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Calculating heterogeneity of Majnoon Field/Hartha reservoir using Dykstra Parsons method

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Abstract:

One of the principle concepts for understanding the hydrocarbon field is the heterogeneity scale; this becomes particularly challenging in supergiant oil fields with medium to low lateral connectivity in carbonate reservoir rocks.

The main objective of this study is to quantify the value of the heterogeneity for any well, and propagate it to the full reservoir. This is quite useful specifically prior conducting detailed water flooding or full field development studies and work, in order to be prepared for a proper design and exploitation requirements, which fits with the level of heterogeneity of this formation.

The main tool used for these purposes is the application of the famous Lorenz coefficient method, in conjunction with the Dykstra Parsons technique for calculating the degree of heterogeneity for any well.

The starting point for this kind of complicated studies needs to start from the basics. In order to understand the big picture and be able to plan properly for the scope to be delivered. Utilizing analytical tools like the ones mentioned above becomes quite necessary, if not crucial, to the success of full field modelling and choosing an optimum water flood pattern and design.

This work covers the methodology for quantifying and calculating the level of heterogeneity in a given reservoir.

The Dykstra-Parsons Coefficient or the variation of Dykstra Parsons (VDP) is commonly used in calculating permeability variation. The method of calculating begins by sorting the property of interest and make the other property fixed value (to calculate permeability you have to make porosity a fixed value for all calculations) and make permeability in order of decreasing magnitude.

For each of the values calculate the percentage of values greater or the 'cumulative probability', so that the probability of X is P(x≤X). Then plot the original permeability values on a log probability graph with the cumulative probability values. The slope value and the intercept of the line of the best fit, for all data are used to calculate the 50th and 84th probability values or by variation layering system to calculate the variation of P10, P50 and P90, which are used to find VDP.

This methodology has been tested successfully in the stated super giant oil field, in which the reservoir is a carbonate rock formation. The reservoir is areally extensive reservoir and not of a great thickness.

The importance of this step is to conclude a utilizing heterogeneity calculation method before conducting any detailed reservoir simulation study. It can save a lot of time and effort by providing guidance to the path, which needs to be followed, and sheds light on the critical elements to be looked after. This also can help to uncover many insights on the reservoir itself, hence allowing the engineer to plan for the necessary voidage replacement and water injection rates to sustain the reservoir pressure and pattern development based on the magnitude of heterogeneity those results from this procedure.

The suggested method, in combination with geological and petrophysical information available, can be applied to majority of the reservoirs. This combination is paramount to ensure optimum time and planning is followed for each reservoir development study that involves for example water flooding.

Key words: heterogeneity, Iraq, Oil field, Dykstra Parsons, Majnoon, Hartha.

حساب عدم تجانسية حقل مجنون \ مكمن الهارثة باستخدام طريقة دايكسترا بارسنز

الخلاصة:

أحد اهم المفاهيم الأساسية لاي حقل هيدروكربوني هو مقياس عدم التجانسية، هذا المقياس تزداد أهميته في الحقول العملاقة. هدف هذه الدراسة الأساسي كان حساب قيمة عدم التجانسية لاي بئر وتعميم هذه القيمة على المكمن ككل. هذه الطريقة مفيدة تحديدا قبل البدء باي دراسة حقن مائي او دراسة تطويرية للحقول لغرض تحضير ما يستلزم لتلك الدراسة مقدما.

الطرق المستخدمة عادة هي طريقة (معامل لورنز) مع طريقة (دايكسترا بارسنز) لحساب درجة عدم التجانسية لاي بئر، وفي هذه الدراسة تم استخدام الطريقة الثانية. حيث يغطي هذا البحث الطريقة المستخدمة لحساب درجة عدم التجانس للمكمن محط الدراسة.

