Estimation of cementation factor for a field of around Brack sandstone Reservoir

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الملخص:

يعتبر إيجاد معامل التماسك هو العامل الأكثر أهمية خلال دراسة تشبع الهيدروكربون/الماء من قياسات المقاومة الكهربية على اللباب السدادى أو من سجلات خط الاسلاك باستخدام معادلة أرشي. ومن تم تحديد قيمة عامل التثبيت بدقة. الهدف من هذه الدراسة البتروفيزيائية هو الحصول على عامل تدعيم أكثر واقعية لبعض عينات من مكمن الحجر الرملي. تم إنشاء المخططات التبادلية بين عامل مقاومة التكوين والمسامية لنقاط البيانات المقاسة ، ومن تم الحصول على قيم عامل الهندسة الداخلية **a** وعامل التماسك **m** من المخططات المتقاطعة لكل حقل. أظهرت المخططات المتقاطعة علاقة جيدة بين الخاصيتين **Ø** , **F** حيث تم حساب الخطأ القياسي لنقاط البيانات الفعلية للحقل ، ويرجع ذلك أساسا إلى عدم التجانس الداخلي والمزيد من الكسور في تكوين الحجر الرملي للحقل. كما تم حساب النسبة المئوية المتوسطة للأخطاء النسبية بين المعادلة الأساسية (**Humble Equation**) ونقاط البيانات الفعلية والارتباط أو العلاقة الجديدة ونقاط البيانات الفعلية للحقل.

ABSTRACT:

Estimation of cementation factor is one of the most important factors in determining the hydrocarbon/water saturations. In order to determine this factor accurately, core sample porosity, formation water resistivity and resistivity of the core sample hundred percent saturated by formation water, were performed using the Archie equation. The objective of this petro physical study is to obtain a more realistic cementation factor for some sandstone reservoir core samples. cross-plots between formation resistivity factor and porosity were created for measured data points The values of internal geometry factor a and cementation factor m were obtained from the cross –plots for each field .the cross-plots showed a good relationship between the two properties F & Ø where the standard error for the actual data points was calculated for a field .This is mainly due to the internal heterogeneity and more fractures in the Brack sandstone formation of field-Q. Also the percentage average relative errors between the humble equation and the actual data points and the new correlation and the actual data points were calculated for this field.

Keywords: cementation factor, porosity, formation resistivity factor, rock samples.

INTRODUCTION:

Petrophysical science is the science concerned with studying the physical properties of rocks and their relationship with fluids. Successful assessments of petrophysical reservoir properties are essential to determine the hydrocarbon capacity and reservoir system action, and help researchers predict the behavior of complex reservoir settings[1]. Previous research indicated that cementation factor value is greatly influenced by porosity, porous throat volume, water and mineral conductivity, and surface area per unit volume and cement. The cementation factor usually depends on the shape and surface area of the compound particles and the tortuosity factor [2-3]. The cementation factor in study was determined by using the experimental data .These measured data including core sample porosity, formation water resistivity and resistivity of the core sample hundred percent saturated by formation water. The analysis of these data were showed that more accurate value for cementation factor can be derived .the data were used in this study are from several wells in field .The Brack formation of the eastern sirte basin consists of mainly sandstones and shale`s resting with non-conformity on a basement complex of igneous and metamorphic rocks, and overlain by the upper cretaceous clastic rocks. The Brack formation is subdivided into three layers .the Brack sandstone represent braided and meandering fluvial deposit, where as the middle member Nubian represents shallow lake deposit. The layers of Brack formation comprise mainly of sandstone interbedded with siltstones and shale`s .the Middle Nubian consists of shale’s and silty shales.

Porosity:

Porosity is one of the most important petrophysical properties, which is a measure of the storage capacity of hydrocarbon. Porosity is defined as the ratio of the pore space within the rock to the total volume of the rock .porosity is created as a result of imperfect contact between rock grains .the void space created between the rock grains is called pore volume and the remaining part of the rock that occupied by the rock grains is called grain volume. Therefore, porosity can be expressed mathematically as

$Ø = Vp/Vb$, $Ø = Vp/(vp+vg)$ (1)

Ø Fractional porosity

Vp pore volume

Vg Grain volume

Vb Bulk volume

The porosity of petroleum reservoir ranges from 5% to 40%, which depends on rock texture and the digenetic process. Porosity is independent of grain diameter but strongly depends on packing and sorting in general small grain size and high angularity tends to increase porosity while an increase in particle size range (sorting) tends to decrease porosity [4].

