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Comparative Analysis of Sedimentation Conditions for Lower Cretaceous Sediments of Zimne-Stavkinsko-Pravoberezhny and Velichayevsko-Kolodezny Reservoirs

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***Abstract*—Comparative analysis of sedimentation conditions for the Hauterivian (IX ledge) and the Aptian (VIII ledge) sediments was realized according to the data of grain-size distribution using cluster analysis. (These sediments belong to the most significant Zimne-Stavkinsko-Pravoberezhny and Velichayevsko-Kolodezny oil fields of Velichayevsko-Maksimokymsky oil-and-gas accumulation zone.) The aim of the research is to prove possibility of hydrocarbon reserves growth due to involving in production operation of these missing oil-and-gas bearing intervals and parts of production ledges (the Aptian and the Hauterivian age). In order to do that, according to the built cumulate curves, the median diameter and Trask's degree of sorting were also determined; Rukhin's genetic diagrams were built; paleohydrodynamic levels (Muromtsev's method) were defined; the cluster method was used to group investigated objects formed in different sedimentation conditions; maps of indicators of sedimentation conditions were also made and analyzed. Realized research allows one to indicate the most perspective areas for the supplementary exploration; and also it has been discovered that the algorithm of cluster analysis helps to optimize volume of graphical constructions and increase effectiveness of areas prediction for oil-and-gas collectors distribution.**

Key words*—*sedimentation conditions; grain-size distribution; cluster method; reservoir properties; level of hydrodynamic activity

Nowadays, most of operated hydrocarbon fields within the eastern Stavropolye are at the final stage of development. At the same time, many scientists and experts think that there are missing intervals in cross-section. These intervals have not been developed due to various reasons. That is why, the crucial task is to study these intervals with the aim to prove possibility of hydrocarbon reserves growth due to the involving in production operation of these missing oil-and-gas bearing intervals and parts of production ledges.

From this perspective, the peculiar interest is the Hauterivian (IX ledge) and the Aptian (VIII ledge) cretaceous sediments. On the grounds that prediction of the spread zone of these reservoirs and its properties is rested upon the reconstruction of facies sedimentation conditions, the topic of the research is very relevant.

Previously the link between sedimentation condition and reservoir properties has been determined; the activity of sedimentation condition in the process of the Hauterivian (IX ledge) and the Aptian (VIII ledge) cretaceous sediments forming has been studied; and the comparative characteristics of paleohydrodynamic sedimentation condition for sedimentary rocks forming of Zimne-Stavkinsko-Pravoberezhny and Velichayevsko-Kolodezny oil fields has been given by different methods [1-5].

In the process of described research, more than 100 grain-size analyses of investigated rocks were examined and analyzed. According to these data, cumulative curves were built; the median diameter and Trask's degree of sorting were also determined. According to these data, genetic diagrams were built for two main productive reservoirs of Velichayevsko-Kolodezny and Zimne-Stavkinsko-Pravoberezhny fields for IX and VIII ledges. Thus, the comparative analysis was made for four objects: IX ledge of Zimne-Stavkinsko-Pravoberezhny area, IX ledge of Velichayevsko-Kolodezny area, VIII ledge of Zimne-Stavkinsko-Pravoberezhny area, VIII ledge of Velichayevsko-Kolodezny area.

Let us consider peculiarities of IX ledge sedimentation (Fig. 1, 2).

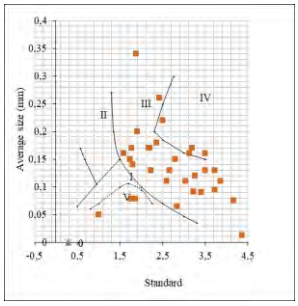

Fig. 1. Rukhin's genetic diagram for IX ledge of Zimne-Stavkinsko-Pravoberezhny area.

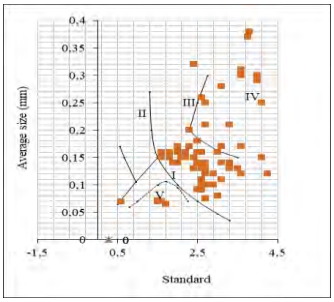

Fig. 2. Rukhin's genetic diagram for IX ledge of Velichayevsko-Kolodezny area.

