Petroleum potential of Lower-Jurassic deposits in Nurolsk megadepression

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Abstract. Based on reservoir temperature measurement data from twenty-three reference well cross-sections and paleotemperature modeling, the thermal history of Lower-Jurassic Togur source rock within Nurolsk megadepression and its framing structures have been reconstructed. Plotted maps showed the density distribution of initial accumulated oil resources for Lower J¹⁵-J¹⁶ formations. Based on performed zoning of reservoirs the areas for priority hydrocarbon prospecting were proposed.

1. Introduction

The developed deposits in the Nurolsk-Koltogorsk area, mainly referring to Upper-Jurassic oil-gas complex (OGC) within which the anticline structures, have been completely explored. Therefore, prospecting and exploration of hydrocarbon deposits in complicated traps being confined to Lower-Jurassic oil-gas complex is of top priority objective in geological survey. Based on geo-temperature regime reconstruction of Lower-Jurassic Togur source rock, the intensive petroleum charge systems were plotted, as well as the zoning of studied area according to the density of possible resources for Lower J¹⁵-J¹⁶ formations was performed.

2. Potential petroleum characteristics

Nurolsk megadepression is a negative I order structure. According to the reflection horizon F₂ of the basement top, its contour curve is -3240 m and its amplitude is 400 m, within an area of 11800 km². The main hydrocarbon source for Cretaceous and Upper-Jurassic oil-gas complex embraces disseminated organic matter (DOM) of Bazhenov sapropelite -type suite (J₃vv) [1].

The major oil generating formation was defined as Togur source rock suite (J¹t¹) for Middle-, Lower-Jurassic and Paleozoic oil and gas bearing complexes. Its location in Nurolsk megadepression is restricted to lowered relief zones, bay-like pinching out towards positive framing structures and crystalline basement protrusions (figure 1a). Generation potential is determined by high content of humus- sapropelite organic matter (up to 10%) and catagenetic DOM maturation from Mesocatagenesis₁²-Mesocatagenesis₂. Hydrocarbon deposits of Lower-Jurassic oil - gas complex are associated with structural-lithological and fault traps. This OGC embraces oil-gas bearing complex J¹⁷-¹⁶ (J₇h-p) and J¹₅ (J₁t₂-J₂q₁) layers of Urmansk and Salatsk suites, respectively.
Late Pliensbach – Early-Toarcian $J_{16}$ formation is characterized by more transgressive lateral bedding than that of the basal $J_{17}$ formation. The deposit formation is confined to the channels of palaeorivers (figure 2a). The areas for priority exploration [4] are those zones of river flow discharge from the of eroded protrusion basement paleo-tops formed from felsic intrusive rocks. These deposits are associated with commercial oil deposits in Mayskoye field and gas-condensate deposits in Severno-Festivalnoye field.

Sand $J_{15}$ formation has a more significant lateral bedding (figure 2b). Pinching out towards Pre-Jurassic basement paleo-protrusions, it often interbeds with the overlying layer forming a single deposit ($J_{14-15}$), similar to that of the one in Srednemayskoye field. Nowadays, three oil and two oil-gas-condensate fields have been discovered, including those deposits in Salatsk suite.

3. Research methods
The reconstruction of the thermal history of the Togur suite deposits was performed by paleotemperature computer modeling [5, 6]. Twenty-three reference wells located within Togur deposits (figure 1b) were selected for paleotemperature modeling. The paleo-temperature calculation technique and schematic map of distribution computational values of mantle basement heat flow density are given in [1].
Figure 2. Schematic maps of J16 (a) and J15 (b) distribution (stroke and fill) of Lower-Jurassic oil-gas complex of Nurolsk megadepression (based on [7]). The figure shows Mayskoye field, Severo-Festivalnoye field with the J16 deposits (a); Yuzhno-Mayskoye field, Mayskoye field, Archinskoye field, Urmanskoye field, Srednemayskoye field with J15 deposits (b). The remaining symbols are indicated in figure 1.

The calculated paleotemperatures in Togur suite sediments (humus disseminated organic matter) at set geological time intervals and temperature gradation catagenesis zones of intensive generation and hydrocarbon migration [8] extrapolate the fact that the source rock migrates into the major oil kitchen zone where intensive generation of Togur oils (from 95°C) begins. According to calculated paleotemperatures the schematic maps involving 22 key geological time intervals from origin to full maturation of each suite formation were plotted. Figure 3 shows the schematic maps of hydrocarbon charge location for six geological time intervals - from origin to full maturation today.

To estimate the relative density distribution magnitude of generated Togur oil, the conditional integral index \( R \) was calculated by the formula [9]:

\[
R = \sum_{i=1}^{20} (U_i t_i \cdot 10^{-2}),
\]

where, \( U_i \) – calculated temperature of oil generation, °C; \( t_i \) – duration of oil generation, millions of years; number of time intervals \( i = 1, \ldots, 20 \) defined by the number of suites during their formation stages. Schematic map (figure 1b) plotted on the basis of \( R \) value interpolation.

The applied approach in estimating hydrocarbon resources cumulatively determines the geotemperature dynamics of source deposit in major oil generation zone [10]. Resource density evaluation is performed using conventional units, which, in its turn, is appropriate for subsequent areal zoning.