Resistivity:

Electric resistivity was the earliest and still the most frequently measured physical property of rocks to locate oil and gas reservoirs [5]. Electrical resistivity methods involve the measurement of the apparent resistivity of soils and rock as a function of depth or position. The electrical resistivity of a material is its ability to resist or impede the flow of electric current. The resistivity of rocks is a complicated function of porosity, permeability, ionic content of pore water, and clay mineralization. Dry rocks are poor conductors; therefore, they normally exhibit extremely high resistivity [6].Reservoir rocks are porous and their pores are generally saturated with water, oil and gas .the formation water normally has resistivity of 0.04 to10 ohm.m at 70°F, which is much lower than that of the rock grains .As a result, they are conductors of moderate conductivity when they are saturated with water. The electric resistivity of a material can be defined by the following equation

$$R = r * A/L \quad (2)$$

Where:

R Resistivity

r Resistance

A cross-sectional area of the conductor available to current flow

L Length of the conductor

A/L Geometric factor which, which depends on the geometrical shape of the investigated rock Porosity and resistivity relationship (the concept of formation resistivity factor)

Archie (1942) found that the resistivity 100 % water saturated rocks is directly proportional to the resistivity of the water that saturates them [7] .The constant of proportionality is called formation resistivity factor (FF),which is defined as the ratio of the resistivity of the fully saturated rock to the resistivity of the water that saturates its pore space .

$$FF=Ro/Rw \quad (3)$$

A strong dependence of formation resistivity factor on porosity was observed Archie (1942). A large number of measurements on rock samples showed that the formation resistivity factor of shale – free rocks could be related to porosity by:

$$FF = Ø^{-m} \quad (4)$$

Where FF is the formation resistivity factor, Ø is the fractional porosity and m is cementation exponent .The above equation implies that a graphical presentation, the logarithm of the formation resistivity factor FF versus the logarithm of the fractional porosity Ø is a straight line with slop m [8] .Thus, cementation factor m as a function of formation resistivity factor FF and porosity Ø is

$$m = -\log FF / \log Ø \quad (5)$$

Therefore, m is generally referred to as the cementation factor; archie relationship was later modified by winsaure to the general form **.**

$$F = a/ Ø^{m} \quad (6)$$

Where a was defined as a constant and is a function of the tortuosity of the capillary path in the rock .winsaure ,et al applird the general Archie form in sandstone formation and they obtained m = 2.15 and a = 0.62.This equation is known as the Humble equation and it is the most widely used for sandstone in the world [9].

$$F = 0.62 / Ø^{2.15} \qquad (7)$$

The most widely used form of Archie equation for both limestone and dolomites is basic: [10-11]

$$F = 1 / Ø^{2} \qquad (8)$$

Experimental Technique:

Full diameter cores from six wells from Brack sandstone were prepared cleaned dried and left to cool in room temperature before conventional core analysis commenced**.**The cell helium expansion gas porosimeter used for measurement the grain volume of samples and calculate the porosity and bulk volume by early equations .The Formation resistivity factor was measured for the previous samples. The clean, dry samples were loaded in a stainless steel saturator and evacuated for 12 hours. A solution of 170 g /l (for x1-x6) sodium chloride was introduced at the end of the period , followed by pressurizing the system at 2000 psig for 12 hours to assist penetration**.**

The bring saturated plugs were placed in turn between electrodes at 1KH frequency and their electrical resistances were measured consecutive days until ionic equilibrium was achieved between the fluid and rock samples

Formation factor measurements are made on 100% brine saturated rock sample either at ambient conditions or elevated reservoir overburden pressure. Sample resistance is measured and converted to resistivity using sample cross-sectional area and length. Formation resistivity factor is calculated as the ratio of the sample resistivity to the resistivity of the water saturating it. The formation resistivity factor of a group of samples is plotted versus their porosities on log-log graph paper. The slope of the best fit line is the value of the cementation factor, m and the intercept is the value of, a.

Data Analysis procedures :

*The formation resistivity factor (F). was calculated for each well using Archie equation:

$F=Ro/Rw$

*The formation resistivity factor (F) was plotted against the porosity (Ø) on logarithmic scales for each well and for each field[12].

*Calculated **m** , **a** from the logarithmic cross plot and the standard error was determined**.**

Where:

a = represent the intercept of an extrapolated trend line on logarithmic F & Ø cross – plot with the porosity axis equal one**.**

m = represents the slope of trend line**..**

Standard error is the positive and negative error of the actual data points**.**

For each constant **a** & **m** the formation resistivity factor was calculated using the general form of Archie equation

$F = a/ Ø^{m}$

*The relative error between the actual equation and Humble equation was calculated**.**

$FA = R_O/R_W$ Actual Equation

$FH = 0.62/ Ø^{2.15}$ Humble Equation

Relative % =((FH – FA) / FA) * 100

*calculate the average error between the actual equation and Humble equation using the following equation**:**

Average error % = Sum error % / no. of point

*Calculate the relative error between the actual equation and the new correlation**.**

$FA = R_O/R_W$ Actual Equation

$FN = a/ Ø^{m}$ New correlation

Relative error % = ((FN – FA) / FA) * 100

*Calculated the average error between the actual equation and new equation.

