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The Optimising of Layered Oil Field Development by the Rearrangement of Exploitation Plays

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Abstract

Selection of exploitation plays is an important part of oil field development projects. Our method of the layer similarity estimation allows to optimally distribute the layers in the exploitation plays. The main purpose of our method is to optimise the multitask wells performance and to decrease the technological risk. The technique of exploitation play selection is based on multicriterial decision-making approach and on fuzzy set theory.

The technique under consideration solves several tasks. One of them is the formation and structuring of a set of characteristics influencing the selection of exploitation plays (geological, technological, technical and ecological). The other is the development of a mathematical procedure on the basis of multicriterial decision-making approach and fuzzy set theory.

Some reservoir characteristics could be modified and changed during the oil field development process. In this case our method allows optimising oil field development by rearranging exploitation plays and selecting the new ones to improve oil recovery.

The method includes the following stages:
- linguistic description of the parameters used for the exploitation plays selection;
- creation of the belonging function;
- structuring of the layer comparison rules;
- estimation of layer similarity along the section and the area of an oil field.

One example of our method implementation for The Middle East oil field is given.

Introduction

An exploitation play (EP) is defined as one or several productive layers of a field, which are allocated according to the geologic-technical conditions and economic reasons for joint development of one well system [1]. Incorporation of several layers in one object seems economically efficient, because such an association requires less number of wells for development of the field as a whole. However, the excessive association of layers in one play can result in the decline of the efficiency of technical and economic parameters [2].

Selection of exploitation plays is an important stage of oil field development projects. Our method allows to determine similarity of the layers on the basis of their combination into one exploitation play. This method uses the Fuzzy Set Theory.

Some of oil fields nowadays are layered fields and characterised by high extent of heterogeneity of their reservoir structure and fluid properties. In addition, at the early stages of development they are also characterised by uncertainty and insufficiency of layer data. The development of layered deposits is influenced by several negative factors, such as the increase of the product watercontent; the non-uniform oil recovery; the decrease of current and final oil recovery of each layer and the field as a whole. These negative factors are caused mostly by combination of different layers in one exploitation play. The basic parameters of further development depend on the quality of play selection. Uniting the layers with close characteristics into one exploitation play allows significantly to reduce the technological risk and to smoothen the impact of adverse factors. Therefore the task of layers similarity estimation is quite urgent.

Brief Methodology Description

The principles of the reasonable selection of exploitation plays may be specified as follows:
- similarity of layers and fluids on the basis of geological parameters;
- possibility of regulating the development of each layer included in exploitation play and exercising effective control over the development process, maximum involvement of all productive layers in the oil field development;
- stability of oil-water and gas-oil contacts in exploitation play.

Selection of the exploitation play is aimed to achieve the following targets:
- minimising the number of joinable and returnable layers, which reduces the lead time and increases the efficiency of capital investment;
- most efficient oil and gas recovery from exploitation plays;
- maximum economic efficiency;
- the best quality of commercial products;
- minimising environmental damages.

To achieve the above aims, it is necessary first to determine how the layers are to be combined into the exploitation play. This work serves as a basis for the selection of exploitation play both for an association of layers into exploitation play (early stage of oil field development), and for splitting of the exploitation play (later stages of oil field development). The assessment of oil layer similarity for the selection of exploitation play allows to chose the layers combination which is characterised by their maximal similarity. As a result, the negative factor influence is decreased.

The assessment of layer similarity is based on their parameters. For each field the set of these parameters is individual. At the beginning of this assessment, the linguistic description of “parameters ratio” is given. Using this description we can determine the layer similarity. Linguistic variable is one of the notions of the Fuzzy Set Theory [3-5]. Its basic difference from a usual variable is that its meanings are not the numbers, but a word or word combinations. It should be stressed that the layers similarity estimation utilises not mere parameters of porosity, permeability, resources and others, but their ratios, for example, "porosity ratios", "resource ratios", etc. The ratio of parameters is not only dimensionless, it is more informative as well, because it at once demonstrates how many times one layer differs from another by a considered parameter.

The next stage is the construction of the belonging functions [5]. The belonging function is one of the notions of the Fuzzy Set Theory, which deals with partial belonging to the set, as opposed to the traditional logic, in which one member can either belong, or not belong to the set. According to this theory, the transition of an object from its complete belonging to the set to its complete nonbelonging occurs not abruptly but gradually. Belonging degree of an element to the set is a number from the ***[0,1]*** interval.

For the majority of our linguistic variables the belonging functions to term-sets "very close layers", "close layers", "far layers" are constructed on the basis of the statistical information on 200 reservoirs of Russia (Ural-Volga, Timano-Pechora and other provinces) (Table 1) [2]. The examples of the belonging functions ("porosity ratio", "permeability ratio", "oil saturation ratio", "net thickness ratio") are represented in Figure 1.