4. Results and discussion
The conditions for Togur oils major in oil generation zone occurred 91.6 Ma during the Alb-Senoman stage. Sources of oil generation are located both in the central part of Nurolsk megadepression and on the north-eastern depression flank (figure.3a).
Figure 3. Schematic maps of computed geotemperature distribution and source location of intensive generation of Togur oils: (a) 91.6 Ma; (b) 86.5 Ma; (c) 61.7 Ma; (d) 37.6 Ma; (e) 24 Ma; (f) present day section. 1 - isotherm, °C; 2 - source contour. The map depicts fields with Lower-Jurassic OGC deposits. The remaining symbols are indicated in figure 1.
From 86.5 Ma (formation period of Ipatovsk suite) the oil generation source territory increases embracing the entire central Nurolsk megadepression. Maximum heating of these Togur sediments reaches 115°C (figure 3b). During the formation of the Gankinsk suite, i.e. 61.7 Ma ago, oil generation expands practically throughout the entire area of Togur sediments, except a small area in south-east of the studied area (figure 3d). These sedimentary formations are heated up to their maximum temperature- 37.6 Ma ago- and the major oil generation zone embraces the entire Togur suite territory. Maximum paleotemperatures are above 130°C (figure 3d). At the beginning of the Neogene paleotemperatures decrease, whereas, in the south and south-east, small areas “break out” of the major oil generation zone (figure 3e). The sedimentary formation cooling is governed by climatic changes in the Oligocene period and is still taking place nowadays. Maximum Togur suite temperature decreased to 115-120°C. The major oil generation zone in the south-east has also “shrunk” due to the lack of relevant conditions (figure 3f).

Based on the areal distribution of J16 and J15 layers, layer zoning pattern was plotted in accordance to the resource density of initial accumulated Togur oils (figure 4). J16 layer boundaries do not extend outside the contour Togur oil distribution zone (figure 4a). Severo-Festivalnoye field- gas-condensate deposit, and Mayskoe field - oil deposit in one and the same formation are located in the areas with high integral index R.

J15 areole distribution overlaps the boundaries of Togur deposits (figure 4b). The major oil deposits are on the northern Lavrovsk mezo-flank. Mayskoe field is also located there. Srednemayskoe field is at the interface of two areas of the highest and lowest R values, while there are no Togur oil source rocks in this zone. Formation of oil deposit in J15 layer within Uzhno-Mayskaya is possible due to the lateral migration of hydrocarbons from the suite source rock distribution zone.

Figure 4. Zoning pattern of J16 (a) and J15 (b) of Lower-Jurassic oil-gas complex in Nurolsk megadepression according to resource density of initial accumulated Togur oils. 1-6 – areas (rating number; range of resource density values, c.u.): 1. – 110….130, 2. – 90 ……110, 3. – 70…110, 4. – 50…110, 5. – 40…90, 6. – less than 40; 7- area boundaries. The remaining symbols are indicated in figure 1.
5. Conclusion

The potentially productive Lower-Jurassic deposit areas have been identified in central Nurolsk megadepression, on the northern Tamradsk depression flank and in the eastern North Nurolsk megadepression barrier. Coincidence of zones of maximum computational values of initial accumulated Togur oil resource density for J_{16} and J_{15} layers considerably increase the significance of these potential productive areas for exploration, as well as geological and economical interest. Such areas could be prospective targets in hydrocarbon prospecting in Lower-Jurassic oil-gas complex.

References

[1] Osipova E N, Prakoyo F S and Kudryashova L K 2014 Petroleum potential of the Neocomian deposit of Nurolsky megadepression. XVIII International Scientific Symposium in Honour of Academician M. A. Usow: Problems of Geology and Subsurface Development 7–11 April, Tomsk, Russia: IOP Conference Series: Earth and Environmental Science. URL: http://iopscience.iop.org/1755-1315/21/1
[2] Isaev V I and Fomin A N 2006 Areas of generation of Bazhenov and Togur types of oil in southern part of Nurolskoy megadepression Russian Geology and Geophysics 47 (6) 734–745
[3] Fomin A N 2011 Katagenez organicheskogo veschestva i neftegazonost mezozoyskih i paleozoyskih otlozheniy Zapadno-Sibirskogo megabasseyna (Novosibirsk: INGG SO RAN) 331p
[4] Gurari F G and Ekhanin A E 1987 Zakonomernosti razmescheniya zalezhay v nizhneyurskich otlozhnyakh Zapadno-Sibirskoy plity Geologiya i geofizika 10 19-26.
[5] Isaev V I, Gulenok R U, Veselov O V, Byichkov A V and Soloveychik Yu G 2002 Komp'yuternaya tekhnologiya kompleksnoy otsenki neftegazovogo potentsiala osadochnykh basseynov Geologiya nefti i gaza 6 48-54
[6] Golenok R Yu, Isaev V I, Kosygin V Yu, Lobova G A and Starostenko V I 2011 Estimation of the Oil-and-Gas Potential of Sedimentary Depression in the Far East and West Siberia Based on Gravimetry and Geothermy Data Russian Journal of Pacific Geology 5 (4) 273–287
[7] Lifanov V A, Nassenova N V and Lapina L V 2011 The geological structure of the basal layers of Ju10–11 in the western part of Tomsk region Geology, geophysics and development of oil and gas fields 12 4–11
[8] Burstein L M, Zhidkova L V, Kontorovich A E and Melenevskii V N 1997 Model katageneza organicheskogo veshestva (na primere bazhenovskoy svity) Geologiya i Geofizika 6 1070–1078
[9] Lobova G A, Popov S A and Fomin A N 2013 Lokalizatsiya prognoznaykh resursov nefti yursko-melovykh neftegazovikh kompleksov Ust-Tymskoy megavpadiny Neftianoe khoziaystvo 2 36-40
[10] Tissot B P 2003 Preliminary data on the mechanisms and kinetics of the formation of petroleum in sediments. Computer simulation of a reaction flowsheet Oil & Gas Science and Technology-Rev. IFP 58 (2) 183-202