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The operational modeling of oil fields by mathematical methods of cluster analysis of facies sediments

Fasiyes sedimanlarının küme analizinde matematiksel yöntemlerle petrol sahalarının operasyonel modellenmesi

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ABSTRACT

In this work, we describe the technique of expeditious modeling of deposits of oil with use of facies and facial heterogeneity during creation of geological and hydrodynamic model. Expeditious diagnosing of facial deposits is based on a mathematical method of a clustering by an algorithm, namely k-means. In this work, merits and demerits of this method and a way of its calculation for differentiation and subsequent grouping of wells with various data are specified. An object of this research is the terrigenous layer of the large-scale deposit of Western Siberia of Early Cretaceous age. In the facial relation, a layer was created in a transitional situation of sedimentation and includes deposits of both sea and transitional geneses. The research was conducted on 900 wells of layer collector, according to geophysical research curves SP, αsp, with control under the curve of GR log.

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By results of the cluster analysis, several groups, excellent in the form of curves obtained from geophysical surveys have been allocated. With the comparison of the allocated groups with given logging received as a result of a clustering with standard forms of curves according to Muromtsev facial deposits of the beach, a gully of strong currents, alongshore gullies, the top part of a prefrontal zone of the beach, transgressive shaft of a prefrontal zone, the lower part of a prefrontal zone of the beach, underwater shaft of a prefrontal zone of the beach, alongshore bars have been allocated. The obtained data have been correlated to their original distribution and the received distribution does not contradict features of sedimentation of this region.

Expeditious diagnosing of facial deposits by means of the cluster analysis allows to estimate more competently the provision of a collector of geological model and to predict petrophysical properties and features of layer, to exclude subjective mistakes of the expert and to lower assessment time during the work with a large number of data.

Keywords: clustering, method, layer collector, model, algorithm.

ÖZ

Bu çalışmada, jeolojik ve hidrodinamik modelin oluşturulması sırasında fasiyes ve fasiyes heterojenliği kullanılarak petrol çökellerinin süratli modellenmesi tekniği tarif edilmiştir. Fasiyes çökellerinin hızlı teşhisi, k-ortalamaları kullanılarak oluşturulan bir kümelenme algoritması şeklinde bir matematiksel yönteme dayanmaktadır. Bu çalışmada, bu yöntemin yararları ve dezavantajları ile kuyuların farklı verilerle ayrılması ve müteakip gruplandırılması için hesaplanma yolu belirtilmiştir. Bu araştırmanın amacı, Batı Sibirya'nın Erken Kretase yaşlı geniş ölçekli karasal kökenli yatağının katmanıdır. Fasiyeslerin ilişkisinde, sedimantasyon açısından geçiş zonunda oluşmuş bir katmanda hem deniz hem de geçiş zonlarının çökelleri bulunmaktadır. Araştırma, üretim katmanına ait 900 kuyu ile ilgili jeofiziksel SP araştırma eğrileri, GR log eğrisi altında kontrol ile αsp'ye göre gerçekleştirilmiştir.

Küme analizi sonucunda, jeofizik etütlerle elde edilen eğriler biçiminde birçok grup oluşturulmuştur. Oluşturulan grupların Muromtsev'in standart kıyı çökelme eğrileri ile karşılaştırılması ile, kuvvetli akımlara bir kanal, kıyıdaki oluklar, plajın *prefrontal bölgesinin üst kısmı, prefrontal bölgenin geçiş mili, plajın prefrontal bölgesinin alt kısmı, prefrontalın sualtı mili plaj alanı ve sahil barları kesimleri oluşturulmuştur.*

Elde edilen veriler orijinal dağılımları ile ilişkilendirilmiştir ve oluşturulan dağılım bu bölgenin sedimantasyon özellikleri ile çelişmemektedir.

Küme analizi ile fasiyes çökellerinin hızlı bir şekilde teşhis edilmesi, bir jeolojik modelin ortaya çıkarılmasında daha yetkin bir şekilde tahmin etmeyi, ilgili katmanın petrofiziksel özelliklerini tahmin etmeyi, uzmanın öznel hatalarını azaltmayı ve çok sayıda veri ile çalışma sırasında değerlendirme süresini kısaltmayı sağlar.

Anahtar kelimeler: kümeleme, yöntem, hazne kaya, model, algoritma.

INTRODUCTION

Facial diagnostics of reservoir beds is one of the important tasks in geological modeling as well as the distribution of residual oil saturation and the rationale for the selection of effective geological and technical measures.