Table 1 The statistical characteristics of the average geologic-physical parameter relations of the productive layers, incorporated in exploitation play, for Russian oil areas (fragment) [2]

Property	**Meal**	**Variation factor , %**
Total thickness	2,03	82,75
Net thickness	1,49	89,93
Porosity	0,99	100,0
Permeability	2,09	113,4
Dismemberness	1,146	54,2
Intermediate layer thickness	60,6	75,46
Oil rate	2,38	77,7
Oil viscosity	0,78	46,15
Oil density	0,989	3,63
Area of a deposit	1,97	48,97
Oil resources	3,66	77,6
Well productivity	1,298	112,0
Initial reservoir pressure	0,998	3,0

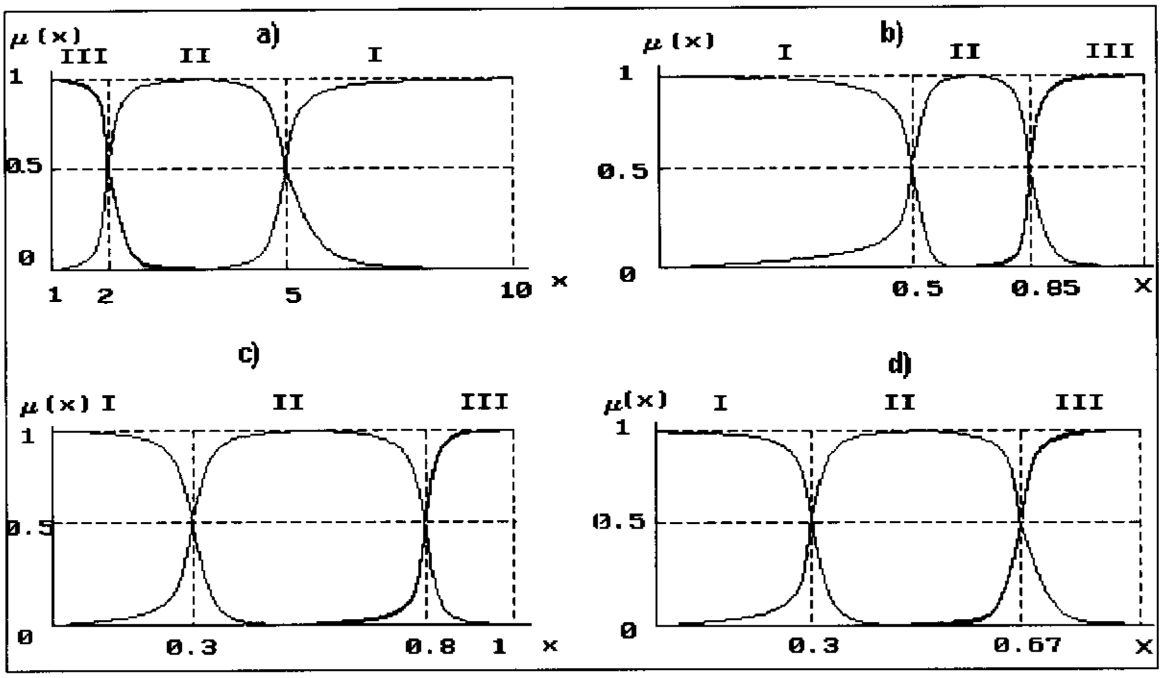

Fig.1. The belonging function: a) - "permeability ratio", b) - "porosity ratio", c) - "net thickness ratio", d) - "oil saturation ratio"

On the third stage the system of layer comparison rules is formed (see Table 2). This step is one of the most important in our approach. When the reservoir engineers try to solve some problem, including the oil field development, they rely on certain knowledge subdivided on skills and rules. These skills for the considered problem include of well-known assumptions and conclusions. In its turn on the basis of certain logical positions the engineers create the rules.

Table 2. The layer comparison rules for “very close” layers in The Middle-East Field

Rules
1.1 IF (∃) “areas ratio” ≥ 0.75 & “oil resources ratio” ≥ 0.48 & “initial reservoir pressure ratio” ≥ 0.9 & “dismemberness ratio” ≥ 0.87 & “net thickness ratio” ≥ 0.67 & “oil saturation ratio” ≥ 0.8 & “permeability ratio” < 2* & “porosity ratio” ≥ 0.85 & “viscosity ratio” < 5 & “hydrogen sulphide content ratio” ≥ 0.67 & “difference of reservoir depths” < 100 **then these layers are “very close” and EP is “very good”** with respect to geological-physical factors.