معامل دايكسترا بارسنز يستخدم عادة لقياس درجة التباين في الخاصية، تبدأ الطريقة بترتيب الخاصية المعنية بطريقة تنازلية، ولكل قيمة من قيم هذه الخاصية يتم حساب الاحتمالية التراكمية ثم رسم القيمة الاصلية لتلك الخاصية على ورق خاص بالاحتمالية. الميل الناتج من الرسم وقيمه القاطع لأفضل خط مستقيم يستخدم لحساب قيمه الاحتمالية 50 و84.

الطريقة المقترحة هي عبارة عن دمج الخصائص الجيولوجية والبتروفيزياوية المتوفرة هذه الطريقة تم استعمالها واختبارها بنجاح في حالة المكمن العملاق، لتكوين صخري كاربوني، الحقل عملاق مساحيا وذو سمك معتدل. اهمية هذه الخطوة كان لأخذ نظرة شاملة عن الحقل قبل البدء بدراسة مكمنية شاملة. حفاظا على الوقت والجهد إضافة الى تسليط الضوء على العناصر الحرجة التي يجب الاهتمام بها. كما ان هذه الطريقة وضحت لكثير من خصائص المكمن مما يسمح للمهندس المسؤول ان يضع بنظر الاعتبار كميات المياه المحقونة للحفاظ على الضغط بناءا على درجة عدم تجانس المكمن.

Introduction:

Heterogeneity is a very important factor in determining the recovery from petroleum reservoirs. Thus; heterogeneity calculations can be classified into static and dynamic techniques.

Heterogeneity is the quality and situation of being heterogeneous. It was first defined in 1898 as the difference or diversity in kind from other kinds. Other definition is consisting of parts or things that are very different from each other [1]. In petroleum studies, it is referred to as the isotropy and anisotropy. Heterogeneity can be named as; complexity, deviation from norm, difference, discontinuity, randomness, and variability. [2]

A number of scholars noted that the difference between homogeneous and heterogeneous was relative, and it was based on the economic considerations [3]. This shows how heterogeneity has a variable concept which can be changed and re-defined to describe any situations arises during production from a reservoir, based on the researchers` experiences and expectations [4].

The disparity between heterogeneous and homogeneous was relative, and economical. Nurmi et al. suggested the previous highlights, which indicates that heterogeneity has a variable meaning which can be defined in other words to depict situations that emerge while the reservoir is under production. The heterogeneity is very tendentious to the researcher`s experience and anticipations [7]. The heterogeneity was defined by some researchers as the variability and complexity of the system characterization in 3D space. All these definitions proposed that the heterogeneity is not necessarily refer to an individual rock unit or an overall system. However, it deals with measurement types, properties, individual units and parameters [3].

These mentioned definitions clarify that heterogeneity does not refer to the overall system, or individual rock or reservoir unit, but instead it deals separately for each individual unit, properties, parameters and measurement types [5].

Dykstra Parsons method

The Dykstra-Parsons Coefficient or the variation of Dykstra Parsons (VDP) is commonly used in calculating permeability variation. The method of calculating begins by sorting the property of interest and make the other property fixed value (to calculate permeability you have to make porosity a fixed value for all calculations) and make permeability in order of decreasing magnitude [6].

For each of the values calculate the percentage of values greater or the ‘cumulative probability’, so that the probability of X is $P(x \leq X)$. Then, plot the original permeability values on a log probability graph with the cumulative probability values. The slope value and the intercept of the line of the best fit, for all data are used to calculate the 50th and 84th probability values, which are used to find VDP [7].

This methodology has been tested successfully in the stated super giant oil field, in which the reservoir is a carbonate rock formation. An important note is that the reservoir is areally extensive reservoir and not of a great thickness. It was concluded that utilizing a heterogeneity calculation method before conducting a detailed reservoir simulation study can save a lot of time and effort by providing guidance to the path which needs to be followed, and sheds light on the critical elements to be looked after. This has also helped to uncover many insights on the reservoir itself, hence allowing the engineer to plan for the necessary voidage replacement and water injection rates to sustain the reservoir pressure and pattern development.