Analysis of Rukhin's genetic diagram [6] showed that sediments were being formed mainly in the conditions of unidirectional sea current.

To determine a level of current activity, we used Muromtsev's method; it defines five paleohydrodynamic levels showing dynamic activity of sedimentation environment [7]. According to this method, levels of paleohydrodynamic activity were determined and distribution histogram for these levels was built (Fig. 3).

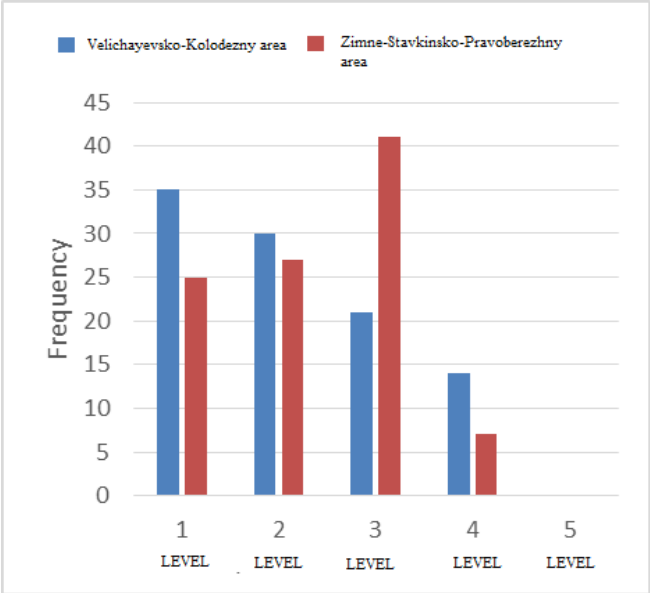

Fig. 3. Distribution histogram of paleohydrodynamic activity levels (IX ledge).

Sedimentation conditions on considered areas were identical in the Hauterivian age, but Velichayevsko-Kolodezny area is characterized by more active sedimentation condition, it promotes forming of oil-and-gas reservoirs with increased reservoir properties; it is verified by analysis of open porosity distribution (Fig. 4).

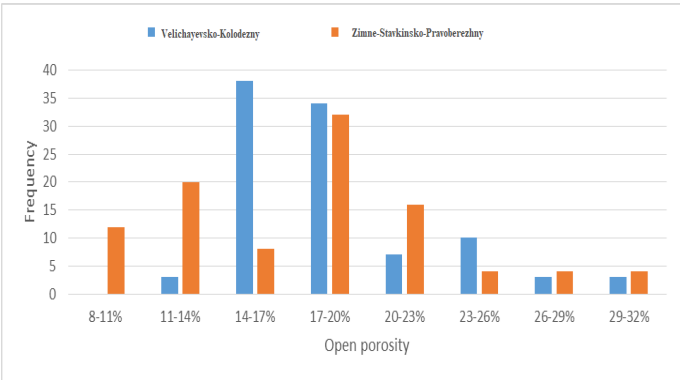

Fig. 4. Histogram of porosity distribution (IX ledge).

These conclusions are correlated with the results of built average values graphics of diagnostic variables of used objects for clustering. These objects were formed in the different sedimentation conditions (Fig. 5, 6). Herewith, the cluster method of analysis was used; it was realized in computer program Statistica.

All examined objects were formed in three clusters. Every cluster is characterized by special variables: a position in the reservoir, a level of activity for sedimentation environment, grain-size distribution, rock carbonate content, value of reservoir properties, a definite size of average values for examined variables and peculiar sizes of distances between clusters [8, 9, 10].

