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ASSESSMENT OF THE INFLUENCE OF COMPOSITION, PROPERTIES AND CONDITIONS OF OCCURRENCE ON OIL QUALITY BASED ON FUZZY CLUSTER ANALYSIS

G. M. Efendiyev*[1], G. J. Moldabayeva[2], S. V. Abbasova[3], O. G. Kirisenko[1]

[1]*Institute of Oil and Gas, Ministry of Science and Education of the Republic of Azerbaijan, Baku, Azerbaijan*

[2]*Satbayev University, Almaty, Kazakhstan*

[3]*Azerbaijan State Oil and Industry University, Baku, Azerbaijan*

A B S T R A C T

The article is devoted to the analysis and assessment of the influence of parameters characterizing the composition, properties and conditions of oil occurrence on its quality. Using the principles of the theory of fuzzy sets, modeling of the dependences of the noted characteristics of oil on the complexity of its production was carried out. Data on the properties, composition and conditions of oil occurrence in the fields of Azerbaijan and Kazakhstan were collected. By implementing the fuzzy cluster analysis algorithm, fuzzy rules are formulated based on the «if..., then...» principle. The classification features are the composition, density and viscosity of oil, the permeability of the reservoir conditions. A brief analysis of existing works on the classification and assessment of the quality of oil from fields with hard-to-recover reserves showed the need to divide the total sample into homogeneous groups (clusters) according to the totality of the noted classification features characterizing the composition, properties and conditions of oil occurrences. A generalized indicator characterizing the quality of oil is proposed.

Keywords: oil field; classification; fuzzy cluster analysis; hard-to-recover oils; sulfur concentration; density; viscosity; permeability.

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Introduction

In recent years hard to recover reserves take a significant place in the total volume of oil produced, which creates a number of different problems of a technological and economic nature at various stages of their production, transportation and processing. The expansion of the volumes of processing of the considered oils, characterized not only by abnormal properties, but also by complicated geological conditions of occurrence, makes the problem of studying the qualitative features of hard-to-recover oils urgent. The relevance of the problems noted is especially important for the most comprehensive estimates of the factors that make it difficult to recover oil. In this regard, this article presents the results of the analysis of the properties and composition of various oil types representing Azerbaijan fields. First, a grounding is given for the necessity of a new approach to the tasks of classifying hard-to-recover reserves based on previous work performed. The need to divide the total sample into homogeneous groups according to the complex of classification features is shown and cluster analysis is most suitable for it [1-5]. In this regard, this we consider the main essence and results of the cluster analysis using the example of earlier work on the fields data of Kazakhstan [6], as well as Azerbaijan [7] and provides a comparative assessment of the difficulty degree in extracting reserves.

**E-mail:* galib_2000@yahoo.com

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Brief Analysis of Existing Works

According to work [8], the geography of heavy oils and bitumen is quite wide around the world: from the basins of Western Canada, Eastern Venezuela (including the Maracaibo region), to the North Caspian, the Volga-Ural region of Russia, and Kazakhstan. The first two (Western Canada and Eastern Venezuela) of these regions account for 42% and 38%, respectively, of the total reserves of heavy oil and bitumen [8]. The formation and distribution of tight oil in China are mainly controlled by tectonic conditions, source rocks, reservoirs and source-reservoir-reservoir relationships. Classification of source rocks and reservoir conditions are the basis for assessing the exploration potential of hard-to-recover oil. The total reserves of tight oil are about one million tons in six major basins (i.e., Songliao, Bohai Gulf, Ordos, Sichuan, Santanhu, Qaidam and Junggar Basins), which are the main areas for tight oil exploration [9]. It should be noted that various studies present different definitions of hard-to-recover oil reserves, hence, as a result, the difficulties associated with their classification.

So, in most cases, for example, according to [10-14], «… Oil reserves represented by sedentary oil are hardly recoverable. (particularly with high viscosity or density and high wax solids content), oils with high (more than 500 m^3/t) or low (less than 200 m^3/t) gas saturation or in the presence of aggressive components in dissolved and/or free gas (hydrogen sulfide, carbon dioxide) in quantities requiring the use of special equipment in well drilling and oil production». Such oils are classified as oils with abnormal physical and

chemical properties. This group also includes oils with a high content of metals due to an increase in their degree of environmental hazard.

A number of works present the results of laboratory studies of oil properties, such as oil viscosity and oil density. Thus, in work [15], results are presented that make it possible to classify oils, dividing them into light, heavy and super-heavy.

However, this approach does not take into account the reservoir conditions, which also determine the degree of difficulty of oil extraction. Therefore, when classifying hard-to-recover oils, it is necessary to take into account the conditions of occurrence, one of the indicators of which is the permeability of the formation.

As a result of these studies, the authors justify and propose appropriate methods for increasing oil recovery.