The suggested method, in combination with geological and petrophysical information available, can be applied to majority of the reservoirs. This combination is paramount to ensure optimum time and planning followed for each reservoir development study that involves water flooding.

This method also called the stratified method or the permeability averaging method.

Results:

The procedure and results of this method can be clarified in Table (1) and Table (2). Note, the layer number, thickness and permeability values are inputs and the rest of the calculations are outputs or the equations results.

The reservoir was divided into 10 major layers considering each of these layers with constant value of permeability; the original reservoir is only 10 meters thick. The output of reservoir is extensive.

Where:

ω: omega factor = -1 (-1 in harmonic and +1 in arithmetic calculations)

The Dykstra Parsons goal seek for avg. permeability = a = 6.551, and goal seek for permeability ratio = b = 0.483

Effective Permeability k_{eff} = [sum (k^ω * h) / sum (h)] ^1/ω

Permeability factor = a * exp (b* layer)

Goal seek desired for permeability contrast by changing b in exp (b*layer) permeability factor equation = 1^{st} permeability factor/ last permeability factor

Table (1) Dykstra Parsons' calculations 1

Layer	Thickness	κ	h*k	h/k	ln(k)	1/k
1	1.000	10.616	10.616	0.094	2.362	0.094
2	1.000	17.204	17.204	0.058	2.845	0.058
3	1.000	27.880	27.880	0.036	3.328	0.036
4	1.000	45.181	45.181	0.022	3.811	0.022
5	1.000	73.219	73.219	0.014	4.293	0.014
6	1.000	118.655	118.655	0.008	4.776	0.008
7	1.000	192.287	192.287	0.005	5.259	0.005
8	1.000	311.613	311.613	0.003	5.742	0.003
9	1.000	504.986	504.986	0.002	6.225	0.002
10	1.000	818.359	818.359	0.001	6.707	0.001
10	10.000	2120.000	2120.000	0.244	45.348	0.244

Table (2) Dykstra Parsons' calculations 2

k^ω	k^ω*h	v^2	κ factor	κ (Descending)	ln(κ)	h	h*gr	%h*gr	Probability
0.094	0.094	0.902	10.62	818.359	6.707	1	0	0	
0.058	0.058	0.844	17.20	504.986	6.225	1	1	0.1	-1.28155
0.036	0.036	0.754	27.88	311.613	5.742	1	2	0.2	-0.84162
0.022	0.022	0.619	45.18	192.287	5.259	1	3	0.3	-0.5244
0.014	0.014	0.429	73.22	118.655	4.776	1	4	0.4	-0.25335
0.008	0.008	0.194	118.66	73.219	4.293	1	5	0.5	0
0.005	0.005	0.009	192.29	45.181	3.811	1	6	0.6	0.253347
0.003	0.003	0.221	311.61	27.880	3.328	1	7	0.7	0.524401
0.002	0.002	1.910	504.99	17.204	2.845	1	8	0.8	0.841621
0.001	0.001	8.181	818.36	10.616	2.362	1	9	0.9	1.281552
0.244	0.244	14.063	77.09						

Depending on the previous results the following can be calculated;

- For layered system, flow parallel to layers, arithmetic means (k_x*k_y)
- Sum k*h / sum h = 212.000 (thickness weighted permeability average)
- Sum k / layer = 212.000 (permeability average)
- Layered system, flow normal to layers, harmonic means (k_z)
- Sum h / sum (k/h) = 40.98 (thickness weighted permeability avg.)
- (1/k) / layer = 10.498 (permeability avg.)
- Random system, log normal k, small variation, geometric mean (if found)

  (k_x*k_y*k_z) ^ (1/3) = 122.579 (thickness weighted permeability)

  The results are:

