Identification of geological facilities of productive deposits at Oil and Gas field by geophysical research data

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SUMMARY

The prediction efficiency of interlayer processes in the development of productive oil and gas horizons largely depends on the detail of its geological model. The entire amount of information used to create a geological model of a deposit is discrete, and its detail is determined by the number of wells that have exposed the productive layers. The problem is the lack of information on the variability of reservoir properties at productive horizons in the space between boreholes. It is important to determine in what setting sediment accumulation occurred within existing wells and what type of facies are correspond to the geological sections of open productive intervals. Lithofacial zoning of the productive reservoir area allows to trace the distribution patterns of different types facies, to determine their relative location, and accordingly to predict the nature of changes in reservoir properties in the inter-well space. The lack of sufficient core material to identify facies significantly complicates the solution of the problem. Another method is used to identify facies by the morphology of geophysical curves. Nowadays, this problem is solved at a qualitative level. In this paper, we propose to apply a quantitative facial identification technique using an artificial neural network. In particular, the morphology of the curves is formalized by a number of parameters that form the input vector of an artificial neural network. At the output of the network clusters of logging curves with similar morphology are formed, which by analytical means are attributed to a certain type of facies. Based on the information obtained, lithofacial zoning of productive horizons and forecasting of their collector properties are carried out.
Introduction. The efficiency of the oil and gas production process depends primarily on the quality of the field development project. The basis of such project is the geological study of productive strata, which is formalized in the form of geological model of the deposit. Part of such a model are geological constructions in the form of maps and profiles of changes along the productive horizons of the petrophysical parameters, which are important for understanding the current situation in the reservoir and forecasting its development in the process of oil and gas extraction. The information content of geological structures is, among other things, also data of geophysical studies of wells. The disadvantage of this information support is that the data of geophysical studies of wells allow to obtain only discrete knowledge in each specific well. Therefore, the prediction of changes in the petrophysical properties of reservoirs in the space between wells remains an urgent problem. The purpose of this work is to substantiate the method of differentiation productive oil and gas fields horizons into sections with different conditions of sediment accumulation on the morphological features of the curves of geophysical well studies using artificial neural networks.

Method and Theory. The reason for the variability of petrophysical characteristics at reservoir rocks along their extension is the difference in the conditions of rock formation in the plane relation and in time. Nowadays, sedimentation analysis is developing in the direction of reconstruction of sediment accumulation conditions. The pioneer of such research was (Reading, 1990), who in his work finally formulated the main provisions, developed the methodology, structure and methods of facial analysis.

One such method was the analysis of curves of geophysical well studies. In their work (Izotova at al., 1993) identified a number of genetic indicators of rocks, which are reflected in the curves of geophysical studies of wells: lithotypes and their paragenesis, structure and texture of sandstones and clays, layering, frequency and relative speed of facies change, breaks in the process sediment accumulation, cyclicity. They have created a number of techniques that allow according to the complex of GWL methods and studies of core material to distinguish in detail the different zones of layers continental and marine environments of sediment accumulation. This area of research was developed in the works (Fedak at al., 2013, where the authors substantiated the method of lithofacial zoning of productive horizons based on the analysis of morphology geophysical curves.

This work is a continuation of research in this area. The process of accumulation of sediments creates an image of rock, which is reflected in geophysical curves, analyzing what can be imagined the time course of events and the circumstances under which its formation occurred: the nature and speed of change of climatic conditions, the depth of the pool of sediment accumulation, dynamics of water geological flows, the intensity of geological movements of the solid surface and etc.

The rapid development of artificial intelligence provides a new tool for recognizing these images - artificial neural networks. The authors created, tuned, and used an artificial neural network such as the Kohonen network for the lithofacial zoning of productive horizons of the Bilokamianskogo oil field by the morphology of geophysical curves.

One of the tasks that is solved through the Kohonen network is the clustering problem. The first input vector x(0) is fed to the network input and searched for a neuron, which is characterized by the smallest distance between the input vector and the corresponding vector of the weight coefficients wk. Such a neuron is a “winner” neuron from this stage of learning.

The next step is the modification of the weight coefficients taking into account the neighborhood function, which specifies a valid modification area. In the case of a negative test for convergence criterion begins a new learning cycle. The first step in this cycle is the modification of neighborhood function, which causes a decrease excitation region around the "winner" neuron. Next, another input vector x (n) enters the input and the learning process continues until a positive result of the convergence criterion is obtained.

Results. It is clustering, not classification that makes it possible to carry out lithofacial zoning of productive horizons for oil and gas fields. The solution to the classification problem is to assign each
Object to one of the predefined classes. In a clustering problem, an object is assigned to one of the predefined classes. Clustering of objects is performed while clusters are formed. Clustering allows you to group similar data, making it easier to solve a task such as forecasting. By assigning a new object to one of the clusters, one can predict its petrophysical properties as they will be similar to the behavior of the objects in that cluster. It should be noted that it is almost impossible to identify clear boundaries between facies. They can move smoothly into each other. This feature will necessarily lead to the appearance of objects from an indefinite (intermediate or transitional) class, which significantly complicates the task solution. It is clustering that avoids this problem. The user is able to interpret each cluster himself. In this regard, it is important to note the role of meaningful interpretation of clusters. Each cluster, and in our case the zone, should be conditionally assigned to a facies of a certain type, and more precisely assign to the cluster objects collection characteristics. To do this, on the basis of a priori geological and geophysical information it is necessary to identify the signs that unite the objects in the zone.

