Total Organic Carbon and Gamma Radioactivity Distribution of the Rudov Beds Formation within the Area Adjusted to Yablunivske O&G Field (Dnieper-Donets Basin)

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SUMMARY

Rudov Beds is an organic rich formation within the Upper Visean (Lower Carboniferous) sedimentary complex located in the Dnieper-Donetsk basin (DDB). Its stratigraphic relation is still debatable. Rudov Beds are related to the tops of XIII Microfaunistic horizon, or related to basal part of XIIa Microfaunistic horizon. Rudov Beds are associated with play known as so-called “productive horizon V-23”. In the central part of the DDB Rudov Beds are overlying the Lower Visean carbonate formation, which was formed under the conditions of the carbonate platform. The uniqueness of regionally distributed Rudov Beds is associated with their unusual siliceous-carbonate and siliceous-shale composition, the presence of biogenic silicites; high organic matter content of mixed composition and high gamma activity. Vertically and laterally distribution of total organic carbon content (TOC) were determined according to the results of well logging data interpretation within the area Yablunivske oil and gas field. The features of the natural radioactivity of the Rudov Beds were investigated; its variability and its relation to the TOC content were analyzed. A regular trend was been identified of increasing the TOC content at 2x times towards the western part of the Yablunivske field area, which can indicate both the formation of sediments in isolated shallow sea conditions and the erosion of their upper part as a result of a break in sedimentation process. The statistical analysis shows that the anomalous values of gamma ray (GR) in the lower part of the Rudov Beds have a specific genesis, which is not correlates with the organic matter content. Keywords: Rudov Beds; TOC, gamma ray, Yablunivske oil and gas field, lateral variability.
Introduction

The Rudov Beds are one of the most unique elements of the Carboniferous stratigraphic section of the Dnieper-Donets basin. A number of publications have been devoted to the study of various aspects of its lithological composition, age, origin, and their role in the formation of hydrocarbon accumulations, not only by Ukrainian scientists but also famous scientists of other countries (Babko et al., 2008; Gavrish et al., 1992; Makogon et al., 2014; Ogar, 2012; Makogon et al., 2014; Misch et al., 2015; Misch et al., 2015; Popova et al., 2018; Pryvalov et al., 2011; Sachsenhofer et al., 2010). As a regional benchmark, Rudov Beds are typically used for stratigraphic correlation to determine the top of the Lower Carboniferous unit, which they overlie within the central part of the DDB. The special feature of Rudov Beds formation is the variable siliceous-carbonate, clastic-shale and shale-carbonate composition, as well as high content of biogenic silicites, shale minerals and abnormally high content of total organic content (TOC). The defining feature of this formation is high natural gamma-radioactivity, with a sharp increase in the base of the formation, which is directly above the surface of the probable regional stratigraphic unconformity, which corresponds to the top of the Lower Visean carbonate formation. Based on these layers, arrangement in the sections, they are often regarded as basal one for the Late Visean sedimentation stage, which corresponds to the XIIa Microfaunistic horizon.

Among the large number of debatable questions regarding the Rudov Beds, the genetic link between the organic component and the gamma-radioactivity of sediments, the varying concentration of TOC both laterally and vertically, are still poorly understood. Further information on these issues can be obtained from the quantitative well-logging data interpretation within local area of oil and gas fields. In order to do that, the area within the Yablunivske oil and gas field was used for current research.

