Petroleum Generation Potential of Bituminous Mudstones in Tomsk Region Bazhen Suite (Western Siberia)

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Abstract. The article reviews the prognosis for Bazhen suite HC generation potential in order to select primary commercially exploitable areas. A map of generation potential density for Bazhen suite passive reserves has been plotted. It is based on published papers on calculation of organic carbon concentration using the data of exploration and prospect well gamma-ray logging. The deliverables are compared with geochemical core examination results. Lithological heterogeneity of deposits underlying the Bazhen suite is systemized in order to estimate the possible decrease of the suite generation potential due to hydrocarbon migration to underlying deposits. Three types of cross-sections are distinguished – predominately sandy, alternating silt-argillous and argillous. An estimate of the proportion of Bazhen suite generation potential required for the discovered hydrocarbon deposit formation within oil-gathering fields of the first (sandy) type thoroughly explored by deep-hole drilling was carried out. Both quantitative (types 1, 3) and qualitative (type 2) estimations of decrease of the initial generation potential density are carried out for the above-mentioned types. Taking into account the specific character of shale oil development, a further work is required in order to design for each type its individual set of shale strata operating conditions.

1. Introduction

Combustible shale development as a promising source of HC resources has been attracting a lot of attention lately. Promising prospects of shale oil within the territory of Western Siberia are mostly based on bituminous shales of Bazhen suite the industrial oil-bearing capacity of which has been proved in a number of areas. Numerous scientific articles and production reports are devoted to studying the prospects of the suite petroleum bearing capacity. Field development programs using modern oil production technologies have been implemented.

Taking into account the necessity of drilling a considerable number of production wells for combustible shale development, it is advisable to perform such operations in deposits where the productive horizons are located stratigraphically lower than shale strata and have high production capacity for recoverable reserves. The South-Eastern part of Western Siberia is an ideal place for such innovations. Virtually all fields discovered in Tomsk Oblast are situated under a layer of Bazhen bituminous clay suite. There are no commercial HC reserves in Bazhen suite deposits found within this region, but tests have shown oil inflow in a number of areas and oil occurrence in well cores have been identified.

As for the question of shale oil exploitation efficiency, two main approaches can be singled out. They are related to Bazhen suite geographical resource distribution and its geological exploitation...
background based on prognosis for various genesis reservoir rocks composing the suite [1, 3, 6]. The present paper deals with the former approach.

2. Estimation Method of Bazhen Suite Generation Potential Density

Multiple articles have shown a direct correlation between the Bazhen suite natural radioactivity and the organic carbon it contains [5], which allows using gamma-ray logging and standard electric logging data from wells drilled within the area to estimate petroleum resources distribution in the shale structure.

From this point of view, the work of Kontorovich V.A. is the most interesting for the Tomsk area [4]. His article is based on the established correlation between organic carbon content in the rock and well log data, and plotted maps of Bazhen suite content $C_{\text{org}}$ and thickness according to the data collected from hundreds of exploration and prospect wells drilled within this area. The shown maps enable to estimate cumulative volume of organic carbon and the character of its distribution over the area, while research of suite generation potential [2] allows estimating hydrocarbon raw stock volume.

The conducted research showed that if the rock contains 10-15% organic carbon, the coefficient of liquid hydrocarbon generation may vary from 0.088 to 0.18. The generation coefficient characterizes the amount of hydrocarbons in $1m^3$ of source rock containing one ton of organic matter at present catagenesis stage. In this connection, the preliminary estimation of the generation density of hydrocarbon passive reserves in Bazhen suite can be defined as a product of the following factors – suite thickness, organic carbon percentage in rock, rock specific gravity and generation coefficient within the examined area (figure 1).

The maps presented in this article can be used to identify suite thickness and $C_{\text{org}}$ content [4]. The values of other factors such as specific gravity (2.3 g/cm$^3$) and average generation coefficient within the examined area (0.1) were adopted according to the data in the article [2]. Analyzing the resulting map, it should be noticed that there are substantial territorial differences in the distribution of the calculated generation potential density.