The identification of the facies characteristics of the reservoir allows: a) to evaluate its internal structure, the distribution of the reservoir and non-reservoir along the section, b) to determine the shapes of various accumulative bodies and the position of the pinching-out and reservoir replacement zones.

At all stages, beginning from processing data to create geological and hydrodynamic models, and assessing the effectiveness and justification of the application of technologies for recovery fluid from the reservoir, it is necessary to take into account various types of reservoir and the belonging of wells to certain facies environments.

The most applicable technology for assessing facies diagnostics is the technology for evaluation and interpretation of geophysical well logging. More often, specialists use the data of well logging methods of electrical log and methods based on the measurement of rock radioactivity.

Software products of geological modeling or map generation do not have specific options according to logging operations and then linking it to a specific type of facies. This procedure is most often performed by specialists in the field of petroleum engineering and is the most labor-intensive. The duration and complexity of the work increase with the complexity of the facilities and a large amount of information. Many fields have a multilayer structure and are developed by several hundred or thousands of wells.

Diagnosis of facies deposits using automatic algorithms of mathematical methods becomes relevant due to the exclusion of the subjective factor for the effective interpretation of logging data and reducing the time for processing information.

The online diagnosis of facies deposits and their distribution zones is a reliable base at the stage of creating geological and hydrodynamic modeling.

A geological model designed using facies diagnostics is the fundamental basis for correctly predicting the location of the reservoir both in area and in the context of the studied field. This model gives a more accurate idea of the distribution of the petrophysical properties of the reservoir bed and allows one to simulate and reliably predict the production of fluid from the reservoir beds during hydrodynamic calculations.

At the moment, there are many different directions, and various algorithms have been created for pattern recognition and interpretation of well logging curves (Chudinova et al., 2017).

The authors of the work selected cluster analysis as a mathematical tool for organizing various objects into more homogeneous groups. Clustering allowed the authors in a short period of time (several minutes) to process and systematizes more than 900 wells with logging data of methods of self-polarization potentials (SP), gamma-ray logging (GR) and relative units of SP data - άsp curves.

The clustering algorithm was chosen - the quadratic error and its subcategory is the k-means (k-means) algorithm. This algorithm is the most common and well-known. The essence of this method is to 9.

The disadvantage of this algorithm is the need to specify the final number of clusters, which will result in the clustering of logging data. Many researchers consider this method to be inaccurate by this principle. However, it was not difficult for the authors to determine the finite number of clusters using the method of analogy of paleogeography of similar objects with the studied one.

The first condition for the correctness of the procedure for clusterization and differentiation of wells into different groups according to the characteristic signs of the similarity of the diagrams of well logs is the procedure of standardization of logging.

Logging standardization is needed to compare and evaluate the logging curves of different wells. Figure 1 presents options for the correlation pattern of standardized logging and logging before standardization, using the PS data curves as an example.