The Kohonen networks are clustering objects that are described by quantitative characteristics. Therefore, in order to allow the use of a neural network for the purpose of lithofacial zoning of productive horizons at oil and gas fields by the morphology of geophysical curves, an input vector was created in the work that contains quantities that quantitatively describe the morphology of geophysical curves.

Analyzing the sedimentological facies models described in (Muromtsev, 1981) and (Izotova et al., 1993), we have identified a number of features that are reflected in the shape of curves and have proposed a method for it formalizing. The process of accumulation sediments which forming facies in different periods of sedimentation is characterized by different hydrodynamic levels. The change in the hydrodynamic level over time on the logging curves is reflected by the steepness of the corresponding section of the anomaly, and can be formalized as the angle of inclination of its median line to the conditional horizontal line (fig. 1, a). The intensity of the sedimentation process is also estimated by the magnitude of the registered geophysical parameters(fig. 1, b). Based on these parameters, the input vector was formed and clustering was carried out.

\[\alpha, \beta, \gamma, \phi\] - the angles of inclination median line to the conditional horizontal line; \(I^1, I^2, I^3, I^4\) – magnitude of the registered geophysical parameters.

To identify the clusters obtained, we analyzed the geological processes that occurred during the formation of the productive horizons at Bilokamianske oil field. In the Chokrak (N1čk) time of sediment accumulation in the study area occurred in the conditions of the inner shelf. The surface of the Maikop deposits up to the beginning of the Chokrak was leveled and had a slight angle of inclination. In the sediment accumulation basin there was a plane wash of terrigenous fine-grained material from the northern land. The river systems brought mostly sand-silt material.
Under the conditions of avandelta, sand-silt deposits formed on the shelf of the Chokrak Sea. Rocks of the Chokrak tier are represented by quartz sandstones, sand-limestone shells or limestones with a large number of fauna remnants. The thickness of sediments ranges from 15 to 45 m. In submerged parts, the tier is composed of clays with sand and sandstone layers. Also, the Chokrak tier includes shells-detrital limestones with layers of conglomerates, loose sands and sandstones. On the Kerch peninsula Chokrak deposits are involved in the construction of diapiric zones with numerous mud volcanoes. Sand material settled in the beds and sleeves, where the flow retained the greatest force. In the cross-section, the sand bodies are characterized by a lenticular structure. In some areas, the streams gradually lost their strength, and the sand spread more widely over the area, occupying larger spaces. The described situation of sediment accumulation existed until the end of the chokrak. It should be noted that during the Chokrack period, sediment accumulation occurred against the background of constant differentiated tectonic deflection of the territory, which led to large thicknesses of the productive complex.

The sediments of the Karagan (N1kg) tier have a genetic link with the underlying Chokrak rocks, so they are often isolated as the only Chakrak-Karagan strata. The tier is composed mainly of quartz, often sandy dark-gray clays with sandstone layers, limestones with freshwater and terrestrial molluscs. Karagan formations of the Kerch peninsula in the west are represented by shallow marls and sands, clay sandstones, rarely by limestones, conglomerates. n the east, the deposits become more deep-sea - clay with layers of limestone, marl, sand.

In the post-Karagan period, the slope of the seabed was almost leveled by sediment, and the underwater-shear phenomena ended. The depth of the basin gradually decreased, and sediment accumulation occurred mainly in the conditions of deltas, estuaries and floods.

As a result of the analysis, the obtained clusters are classified by us into the following types of facies: facies of beaches, facies of gutters breaking stream, facies of regressive along-shore bars and coastal shafts, facies of the main parts of erosion currents. Based on clustering, lithofacial zoning of productive horizons at Bilokamianske oil field was performed, and zones with different sediment accumulation conditions and, accordingly, different reservoir properties were identified (fig. 2).

Conclusions. Existing techniques for interpreting geophysical well data do not provide complete information on reservoir rocks. In particular, little attention is paid to the analysis of the morphology of geophysical curves, despite the fact that a number of scientists have proved a close relationship of logging curves with sedimentation geological models. This work is a continuation of research in this direction and develops a technique for quantitative interpretation of morphological features of geophysical logging curves in order to determine the type of facies to which the studied layers belong, and further lithofacial zoning of productive horizons as an element of the geological deposit model. The parameters of quantitative estimation of anomalies at geophysical curves, which reflect changes in the dynamics of sedimentation processes during the period of sediment accumulation, are proposed in the paper. In order to eliminate the influence of subjective factors, the processing of certain parameters is proposed to be performed using an artificial neural network of the Kohonen network type, as a result of which the formalization of logging curve anomalies are divided into several clusters reflecting the corresponding sedimentation conditions. The schemes of zones location with different dynamics of sediment accumulation, constructed by this method, are confirmed by the results of geological-geophysical researches and industrial exploitation of productive horizons. The use of this technique in the process of geological modeling will allow in the analysis of the morphology of geophysical curves to obtain additional valuable information about the reservoir properties of productive horizons in the space between borehole, to reduce the time of processing geophysical information, to eliminate errors arising from subjective factors, to increase the information content about geological model of the deposit.
Figure 2 An example of lithofacial zoning (IV productive pack of Bilokamianske oil field)

References

Muromtsev V.S. (1981). Methods of local prediction of sand bodies - lithological oil and gas traps according to electrometric models of facies. [in Russian].