Thus, it should be noted that none of the physicochemical classifications of oil can be recognized as universal. In addition, the classification should also take into account the oil occurrence conditions, and all the marked signs should be covered simultaneously. All this leads to the uncertainty of the classification conditions, in connection with which it is necessary to consider and review this circumstance when solving classification problems. As is known, all estimates associated with the extraction of hard-to-recover oils include uncertainty. In [16], uncertainty is expressed in words such as «low», «medium» or «high» uncertainty, and an assessment is given of the risk or probability of assessing the maturity of resources.

The paper provides a classification summary showing volume uncertainty (low, medium or high) with increasing probability of a deposit existing and being commercially exploited, reflecting greater resource maturity. Resource classes are low, medium, high. To solve this problem, it is necessary to attract approaches based on the use of methods that presuppose the presence of uncertainties in advance, with the implementation of mutual complementation of methods of mathematical statistics and fuzzy logic.

In general, an analysis of studies devoted to the classification of hard-to-recover oils allows us to establish the difficulties of this procedure, mainly associated with uncertainties of various types. When solving classification problems, it is necessary to use methods that allow simultaneous classification according to all criteria, taking into account the uncertainty expressed in the blurriness of the boundaries between individual homogeneous classes. One of these methods is the method of fuzzy cluster analysis, proposed by L. Zade and further developed in the works [4, 5, 7, 17-19]. Based on this, we made an attempt to solve the classification problem in this formulation using fuzzy cluster analysis.

Results of a cluster analysis of hard-to-recover oils based on signs characterizing the properties and conditions of occurrence of oils

As it is noted in the relevant literature, to date, a large number of works have been accumulated in which various clustering algorithms have been proposed, among them hierarchical and non-hierarchical cluster analyses, fuzzy clustering are distinguished [1-5, 10, 11, 13, 14, 20].

In recent years, these methods have been widely applied in various fields. At the same time, the principles of the algorithms of «traditional cluster-analysis methods» and their difference from unconventional, i.e., fuzzy clustering methods are described and the advantages of fuzzy clustering are shown, [4, 5]. Refs. 1-3 shows the solution of the classification problem of geological objects using cluster analysis.

In these works, in order to classify hard-to-recover reserves, clustering has been performed using a fuzzy cluster analysis algorithm based on geological and geochemical information obtained from Kazakhstan deposits data.

In this article, the collected data from the fields of Kazakhstan and Azerbaijan were processed and clustered using a fuzzy cluster analysis algorithm. The results of clustering in the form of term sets of viscosity, oil density and oil permeability using data from Azerbaijan and Kazakhstan fields as an example are shown in figure. In the last figure, term sets of a generalized characteristic representing the degree of difficulty of oil extraction are shown [2, 12, 20].

As a result of the implementation of fuzzy cluster analysis program, three classes were obtained in work [6], each of which characterizes the degree of difficulty in extracting oil. The analysis has been carried out according to five features: sulfur concentration, chloride concentration, density, viscosity and permeability of the occurrence conditions. As a result of the implementation of the fuzzy cluster analysis algorithm for the fields considered, three groups homogeneous in composition, properties and conditions of oil occurrence were identified. Calculation results are given in Work [6]. The work presents the analysis results of changes in the membership functions of each marked features and characteristics, conditionally called the «oil extraction difficulty». Hence, it follows that the data in question includes characteristics based on values varying widely.

The analysis also makes it possible to determine the conformity of qualitative assessments of signs with the values of the oil extraction difficulty using fuzzy rules based on the principle of «if…, then…» the formulation of which is presented in the noted work. Here, similar studies were carried out on the basis of information obtained from the data collected in the fields of Azerbaijan and comparative analysis was carried out. In [6] and figure, the results of a cluster analysis performed on the basis of information about the fields of Kazakhstan [6] and Azerbaijan, respectively, are presented. The boundaries of classification features have been established for both results.

The results obtained were summarized and presented in the form of the following fuzzy rules:

Azerbaijan:

1. If permeability (logarithm) low ($K_{per} \leq 1.8$) and ν^*=converted viscosity high (log ($\nu \times 10$) $\nu^* \geq 1.8$)) and density of reservoir oil high ($\rho \geq 0.89$) then composite oil quality index low ($K \geq 1.4$);
2. If permeability (logarithm) high ($K_{per} \geq 2.2$) and ν^*=converted viscosity medium (log ($\nu \times 10$) ($0.8 < \nu^* < 1.8$)) and density of reservoir oil medium ($0.85 < \rho < 0.89$) then composite oil quality index medium ($1 < K < 1.4$);
3. If permeability (logarithm) medium ($1.8 < K_{per} < 2.2$) and ν^*=converted viscosity low (log ($\nu \times 10$) $\nu^* \leq 0.8$)) and density of reservoir oil low ($\rho \leq 0.85$) then composite oil quality index high ($K \leq 1$).