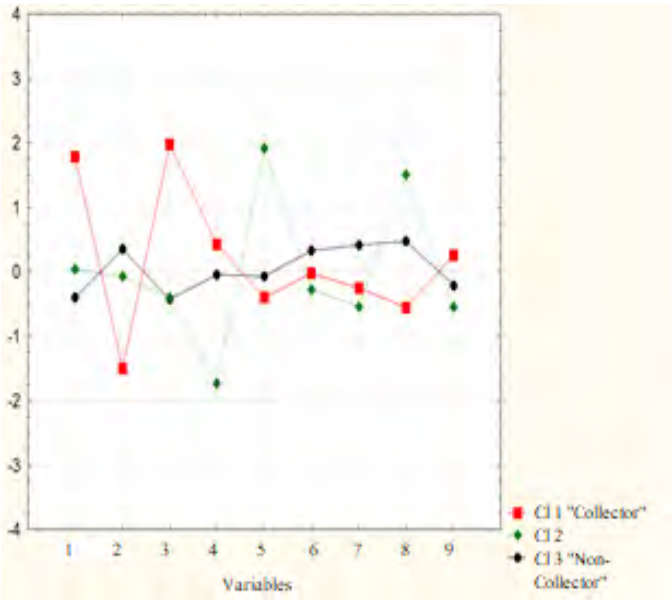

Fig. 5. Average values graphics of diagnostic variables to mark clusters for Velichayevsko-Kolodezny field (IX ledge): 1 – open porosity; 2 - volume weight; 3 - permeability; 4 - sand; 5 - aleurite; 6 - clay; 7 - median diameter; 8 - degree of sorting; 9 - core depth.

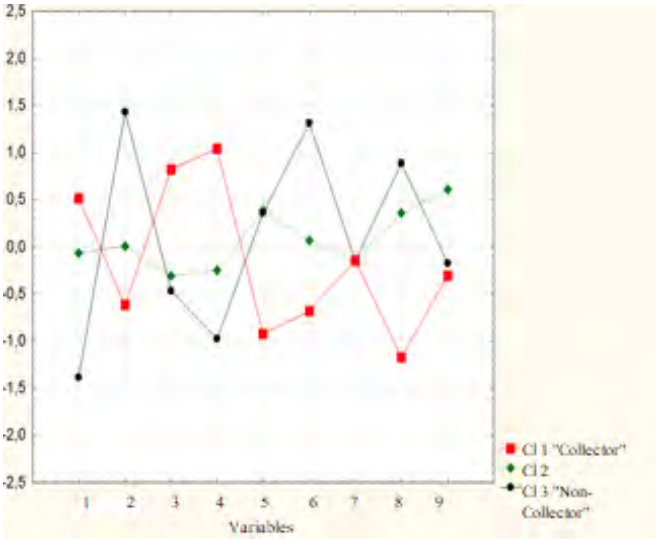

Fig. 6. Average values graphics of diagnostic variables to mark clusters for Zimne-Stavkinsko-Pravoberezhny field (IX ledge): 1 – open porosity; 2 - volume weight; 3 - permeability; 4 - sand; 5 - aleurite; 6 - clay; 7 - median diameter; 8 - degree of sorting; 9 - core depth.

Variation analysis of the size for average values and peculiar sizes of distances between clusters certainly allows one to determine the cluster «collector» - the first cluster and «non-collector» - the third cluster according to the coefficients of open porosity, permeability (defined by regular bedding), rock volume weight, sand and aleurolite content which are characterized by considerable distances between clusters.

Maps of open porosity, a median diameter, a degree of sorting and residual water were also made and analyzed (Fig. 7-14).

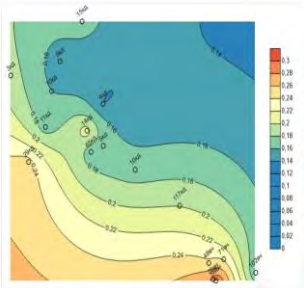

Fig. 7. Map of porosity for Velichayevsko-Kolodezny reservoir.

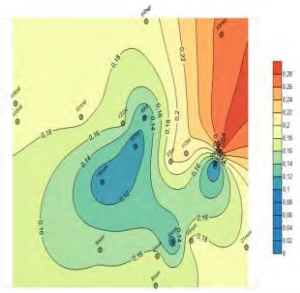

Fig. 8. Map of porosity for Zimne-Stavkinsko-Pravoberezhny reservoir.