Research Methods

Unlike classical geological approaches of well section studies using the core samples data, modern well-logging methods allow to study with great detail the whole spectrum of lithological, reservoir and physical / geophysical characteristics, to create spatial complex geological models. According to the results of the well-logging data interpretation of wells drilled within the Yablunivske field, we determined the lithological composition of the well section, its shale content, relative hydrogen content (neutron porosity), the total organic carbon content (TOC), as well as the adjustment of the GR (gamma ray) and NGR (neutron gamma ray) logs for downhole conditions. This allowed us to estimate the real values of the natural gamma radioactivity of the well section, to investigate its change in the well sections of different wells, to analyze the spatial variability of the TOC within the Yablunivske field area (more than 10 km area), and to identify certain regularities of the studied rock parameters distributions in the Rudov Beds. TOC estimation was done using the well-known ∆logR technique (Passey et al., 1990; Spears et al., 2011). Adjustment and verification of the interpretation model was performed applied to Rudov Beds section in the well #2-Rudivska using the results of core samples. It should be noted that in terms of lithological and geophysical characteristics, the well sections of Rudov Beds formations are identical within the areas of Rudivske field and area of Yablunivske field.

Discussion

Graph with well 201-Yablunivska (Fig.1-A) illustrates logging features of the Rudov Beds section and its uniqueness comparing with overlying and underlying formations. On the section of the well 3-Yablunivska (Fig. 1-B) vertical lines mark specific values of logs and the bed thickness: “TOC Rudov” - the average content of TOC; “h Rudov” the thickness of Rudov Beds upper part (above the anomalous values of GR); “h low” the thickness of the lower part of the thickness (within the anomalous values of gamma radioactivity); and the average GR values at the top part – “GR high” and anomalous GR values at the bottom – “GR low”. In order to obtain a representative overview of the lateral distribution of individual parameters and to identify the relationships between them, logs from 10 wells were used within the Yablunivske field area. In the table #1 it is shown the statistics of all mentioned parameters. It should be noted that the lateral distribution of the average TOC values at wells even at this relatively small area (10 km) is significant - from 1.8% to 4.1%. The same applies to the total thickness, which varies from 22 to 34 m. Also note that the separated borders of the Rudov Beds along the logging curves (as accepted by other researchers) coincide with the area of abnormal TOC content (see Fig. 1b).
The anomalous values of gamma radioactivity in the lower part of Rudov layers also change significantly; the standard deviation here is 6.92 µR/h. The nature of the radioactivity here is associated with the high uranium content, much less thorium. As determined by other researchers (Babko et al., 2008), uranium content in this part of the layers according to laboratory studies of the core of some sections of the Dnieper-Donetsk Basin varies from $21 \cdot 10^{-4}$ to $39 \cdot 10^{-4}$ %; the thorium content does not exceed the clark values. In the upper, major part of the Rudov layers, the nature of the gamma-radioactivity is another, – uranium-thorium (Babko et al., 2008). The thickness of the section interval, which is characterized by anomalous radioactivity values, varies significantly from 4 m (well 3-Yablunivska) to 8 m (well 20, 200-Yablunivska). Also noticeable is the reduction of the diameter (caliper) of the wells in the intervals that coincide with the lower part of the Rudov layers, compared to the intervals corresponding to their upper parts. This is uniquely associated with the increase of the strength of the rocks at the bottom of the Rudov Beds.

A cluster analysis was applied to evaluate the "genetic" relationships between individual characteristics of the Rudov Beds. For the correct statistical analysis procedure, all parameters values (Table 1) were normalized. The results of the analysis are presented in the form of a dendrogram as grouping of the parameters (Fig. 2). There is only one compact group that combines organic carbon (TOC) content, or organic matter and beds thickness. That is, as the thickness of the layers increases, the specific TOC content also increases here. Other characteristics of the Rudov Beds within the study area are almost invariant; their connections are very weak and fuzzy.
Table 1. Statistics of Rudov Beds’ average parameters estimated from well logs of Yablunivske field