The last stage of our approach consists of actual comparison of layers by a complex of parameters. At the beginning, the “basic layer” is selected from the whole layer set according to the size of its resource (30 or more per cent of ultimate reserves). Further comparison is make in relation to this layer. If such a layer is not distinguishable, then comparison of layer pairs is made. In any case, this is made as follows: firstly, the parameter ratio determination; secondly, determination of the degree of belonging to the term-sets; thirdly, utilisation of the minimum-operator (pessimistic estimation). This operator determines the layer similarity by the parameter complex. The closest layers are united in exploitation play.

This layer comparison consists of two parts. In the first part the layers are compared by their average parameters (along the section), while in the second part - by the well parameters (on the area of oil field). The software package has been created for these two parts of the layer similarity estimation [7]. The first part of the estimation results in construction of the similarity charts (Figure 2, 3). The result of the second part of the estimation is construction of the maps of successfulness on the area of allocated plays.

Results

It can be shown that the field performance depends on how successfully several horizons with similar properties can be united in one exploitation play. The field of The Middle East contains seven large horizons characterised by high heterogeneity of their reservoir structure and fluid properties. To achieve high technical and economic results of The Middle East field development the horizons with similar geologic-physical characteristics can be united in exploitation plays. The calculations present only the first part of estimation, since there are only five wells in the field. Let's consider the results of these calculations.

The horizon #1 is closest by geologic-physical parameters to horizon #2. Their similarity degree is equal to 0.43, while the similarity degree with other horizons is less than 0.25 (Figure 2). The similarity degrees between horizon #2 and other ones are also low. The horizon #3 is closest to horizons #4 and #5 (similarity degree is respectively 0.47 and 0.44). The similarity degree with other horizons is less than 0.27. The horizon #4 is very close by the properties to the horizon #5 (the similarity degree is 1.0), and to horizons #3 (0.47) and #7 (0.41). The similarity degrees between horizon #6 and other horizons are low. The highest similarity has been discovered between horizons #5 and #4 (1.0), #5 and #7 (0.67), while the similarity between horizon #6 and others is relatively small. The similarity degree between horizon #6 and all the other horizons is rather low (less than 0.2) (Figure 3).

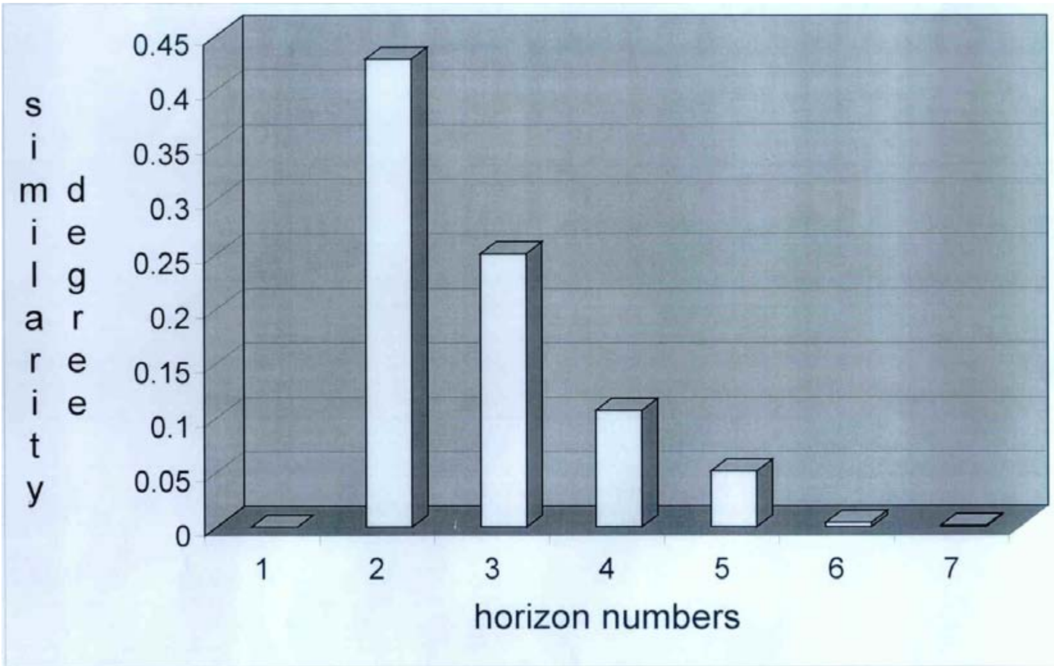

Fig.2. The diagram of similarity of horizon #1 with respect to other horizons of The Middle East field.

Judging by the calculations, we can see that two variants of the selection of exploitation plays are the most preferable (Table 3).