Kazakhstan:

1. If chloride's concentration high ($Cl \geq 0.08$) and S^*=converted sulfur concentration high

(log (S×1000) S^*≥3) and ν^*=converted viscosity high (log (ν×10) ν^*≥1.7)) and $\rho^*=\rho/\rho_{water}$ - oil to water density ratio high (ρ^*≥0.88) then composite oil quality index low (K≥2.2);

2. If chloride's concentration low (Cl≤0.03) and S^*=converted sulfur concentration medium (log (S×1000) 2<S^*<3)) and ν^*=converted viscosity low (log (ν×10) ν^*≤1) and $\rho^*=\rho/\rho_{water}$ - oil to water density ratio medium (0.78<ρ^*<0.88) then composite oil quality index medium (1.7<K<2.2);
3. If chloride's concentration medium (0.03<Cl<0.08) and S^*=converted sulfur concentration low (log (S×1000) S^*≤2) and ν^*=converted viscosity medium (log (ν×10) 1<ν^*<1.7)) and $\rho^*=\rho/\rho_{water}$ - oil to water density ratio low (ρ^*≤0.78) then composite oil quality index high (K≤1.7).

The resulting fuzzy rules make it possible to establish a correspondence between the composition and properties of oils (fig.).

Thus, the use of fuzzy cluster analysis allows us to evaluate the relationship between input and output variables under conditions of non-statistical uncertainty, i.e. when it is impossible to construct mathematical expressions using probabilistic and statistical methods. In other words, fuzzy cluster analysis allows us to identify a homogeneous group, within which a rule is formulated that allows us to evaluate the influence of input variables on the output one at a qualitative level.

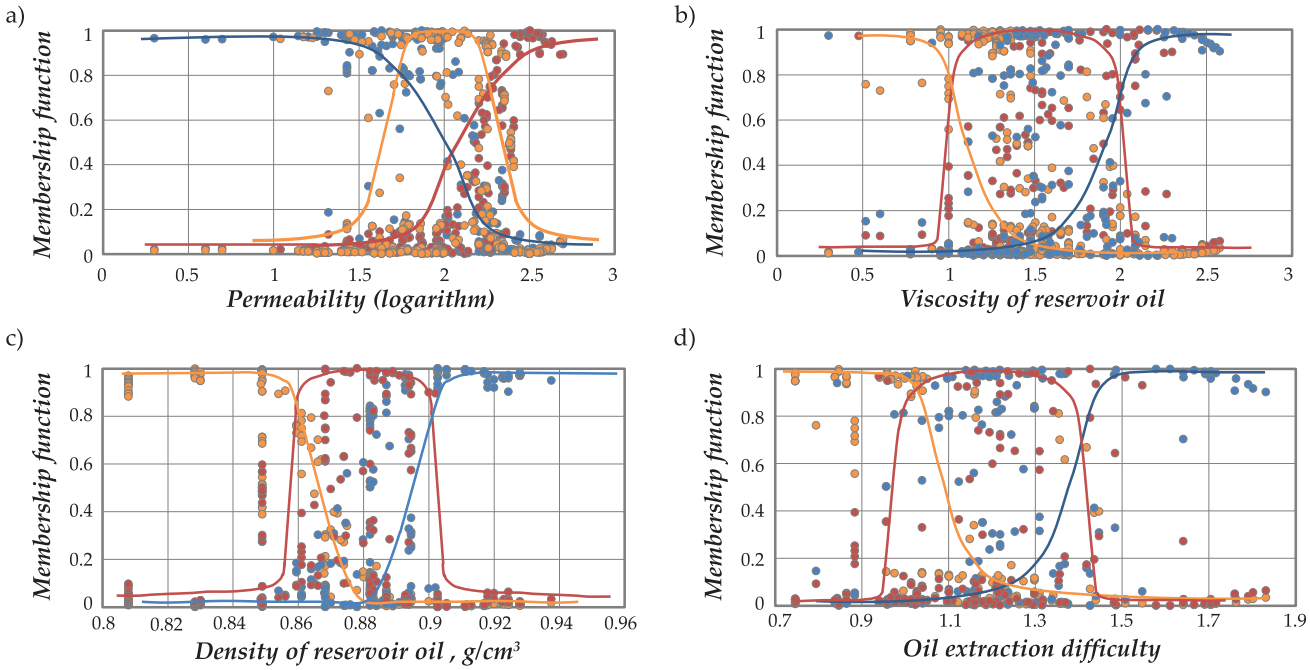

Fig. Membership functions for different clusters of: a) permeability (logarithm), b) converted viscosity, c) density of reservoir oil, d) corresponding values of oil extraction difficulty

Conclusion

A comparative analysis of information on hard-to-recover oil reserves in Azerbaijan and Kazakhstan, based on the application of a fuzzy cluster analysis algorithm was performed in the work.