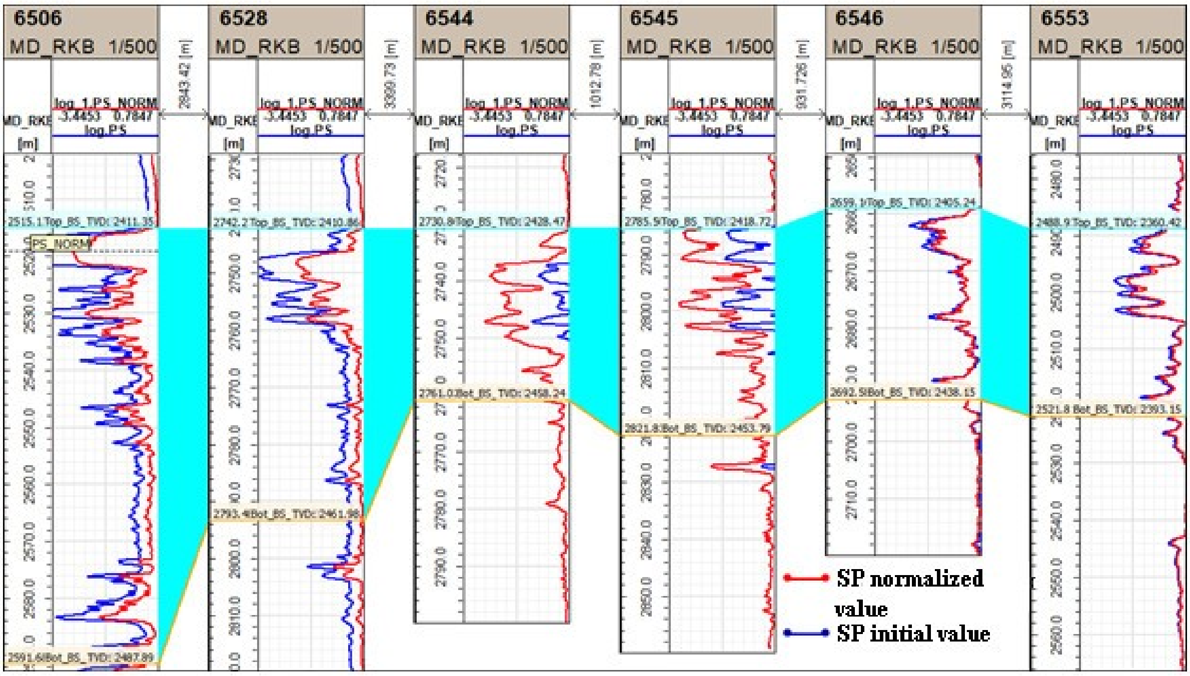

Figure 1. An example of a correlation pattern of wells with initial data of SP curves and after standardization 12.

Şekil 1. SP eğrilerinin ilk verileri ve 12 standardizasyon sonrası kuyuların bağıntı modeline bir örnek.

The k-means algorithm works on the principle of finding random entries from the total number of values that will be the initial centers of the clusters. After that, the so-called centroid-centers of gravity of the clusters are calculated, where each center of the clusters subsequently shifts.

The algorithm is stopped when the boundaries of the clusters and the arrangement of the centroids do not cease to change from iteration to iteration, which means that at each iteration, in each cluster, the same set of records will remain (Basegroup, 2019).

The schematic diagram of the algorithm is presented in Figure 2.

The definition of the cluster for each seed point of the analyzed set by this method occurs according to the formula (1)

$$V = \sum_{i=1}^{N} (\arg min_j \|x_i - c_j\|_2^2) \quad (1)$$

where x_i is the analyzed point of the original set;

c_j - representative of the cluster.

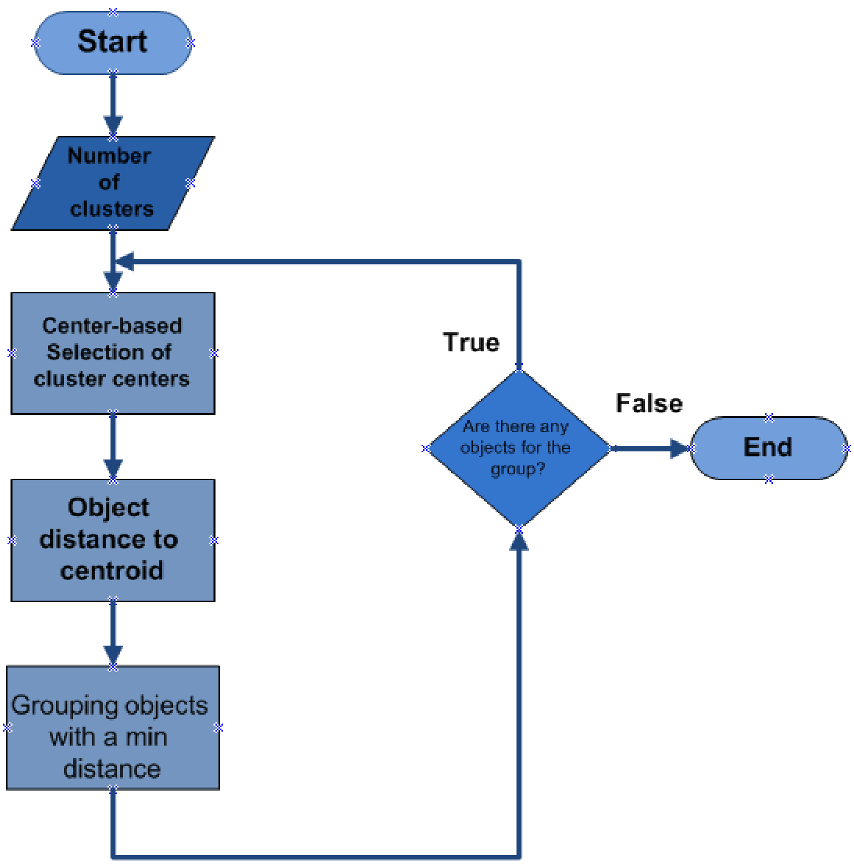

Figure 2. Schematic diagram of the k-means15 clustering algorithm.