Table (3) The variation results of Dykstra Parsons

Standard deviation	265.000		Fit Line	: ln(k) vs. z			
Variance	70225.092			M	-1.60689		
P10	16.545			B	4.2934517		
P90	536.323			Prob		ln(k)	k
P90/P10	32.416		P50	0.5	0	4.293452	73.21876
P50	95.937		P84.1	0.841	0.9985763	2.68885	14.71474
sum k	2120.000						
sum k^ω*h	0.244			**DP**	**0.7990305**		
sum h	10.000						

where;

- Heterogeneity parameter Hp = $k_{effective}$ / $K_{average}$ = (1+ sum v^2 /h) ^ -1
- v^2 = (1 - K_i/$K_{average}$) ^2
- $K_{average}$ = 212.000 , $k_{effective}$ 88.104 , HP 0.416 (1 for homo, 0 hetero)

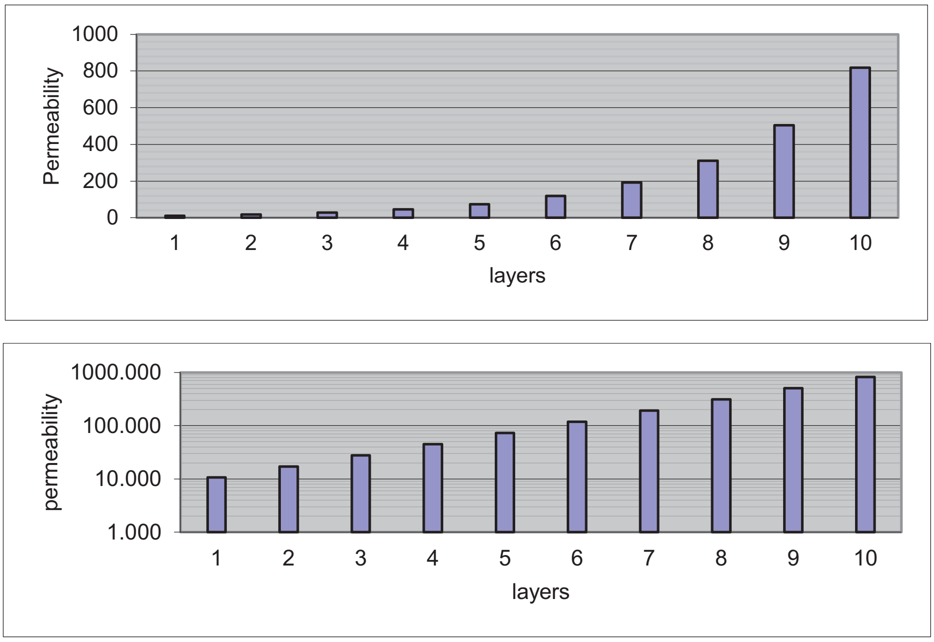

Fig. (1) (A, B) Permeability variation of layers of Dykstra parson's method

It can be found that the value of the Dykstra Parsons` coefficient = 0.799 which indicates a very heterogeneous reservoir (0 homo – 1 hetero). That proves that Hartha reservoir / Majnoon field is a very heterogeneous reservoir.

Discussion:

Although, it is the first time for calculation the heterogeneity for Majnoon Field / Hartha reservoir, but it is somehow expected that all the Iraqi reservoir have heterogeneous nature.

The degree of heterogeneity which can be only calculated by such methods it what matters, so the researcher can have a full idea about the field or the reservoir.

The higher heterogeneity is more preparations and considerations, must be taken during any later work especially when planning to water flooding and choosing the most proper design. The creating reservoir or geological model because these models cannot be undetailed or else all the importance of heterogeneity will be lost and thus the authenticity of the model will be lost as well.

The main model or design of Hartha reservoir must be detailed and with the fine gridding system.

Conclusion:

1- Dykstra Parsons is a straight forward method to calculate heterogeneity efficiently and accurately.
2- Hartha reservoir – Majnoon Field is a very heterogenous reservoir with a complicated nature.
3- Any further work on tis reservoir must be taken into consideration the detailed properties, and the authenticity of the model would be lost.

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