- The analysis revealed difficulties associated with uncertainty, in the form of a lack of information, as well as ambiguity and blurred boundaries between individual categories. This circumstance made it possible to justify the use of fuzzy cluster analysis to solve the problem of classifying oils according to a set of characteristics.
- a parameter characterizing the degree of difficulty in extracting reserves, including characteristics of composition, properties and conditions, which allows for comparative analysis has been proposed and fussy rules are formulated to assess the degree of difficulty in extracting oil in uncertainty conditions;
- the results of classification of hard-to-recover reserves have shown that along with fields where oils are characterized by composition and properties that worsen their quality, a large proportion of hard-to-recover reserves is also associated with conditions having very low reservoir permeability, as well as low reservoir pressures, which is typical for most older fields.

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Оценка влияния состава, свойств и условий залегания на качество нефти на основе нечеткого кластерного анализа

Г. М. Эфендиев[1], Г. Ж. Молдабаева[2], С. В. Аббасова[3], О. Г. Кирисенко[1]
[1]Институт нефти и газа, Министерство науки и образования Азербайджанской Республики, Баку, Азербайджан
[2]Satbayev University, Алматы, Казахстан
[3]Азербайджанский государственный университет нефти и промышленности, Баку, Азербайджан

Реферат

Статья посвящена анализу и оценке влияния параметров, характеризующих состав, свойства и условия залегания нефти, на ее качество. С применением положений теории нечетких множеств выполнено моделирование зависимостей отмеченных характеристик нефти от сложности ее добычи. Собраны данные о свойствах, составе и условиях залегания нефти на месторождениях Азербайджана и Казахстана. Путем реализации алгоритма нечеткого кластерного анализа сформулированы нечеткие правила по принципу «если..., то...». В качестве классификационных признаков служат состав, плотность и вязкость нефти, проницаемость условий залегания, краткий анализ существующих работ по классификации и оценке качества нефти месторождений с трудноизвлекаемыми запасами показал необходимость разделения общей выборки на однородные группы (кластеры) по совокупности отмеченных классификационных признаков, характеризующих состав, свойства и условия. залегания нефти. Предложен обобщенный показатель, характеризующий качество нефти.

Ключевые слова: нефтяное месторождение; классификация; нечетко-кластерный анализ; трудноизвлекаемые нефти; концентрация серы; плотность; вязкость; проницаемость.

Neftin tərkibi, xassələri və yatma şəraitinin onun keyfiyyətinə təsirinin qeyri-səlis klaster analiz əsasında qiymətləndirilməsi

Q. M. Əfəndiyev[1], G. J. Moldabayeva[2], S. V. Abbasova[3], O. G. Kirisenko[1]
[1]Azərbaycan Milli Elmlər Akademiyasının Neft və Qaz İnstitutu, Bakı, Azərbaycan
[2]Satbayev University, Almatı, Qazaxıstan
[3]Neft və Qaz İnstitutu, Azərbaycan Elm və Təhsil Nazirliyi, Bakı, Azərbaycan

Xülasə

Məqalə neftin tərkibini, xassələrini və yatma şəratlərini xarakterizə edən parametrlərin onun keyfiyyətinə təsirinin təhlili və qiymətləndirilməsinə həsr edilmişdir. Qeyri-səlis çoxluqlar nəzəriyyəsinin prinsiplərindən istifadə etməklə neftin qeyd olunan xüsusiyyətlərinin onun hasilatının mürəkkəbliyindən asılılığının modelləşdirilməsi aparılmışdır. Azərbaycan və Qazaxıstan yataqlarında neftin xassələri, tərkibi və yatma şəraiti haqqında məlumatlar toplanmışdır. Qeyri-səlis klaster analizi alqoritmini tətbiq etməklə «əgər... onda...» prinsipi əsasında qeyri-səlis qaydalar formalaşdırılır. Təsnifat xarakteristikaları neftin tərkibi, sıxlığı və özlülüyü, lay şəraitinin keçiriciliyi, çətin bərpa olunan ehtiyatlara malik yataqlardan neftin təsnifatı və keyfiyyətinin qiymətləndirilməsi üzrə mövcud işlərin qısa təhlili neftin belə bir təsnifata ehtiyac olduğunu göstərdi. Belə bir təsnifat nəticəsində üç bircins qrup əmələ gəlmişdir. Neftin keyfiyyətini xarakterizə edən ümumiləşdirilmiş göstərici təklif olunur.

Açar sözlər: neft yatağı; təsnifat; qeyri-səlis klaster analizi; çətinçıxarılabilən neftlər; kükürd konsentrasiyası; sıxlıq; özlülük; keçiricilik.