Şekil 2. k-ortalamaları küme algoritmasının şematik diyagramı.

The k-means method tries to minimize the distance of each analyzed point to the center of the cluster closest to it. Differentiation and grouping of objects are carried out in this way.

The authors set a finite number of clusters at the initial stage, which is equal to 8. This choice is due to the analogy with the distinguished facies environments of the reservoir bed with similar paleogeography, as well as based on the study of facies types of the northern part of the bed.

AN EXAMPLE

The object of research in this work is the southern part of the BS10-2 / 3 bed of a large deposit of the Surgut convex, in Western Siberia, Russia.

The geological section of the deposit is represented by terrigenous deposits of the Meso-Cenozoic age.

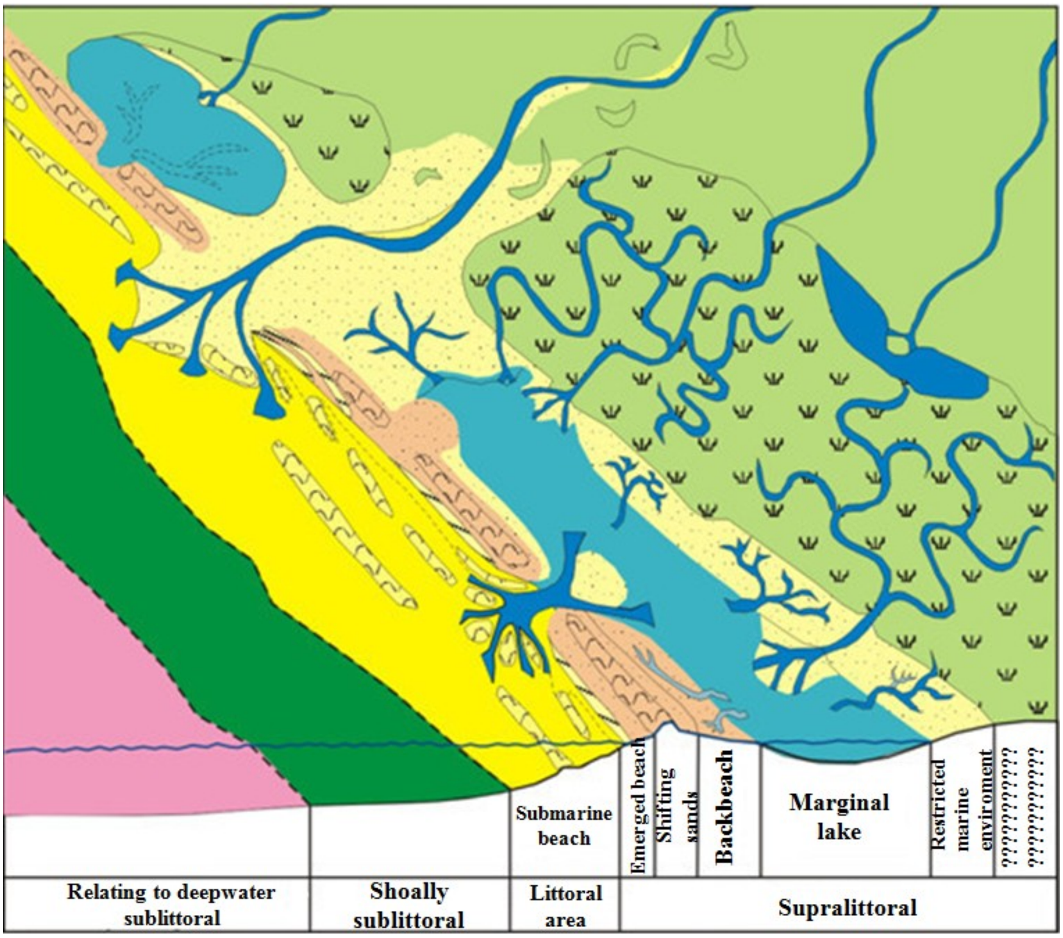

Figure 3. Reconstruction of coastal geomorphological structures of various sedimentation environments according to Reineck and Singh (1972).

Şekil 3. Değişik çökelme ortamlarının kıyı jeomorfolojik yapılarının yeniden oluşturulması (Reineck ve Singh, 1972'ye göre).

