fluids can be a "force", the power of which can lead to hydraulic fracturing of rocks, and thus the formation of vertical migration channels (block boundaries in the GFS) of groundwater, which facilitate their mixing and transformation of the composition.

The contrast of the hydro-geodynamic field, the alternation of piezominimums and piezomaximums within the Krasnolenysky arch in the Lower-Middle Jurassic complex, can in many ways be related to the manifestation of two oppositely directed flows of pore fluids [6]. Using the example of the basal productive deposits of the Talinskaya area, it has been shown that high-temperature, weakly mineralized hydrothermal fluids that have acidic composition intensively dissolve unstable minerals, forming at their expense a secondary capacity, which must necessarily lead to an improvement in the reservoir properties of the rocks, which they enter.

4. Conclusion
An analysis of the hydrogeological conditions of the lower part of the Krasnoleninsky section shows that at the late stages of the development of the West Siberian megabasin, the main reason for the transformation of the hydrogeochemical and hydrogeodynamic fields is the neotectonic processes. Their action leads to the frequent occurrence of the hydrocarbonate-sodium type of waters by V.A. Sulin with low mineralization, occurrence of areas with lower- and superhydrostatic reservoir pressures. In the area of research, the products of hydrothermal activity of deep fluids are widespread, often changing the reservoir properties of rocks, both by forming channels of vertical migration, and vice versa - hydrodynamic screens due to secondary mineral formation.

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