Table 3. Variants of the selection of exploitation plays

	variant 1	**variant 2**	**variant 3**
Exploitation play #1	##1-7	#1, #2	#1, #2
Exploitation play #2		#3 - #7	#3, #4, #5
Exploitation play #3			#6, #7

In the first variant the lower horizons are developed first, followed by the upper ones. In the second variant it is proposed to unite the carbon horizons #1 and #2 in the first exploitation play and terrigeneous horizons #3 - #7 - in the second one. In the third variant carbon horizons are incorporated in the first exploitation play, and terrigeneous horizons are divided into two independent plays with horizons #3, #4, #5 forming second exploitation play and horizons #6 and #7 – the third one. There are certain reasons for such a selection. Firstly, large intervals of depths between horizons #4 and #6; and secondly is the absence of the impermeable section between horizons #6 and #7. The results of the calculations of horizon similarity and their incorporation in exploitation plays are included into The Middle East field development project.

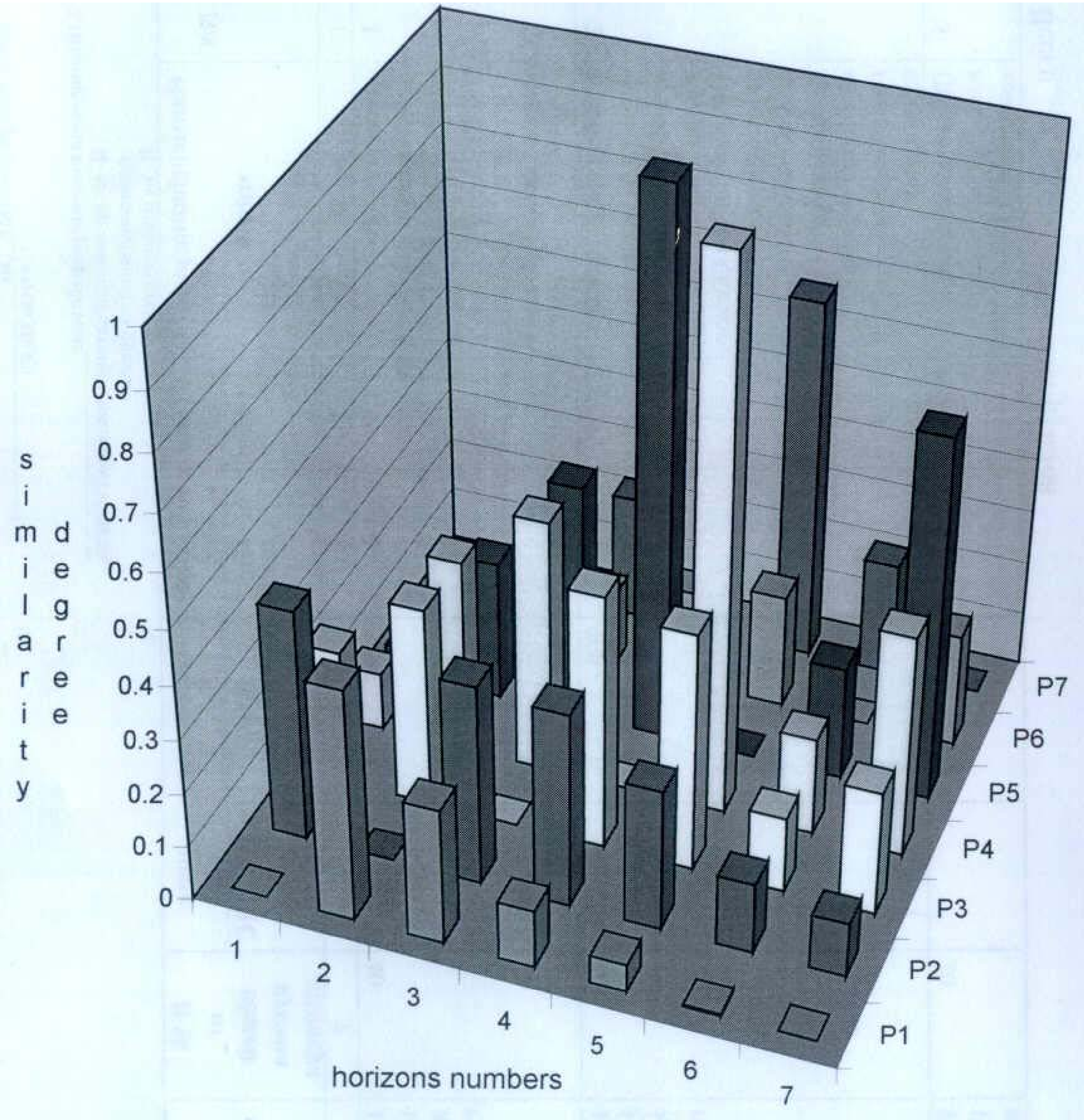

Fig.3. The diagram of all layer similarity

Conclusions

The methodology of the layer similarity estimation allows to avoid the inaccuracy and incompleteness of geological information and to solve the problem of the selection of exploitation plays. This improves the quality and reliability of design decisions and the results in optimisation of the layered oil field development.

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