The reservoir layer has a clinoform structure, the facies deposits of which have the character of a transitional and marine genesis. Deposits of the studied formation were formed in the conditions of the coast of the delta complex.

The coast has a profile, deepening towards the sea, known as the flooded area of the beach, where wave and wave-induced processes operate (Muromtsev, 1984; Reading, 1990; Valeev et al., 2016). The groups of identified facies correspond to the paralic hydrodynamic zones shown in the diagram of geomorphological units of the sea coast shown in Figure 3.

As a result of clustering, it was possible to obtain groups of wells on the one hand with similar SP and άsp curves within each group, and on the other hand, different from other groups. Figure 4 shows the main shapes of the άsp curves of wells, divided into different groups.

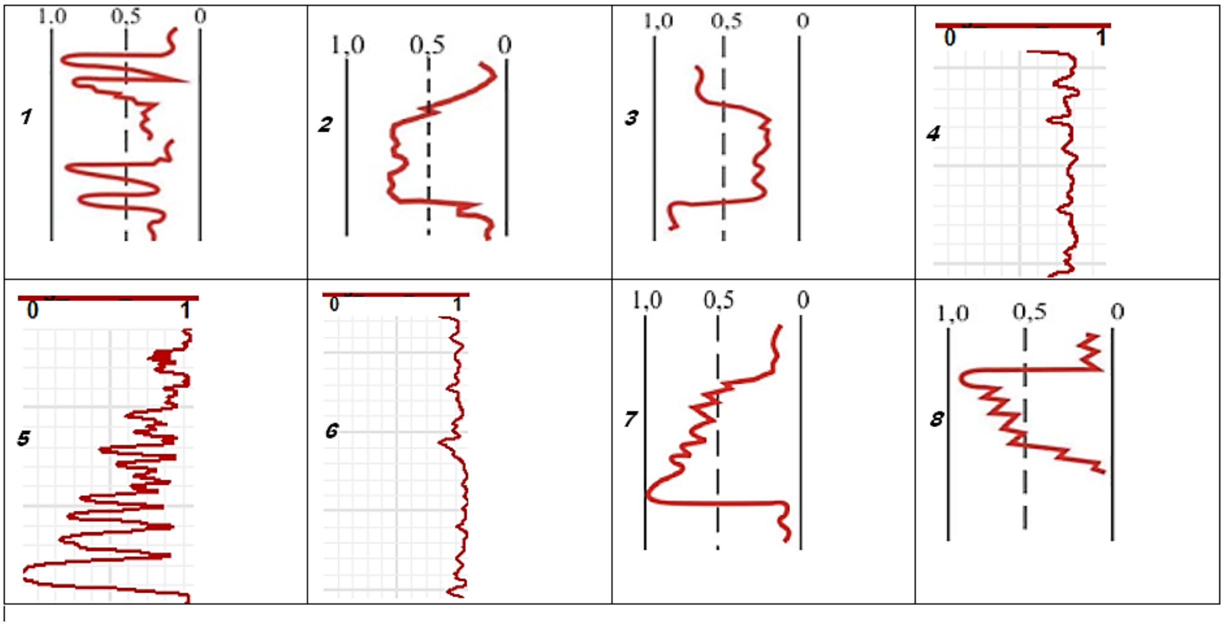

Figure 4. Examples of typical forms of άsp curves for groups obtained by clustering.
Şekil 4. Kümeleme ile oluşturulan grupların άsp eğrilerinin tipik şekillerine örnekler.

When comparing the groups of curves obtained as a result of clustering with typical forms of curves according to Muromtsev (1984), the authors concluded that the first type is associated with the shape of the άsp beach curve, the second type with gall water of rip flow, the third type with facies of longshore gall water, the fourth type is the upper part of the prefrontal zone of the beach floods by the sea, the fifth type is associated with the transgressive swell of the shoreface, the sixth type is the lower part of the shoreface, the seventh type is the facies of submarine swells, the eighth type is the longshore regressive bars and submarine swells.

The obtained value of the distribution of facies zones over the area coincides with the distribution of facies zones of the northern part of the deposit. Facies deposits replace each other from the west of the deepwater part, represented by the lower part of the prefrontal zone and the network of submarine swells until the formation tailing out in the east. Submeridional bands trace the position of the facies zones of the beach and the sand bodies of the swells and bars. The obtained distribution of points, the analyzed data is consistent with the formation model and the features of sedimentation of the Lower Cretaceous deposits of the studied formation in the northern part of the Surgut convex, obtained as a result of a comprehensive interpretation of deep drilling data, seismic exploration and representations of conditionally prognosticated facies, with models of modern environment. The spatial position of the groups of wells obtained by the results of cluster analysis is presented in Figure 5.