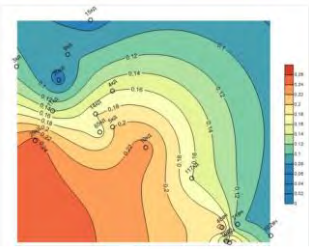

Fig. 9. Map of median diameter for Velichayevsko-Kolodezny reservoir.

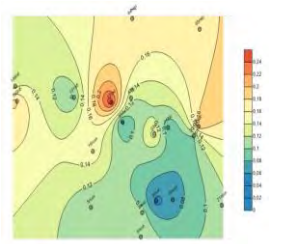

Fig. 10. Map of median diameter for Zimne-Stavkinsko-Pravoberezhny reservoir.

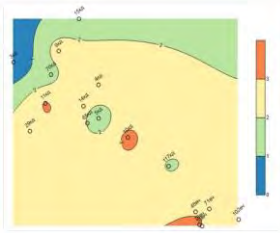

Fig. 11. Map of sorting degree for Velichayevsko-Kolodezny reservoir.

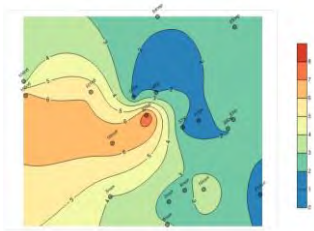

Fig. 12. Map of sorting degree for Zimne-Stavkinsko-Pravoberezhny reservoir.

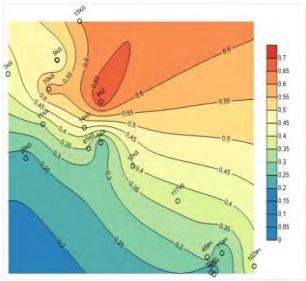

Fig. 13. Map of residual water for Velichayevsko-Kolodezny reservoir.

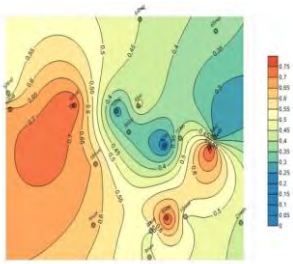

Fig. 14. Map of residual water for Zimne-Stavkinsko-Pravoberezhny reservoir.

Increased values of open porosity for both areas are confined to the zone of heighten values for the median diameter.

Velichayevsko-Kolodezny area is mainly characterized by well and moderately sorted particles; Zimne-Stavkinsko-Pravoberezhny area is characterized by well, moderately and even poorly sorted particles. Collector zones for both areas are confined to the moderately sorted zones and the least values of residual water.

Realized schemes allowed studying sedimentation conditions of IX ledge sediments of the low cretaceous; it gives an opportunity to determine the most perspective areas for the supplementary exploration. Firstly, this is the south part of Velichayevsko-Kolodezny area, where there are the highest values of open porosity coefficient, increased levels of activity; it is a very well sorted zone. For Zimne-Stavkinsko-Pravoberezhny – the northeast area.

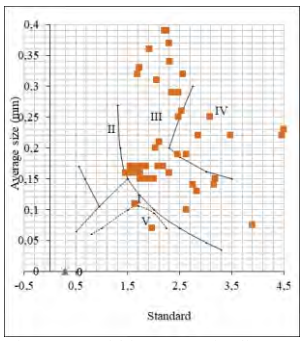

Fig. 15. Rukhin's genetic diagram for VIII ledge of Zimne-Stavkinsko-Pravoberezhny area.

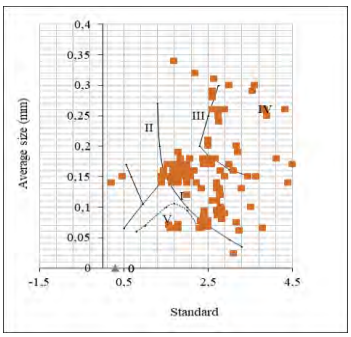

Fig. 16. Rukhin's genetic diagram for VIII ledge of Velichayevsko-Kolodezny area.