Average error % = Sum error % / no. of point

The cross-plots of the formation resistivity factor versus porosity for wells Q2,Q4,Q5 and Q6 are showing blew, the cross-plots illustrate the obtained internal geometry factor **a** , cementation factor **m** ,correfficient $\mathbf{R^2}$ and the stander error.

Table (1) shows the measured data of well Q2

Well #	Sample #	Porosity fraction	Rw ohm-m	Ro ohm-m	FA
Q2	1	0.1021	0.061	5.290	86.72
	2	0.1571	0.061	1.886	30.92
	3	0.0709	0.061	4.610	75.57
	4	0.0964	0.061	3.613	59.23
	5	0.0802	0.061	5.185	85.00

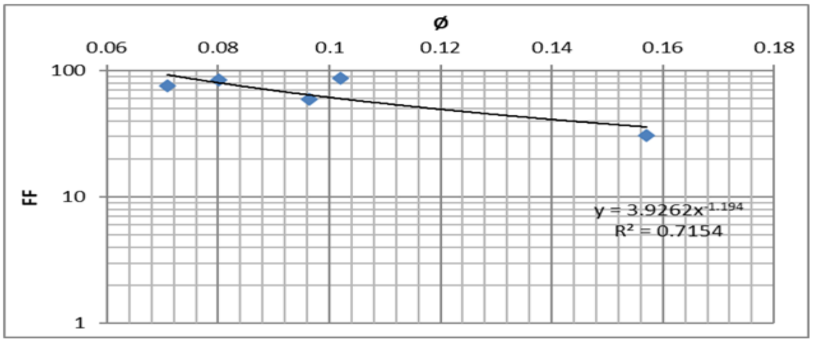

Figure (1) shows the formation resistivity factor versus porosity fro well Q2

Table (2) shows the measured data of well Q4

Well #	Sample #	Porosity fraction	Rw ohm-m	Ro ohm-m	FA
Q4	1	0.062	0.061	4.469	73.26
	2	0.131	0.061	2.365	38.77
	3	0.0992	0.061	3.068	50.30
	4	0.0879	0.061	3.135	51.39
	5	0.1443	0.061	1.804	29.57
	6	0.0545	0.061	4.574	74.98
	7	0.0961	0.061	3.384	54.89
	8	0.074	0.061	4.362	71.51
	9	0.1053	0.061	2.130	34.92
	10	0.0639	0.061	4.256	69.77
	11	0.1696	0.061	1.555	25.49

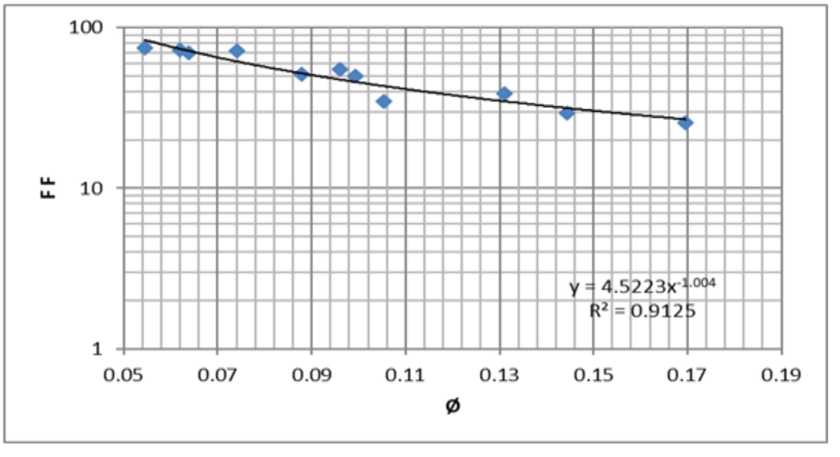

Figure (2) shows the formation resistivity factor versus porosity fro well Q4

Table (3) shows the measured data of well Q5

Well #	Sample #	Porosity fraction	Rw ohm-m	Ro ohm-m	FA
Q5	1	0.1731	0.061	1.995	32.70
	2	0.1037	0.061	2.968	48.66
	3	0.1271	0.061	2.372	38.15
	4	0.1372	0.061	2.072	33.97
	5	0.1418	0.061	2.901	47.56
	6	0.1262	0.061	2.332	38.23
	7	0.1201	0.061	3.357	55.03
	8	0.1218	0.061	1.695	27.79
	9	0.1366	0.061	2.221	36.41
	10	0.1049	0.061	3.507	57.49
	11	0.1022	0.061	3.361	55.10
	12	0.1301	0.061	2.102	34.46
	13	0.1054	0.061	3.179	52.11
	14	0.1473	0.061	1.671	27.39
	15	0.1617	0.061	1.548	25.38
	16	0.0963	0.061	3.430	56.23