It is more significant within negative structures of the first order – Ust-Tymsky, Nyurolsky and Koltogorsky oil and gas areas (OGA) where these values vary from 300-400 to 1000 thousand tons/km$^2$. The considered parameter is lower for two large positive structures Nijnevartovsky, Kaimysovsky, Srednevasyugansky and Parabelsky oil and gas areas. It is estimated at 100-500 thousand tons/km$^2$. Pudinsky and Aleksandrovsky oil and gas areas can be considered as exceptions, because the local heightened anomalies of hydrocarbon generation density can be noted there, due to rift zones (Pudinsky OGA) and granite massifs (Aleksandrovsky OGA). As a whole, a general decrease of hydrocarbon generation density is noted in the eastern direction which is conditioned by facial substitution of Bazhen bituminous mudstones for Maryanovsky suite mudstones.

The plotted map is in excellent correlation with laboratory research data on calculation of Bazhen suite hydrocarbon generation density that were accomplished in the Laboratory of Geochemistry and Crude Oils at OAO TomskNIPIneft by I.V. Goncharov. As from figure 1, the distribution of hydrocarbon generation density within a specific license block is similar to those maps plotted by different methods, while geochemical research carried out in step-out wells Zapadno-Ambarskaya 6 and Yujno-Nazinskaya 232 shows data that are close or correspond to the prospects of the parametric map.

Estimating the prospects of the Bazhen suite oil and gas content, it should be noted that part of its generation potential was depleted during the formation of hydrocarbon deposits situated in sandstones of Vasyuganskaya and Naunakskaya suites underlying the shale formation.
Figure 1. Map of HC generation potential density for Bazhen suite of Tomsk region area.
Figure 2. Bazhen suite zoning according to the type of lithological heterogeneity of underlying deposits.
Considering the scale of hydrocarbon migration, it is necessary to pay attention to the relation between the discovered deposits in Vasyuganskaya and Naunakskaya suites and lithological heterogeneity of rock directly underlying the Bazhen suite. Three types of cross-sections can be distinguished according to this characteristic. In the first type, Bazhen suite lies alone or jointly with 2-8 meters thick underlying Georgievskaya suite mudstones on top of J\textsubscript{1} sandstone reservoirs of Vasyuganskaya suite. Locally developed layers J\textsubscript{1}\textsuperscript{1}, J\textsubscript{1}\textsuperscript{2} and layer J\textsubscript{1}\textsuperscript{3-4} with a large areal extent (fig. 2) can be distinguished downright within the horizon. The second type is characterized by alteration of mudstones, low permeable sandstones and siltstones. The third type can be found in areas where the thickness of Georgievsky mudstones exceeds 9 meters, which, according to the study [2], eliminates the possibility of HC migration to underlying reservoirs. The presence of a considerably thick cluster of Kulomzinskaya suite mudstones overlying bituminous shales, significantly limits HC migration to sandstone layers overlying the deposits.

It is possible to give a preliminary estimate of generation potential decrease in the first type of the cross-section by calculating the generation potential density required for oil deposits formation within oil-gathering fields explored by seismic methods and deep-hole drilling.

There are two blocks in the considered area. The first block (figures 1 and 2) is situated within a positive structure of the first order corresponding to Kaimyovsky oil and gas area (OGA), where the Bazhen suite deposits are at MK\textsubscript{1}\textsuperscript{1}-MK\textsubscript{1}\textsuperscript{2} catagenesis stage [7]. All anticline highs within the block under dense seismic observations were explored by deep-hole drilling. Commercial production of oil deposits in the strikes is carried out in layers J\textsubscript{1}\textsuperscript{1} and J\textsubscript{1}\textsuperscript{2} which supports the validity of proved hydrocarbon reserves estimation. Considering proved HC reserves, as a result of secondary migration from a specific oil-gathering area, the generation density of Bazhen suite can be determined for further deposit formation. Dividing the discovered prospective oil by the surface of oil-gathering block gives the required generation potential that can be estimated at 120 thousand tons/km\textsuperscript{2}.