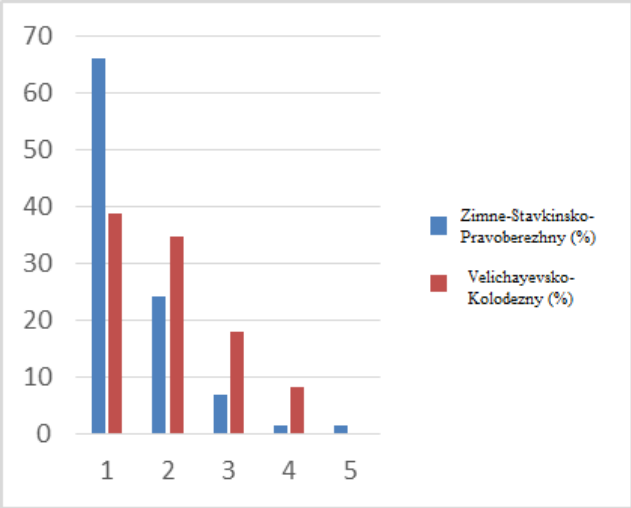

Fig. 17. Distribution histogram of paleohydrodynamic activity levels (VIII ledge).

Analysis results of sedimentation conditions for the Aptian sediments (VIII ledge, Fig. 15-17) allowed determining that sediments in the Aptian time were mainly being formed in the conditions of unidirectional sea currents. Basically, sedimentation conditions on examined areas were identical, except that on Velichayevsko-Kolodezny area there are found the isolated incidents of sediments forming which were deposited during oscillatory turbulent water motions in the coast of basins.

The results of cluster analysis for VIII ledge of Zimne-Stavkinsko-Pravoberezhny field to define collectors - non-collectors are more contrast and definite in comparison with data of Velichayevsko-Kolodezny field (Fig. 18, 19). Consequently, for Zimne-Stavkinsko-Pravoberezhny area we can determine the most perspective parts with the aim of oil-and-gas presence according to the median diameter and the activity level with the high probability.

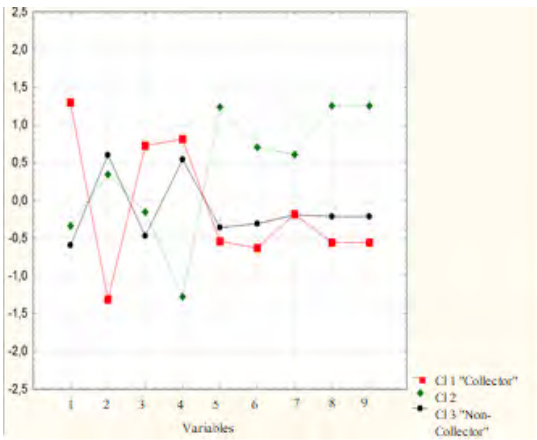

Fig. 18. Average values graphics of diagnostic variables to mark clusters for Velichayevsko-Kolodezny field (VIII ledge) : 1 – open porosity; 2 - volume weight; 3 - permeability; 4 - sand; 5 - aleurite; 6 - clay; 7 - median diameter; 8 - degree of sorting; 9 - core depth.

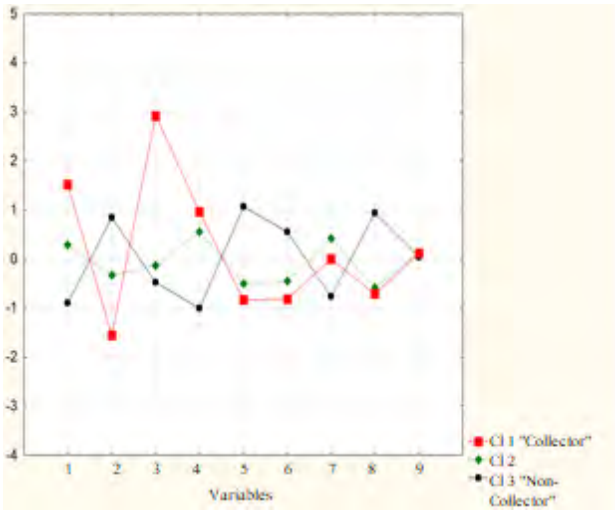

Fig. 19. Average values graphics of diagnostic variables to mark clusters for Zimne-Stavkinsko-Pravoberezhny field (VIII ledge) : 1 – open porosity; 2 - volume weight; 3 - permeability; 4 - sand; 5 - aleurite; 6 - clay; 7 - median diameter; 8 - degree of sorting; 9 - core depth.