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Std.Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOC, %</td>
<td>2.97</td>
<td>1.8</td>
<td>4.1</td>
<td>0.90</td>
</tr>
<tr>
<td>h Rudow, m</td>
<td>28.4</td>
<td>22</td>
<td>34</td>
<td>3.95</td>
</tr>
<tr>
<td>h low, m</td>
<td>5.9</td>
<td>4</td>
<td>8</td>
<td>1.35</td>
</tr>
<tr>
<td>GR high, µR/h</td>
<td>18.3</td>
<td>14.5</td>
<td>23</td>
<td>3.08</td>
</tr>
<tr>
<td>GR low, µR/h</td>
<td>33.1</td>
<td>27</td>
<td>50</td>
<td>6.92</td>
</tr>
</tbody>
</table>

**Figure 2. Dendrogram of grouped parameters of the Rudov Beds based on Euclidean distance**

In Fig. 3 it’s showing the results of spatial (lateral) modeling of the TOC content and thickness distribution of the Rudov Beds. The location of the wells, that were used for the well-logging data interpretation to evaluate the TOC content is indicated. There is a clear trend of increasing the content of organic matter in the western direction. A similar tendency is found with respect to the total thickness of the Rudov Beds.

**Figure 3. Lateral distribution of the total thickness (h) and TOC content of the Rudov Beds at the area of the Yablunivske oil-gas-condensate field**

**Conclusions**

The variability of the TOC content, the thicknesses of the Rudov Beds, and the gamma radioactivity within a relatively small area of research are dependent on the specific paleo-facies depositional conditions. From published data it is known that silicites of Rudov Beds are composed of remnants of siliceous organisms, mainly sponges. This indicates their formation in a marine, but very specific environment. It was characterized by a high content of silica dissolved in seawater. In addition, the increased content of organic matter, radioactive and some other elements (Gavrish et al., 1992) indicates the characteristic of the basin environment of anoxia. Most researchers believe that such conditions have arisen in deep-water stagnant pools of the “euskin type” as a result of global transgressions. The source of silica at the same time acted as deep enthalpy solutions or magmatic processes. It should be noted that the specifics of the Rudov sea basin could be due to completely different factors (Ogar, 2012). Sedimentation could occur in a desalinated relatively shallow sea gulf. The desalination was the result
of significant river runoff, characterized by humid climate and lowland wetlands and rainforests surrounding the land. The intense lateritic weathering of the Precambrian rocks, which took place within the former Eastern European Platform, led to the removal of enormous amounts of silica dissolved in river waters, more mobile than thorium, uranium and organic matter. Stagnant conditions in the bottom layers of the bay were formed due to periodic (rainy seasons) desalination of the upper horizons.

The conditions described below correspond to the lower part of the Rudov Beds formation within the Yablunivske field area with significant development of biogenic silicites. This is emphasized by the significant decrease of the well diameter and the maximum values of gamma radioactivity due to the high content of uranium. The variability of the thickness in this part of the section is explained by the filling of the irregularities of the surface of the carbonate platform in the process of sedimentation. At the same time, the upper part of the Rudov Beds is characterized by an increase of the diameter of the wells, and some decrease of gamma radioactivity, which, unlike the lower part, has an uranium-thorium nature (Babko et al., 2008). The latter may be conditioned by the admission into the basin of sedimentation of terrigenous components enriched with thorium, progressive grinding, and, finally, by the final regression with subsequent disintegration and partial erosion of the Rudov Beds. The presence of break and erosion of their upper layers is confirmed by a significant change in thickness even on the limited size of the Yablunivske field area (increase of thickness and increase of TOC in the western direction) and contradicts the known regional patterns. The break in sedimentation is also evidenced by the significant development of disintegrated rocks and the proliferation of complexly constructed secondary reservoirs of the cavernous-fractured type, discovered at a number of deposits in the Srebnian sub-depression in the upper part of the Rudov Beds (Havrysh et al., 1992; Ogar, 2012).

Somewhat unexpected for the Yablunivske field area was the lack of correlation between the values of gamma radioactivity and the TOC content in the Rudov Beds. It is likely that the concentrations of uranium and thorium in them were controlled by the composition, content and distribution of shale minerals. This assumption needs to be confirmed by additional studies of core samples.

References