The second block singled out within the negative structure of Nyurolsky OGA of Bazhen suite has similar structure and is at MK\textsubscript{2}\textsuperscript{1}-MK\textsubscript{2} catagenesis stage. The density of generation potential of Bazhen suite required for oil deposit formation within this block is estimated at 140 thousand tons/km\textsuperscript{2}. According to the accomplished research the loss of bituminous shale P\textsubscript{C} generation potential within the cross-section of the first type can be up to 120 -140 thousand tons/km\textsuperscript{2}.

The cross-section of the second type is characterized by oil saturation identified from the cores retrieved from low-permeable siltstones. As a rule, there is no reservoir fluid inflow during well testing. This can be explained by hydrocarbons escaping into the low-porous siltstone and sandstone matrix during the first migration of hydrocarbons, with no lateral movement. It is difficult to estimate the loss of Bazhen suite generation potential within the cross-section of the second type. Nevertheless, the absence of oil deposits in underlying sand layers J\textsubscript{1}\textsuperscript{3-4} can be indicative of stratigraphic scale limitation of hydrocarbon primary migration. As for the third type of cross-section, what has been stated above shows no loss in Bazhen suite generational potential.

3. Conclusion
The presented method of estimation of Bazhen suite generation potential density is based on the estimation of organic carbon content according to well log data (gamma-ray and standard electric logging) [4] and on defining zones for liquid hydrocarbon generation coefficient within the examined area [2].

Taking into account exploration and prospect well data, the resulting map shows considerable detalization improvement for HC generation potential density of Bazhen suite in Tomsk Oblast, and allows zoning the area according to the volumes of raw HC in bituminous formation. The comparative data analysis to specific geochemical core analysis results in previously and newly drilled wells showed good correlation, so it is possible to consider the presented map as a basis for commercial development of Bazhen suite reserves.

In order to differentiate the loss of bituminous formation generation potential resulting from hydrocarbon migration to underlying deposits, three types of deposit zones were identified: 1 –
sandstones, 2 – alternating mudstones, sandstones and siltstones, 3 – shales. These types of lithological heterogeneity of deposits underlying the Bazhen suite allow to estimate its residual generation potential at both qualitative (type 2) and quantitative (types 1, 3) levels. Taking into account the specific character of shale oil development, each type requires its own set of operating conditions.

References
[1] Gurari F G and Gurari I F 1974 Oil Deposit Formation in Bazhen Suite Shales in Western Siberia. *Oil and Gas Geol.* **5** 36 – 40.
[2] Gurari F G, Vaits E Y and Malenevsky V N 1988 Conditions of Oil Deposit Formation and Exploration Methods in Bazhen Suite Shales *Mineral Res.* 199
[3] Zubkov M Y, Pormeister Y A and Bondarenko P M 2002 Fractured Reservoir Prognosis Based on Tectonical and Physical Simulation Results for Bazhen and Abalakskaya Suites Deposits. *Oil and Gas Potential Enhancement in Khanty–Mansi Autonomous Okrug* **1** 244 – 253
[4] Kontorovich V A 2001 Generation potential of Volsky Deposits in South-East of Western Siberia. *Oil and Gas Geology* **1** 26-32
[5] Parfenova T M, Melenevsky V N and Moskvin V I 1999 Gamma-Ray Logging for Organic Matter Test in High-Carbon Sedimentary Formations (Illustrated by Bazhen Suite Example) *Oil and Gas Ind. Geology, Geophysiscs and Oilfield Dev.* **11** 29-34
[6] Khalimov E M and Melik-Pashaev V S 1980 On Exploring Production-Scale Petroleum Agglomerations in Bazhen Suite *Oil and Gas Geology* **6** 1 – 10
[7] Fomin A V 2011 Organic Matter Catagenesis and Oil-and-Gas Content in Mesozoic and Paleozoic Sediments of the Western-Siberian Megabasin *Novosibirsk: Inst. of Petroleum-Gas Géol. and Géophys. of the Siberian Branch of the RAS* 184 – 193.