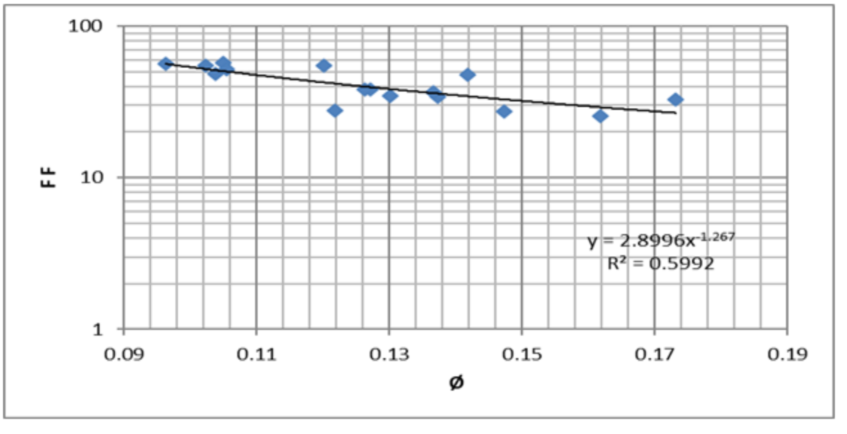

Figure (3) shows the formation resistivity factor versus porosity fro well Q5.

Table (4) shows the measured data of well Q6

Well #	Sample #	Porosity fraction	Rw ohm-m	Ro ohm-m	FA
Q6	1	0.132	0.061	2.489	40.80
	2	0.1016	0.061	4.338	71.11
	3	0.0936	0.061	4.871	79.85

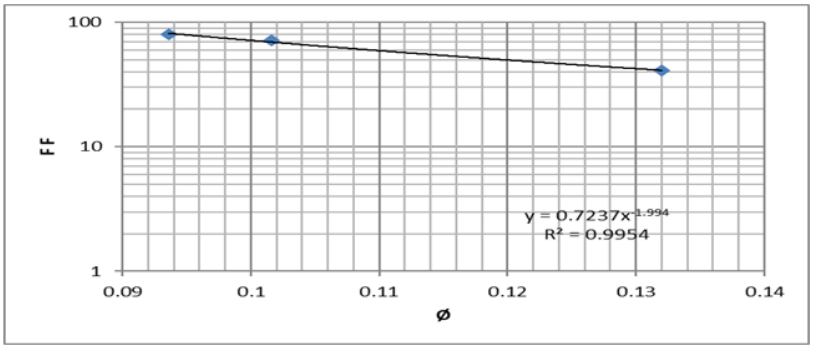

Figure (4) shows the formation resistivity factor versus porosity fro well Q6

Table (5) shows the results of internal geometry factor a, cementation factor m and the standard error for all field.

Well #	Internal geometry factor a	Cementation factor m	Standard error
Q2	3.94	1.19	0.11486
Q4	4.54	1.00	0.04873
Q5	2.90	1.27	0.07970
Q6	0.72	1.99	0.01506
Field	2.96	1.25	0.0776

Results and discussion:

The cross-plots of formation resistivity factor against the fraction porosity on the logarithmic scale were showed a good correlation all wells in the field .many samples selected from all wells and represent around the sandstone formation were used in this petrophysical analysis **.**

The following are the results of an average relative error of field.

•The average relative error of field from Humble equation is equal 62.18%.

•The average relative error of field from New correlation is equal 1.36%.

Conclusions :

- More realistic values for cementation factor m and the internal geometry factor a were derived from this petrophysical study for the field representing the Brack sandstone formation and using Archie general equation the proper correlation for field.

  $$F = 2.96 / Ø^{1.36}$$

- The calculated error of the data points when deriving the correlation was very small which indicated that the correlation is consistent.
- This study showed that Humble equation could not be applied for this formation due to the large difference and error, which were observed between this equation and the actual data points.
- The study showed using of the experimental data to derive the values of a & m will produce more accurate and correct results .

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