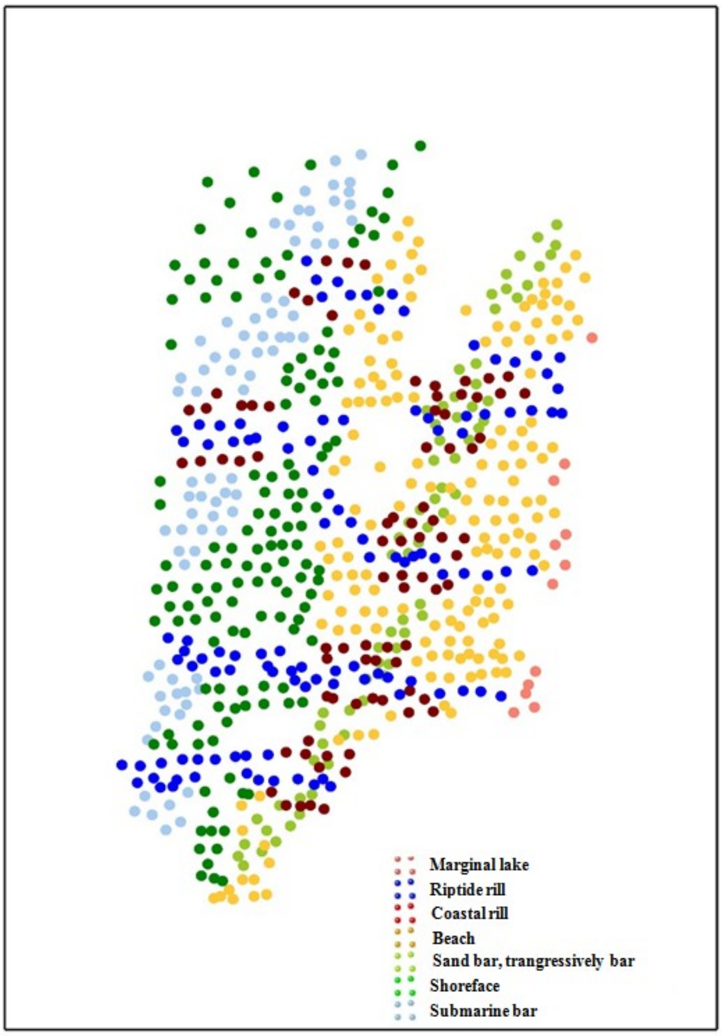

Figure 5. The spatial position of the groups of wells by the area of the studied object.
Şekil 5. Kuyu gruplarının incelenen nesne alanına göre mekânsal konumu.

The obtained value of the operative diagnosis of facies environments gives only an approximate value to the distribution of the real paleogeography of the object and subsequently should be controlled by a geologist. This approach facilitates to solve the task of grouping wells by area and conditionally drawing zones of facies environment. In the areas where there is a consistent change in one sedimentation environment to another, it should be further analyzed by a specialist.

The obtained values must be tied to the core by wells, and also other diagnostic features, such as lithological, faunistic, texture and structural features of rocks composing graphic of wells of conventionally allocated facies, should be taken into account.

CONCLUSIONS

The paper presents the operational diagnosis of facies deposits by the mathematical method of well logs data for objects with a large amount of information. The method of diagnosing facies environments and subsequent grouping was chosen cluster analysis, and the clustering algorithm - k-means. The proposed technique can be used for rapid automated analysis of the region's paleogeography.

Due to the efficiency of diagnosing facies deposits, the process of modeling oil deposits in the process of creating a permanent geological and hydrodynamic model solves the following problems:

- tracking the position of geological bodies;
-the correct distribution of the collector over the area and in the context of the deposit;
- the correct modeling of reservoir properties of the reservoir taking into account facies deposits;
- the traceability of the hydrodynamic features of the object;
- the modernization of the existing development system;
- the forecasting the development of oil reserves;
- the selection of effective geological and technical measures to increase oil recovery and, as a consequence, reduce economic risks (Andreyev et al., 2016);

The approach presented in the paper also reduces the time and labor required to evaluate and determine facies environments.

The principle of the diagnosis of facies deposits described in the article and any highly qualified task must be monitored by a specialist.

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