The following maps (Fig. 20-23) confirm these conclusions. In such a way, map analysis of the median diameter and levels of environment activity for VIII ledge of Zimne-Stavkinsko-Pravoberezhny field allows one to determine the dependence presence of sand particles size from environment activity. There is no such dependence of the median diameter with the map of activity levels for Velichayevsko-Kolodezny field.

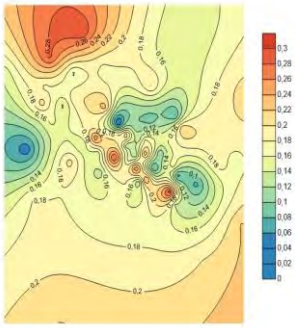

Fig. 20. Map of median diameter for Zimne-Stavkinsko-Pravoberezhny field.

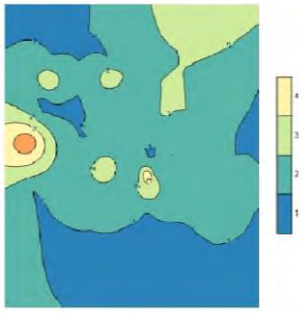

Fig. 21. Map of level activity for Zimne-Stavkinsko-Pravoberezhny field.

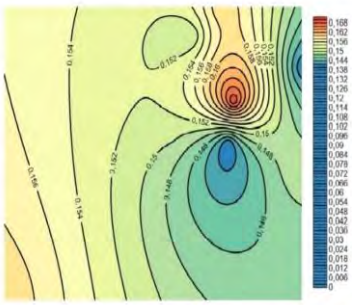

Fig. 22. Map of median diameter for Velichayevsko-Kolodezny field.

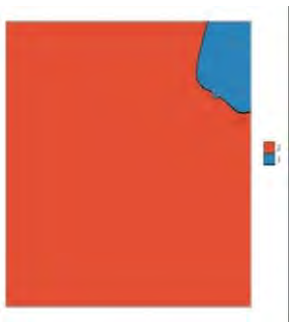

Fig. 23. Map of level activity for Velichayevsko-Kolodezny field.

Maps comparison of hydrodynamic activities levels for VIII ledge of Zimne-Stavkinsko-Pravoberezhny and Velichayevsko-Kolodezny areas showed that the kind of hydrodynamic activity of sedimentation conditions was different on these areas. If all the territory on Velichayevsko-Kolodezny field is practically characterized by high hydrodynamic activity, on Zimne-Stavkinsko-Pravoberezhny field there are very high, high and average hydrodynamic activities (I,II,III levels) on separate parts.

This may be connected with peculiarities of undercurrents and relief of basins bottom for sedimentation; i.e. on Velichayevsko-Kolodezny area we may suppose relatively calm relief character, on Zimne-Stavkinsko-Pravoberezhny area – presence of rather low and high parts which are characterized by a different level of hydrodynamic activity.

As a whole, VIII ledge of Zimne-Stavkinsko-Pravoberezhny area is characterized by more active sedimentation condition in comparison with Velichayevsko-Kolodezny area. Such condition is able to form collectors with high reservoir features.

According to the results of studying sedimentation conditions for VIII ledge sediments, we may conclude that the most perspective sectors to predict oil-and-gas presence are the north-west parts of Zimne-Stavkinsko-Pravoberezhny area, where there are increased levels of activity and the median diameter.

Thus, grain-size analysis allows evaluating sedimentation conditions of terrigenous sediments, but the algorithm of cluster analysis helps to optimize the volume of graphical constructions realized in this case and increase effectiveness of areas prediction for collectors' distribution confined to different zones of oil-and-gas accumulation.

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