USES OF (EPT) LOG AS AN AID IN ENHANCING OIL SATURATION CALCULATION FOR CARBONATE RESERVOIRS

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ABSTRACT

A method for calculating water saturation (Sw) using (EPT) log is suggested and applied on one of carbonate reservoir. The present method assumes the petrophysical of Archie's law (m, n) are variables and (a) equal one. This gives a good agreement with Schlumberger interpretation and the production tests of the selected well. Water saturation was also calculated by Archie's law using the above constants obtained from core analysis of the studied well according to the reservoir units and rock type. It appears that there is very good agreement between the calculations which depend on core analysis according to rock type and the newly interpreted water saturation values by using the suggested method.

INTRODUCTION

Water saturation is one of the most important parameters used in reservoir studies due to it's importance in calculating oil saturation and therefore in obtaining oil reserve. There are several methods available for calculating these parameters such as Archie's law. According to this law, formation constant (a), cementation (m) and saturation exponent (n) factors are regarded constants in routine interpretation techniques. This may lead some errors in calculating water saturation and hence various works made by (IONC) have attempted to determine this parameter precisely.

Consequently, Electromagnetic Propagation Tool (EPT) log is used in present study to obtain a representative value of the cementation factor (m) which can be used properly for finding the water saturation of any carbonate oil reservoir.

Electrical resistively and petrophysical analysis of the studied cores were compared with the results which obtained from (EPT) log in an attempt to determine the most accurate estimation of the water saturation.

METHODS OF CALCULATIONS

The petrophysical constants (a, m, and n) can be obtained by using the open hole logs and core analysis as follows: (Schlumberger, 1987).

1. **(EPT) log in which $\left(S_{X_0}\right)$ can be calculated as:**

$$S_{X_0} = \frac{\left(t_{pl} - t_{pm}\right) + \phi\left(t_{pm} - t_{ph}\right)}{\phi\left(t_{pw} - t_{ph}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where:

S_{X_0} : Oil saturation of the invaded zone.

t_{pl} : Electromagnetic wave transmission time from (EPT) log.

t_{pm} : Electromagnetic wave transmission time through matrix.

t_{ph} : Electromagnetic wave transmission time through hydrocarbon.

t_{pw} : Electromagnetic wave transmission time through water.

ϕ: Porosity, which be calculated from the compensated Neutron log or (EPT) log.

(S_{X_0}) Can also be calculated from Microspherical Focused Log (MSFL) by using the equation below:

$$S_{X_0}^{n} = \frac{a * R_{mf}}{\phi^{m} * R_{X_0}} \qquad \text{………………………………….. (2)}$$

Where:

R_{mf} : Resistivity of mud filtrate.

R_{X_0} : Resistivity of the invaded zone.

By equating equations (1) and (2), cementation factor (m) can be calculated and then used to obtain water saturation value by direct application of Archie's law according to the following assumptions:

a. Formation factor (a) is constant and equal one.

b. (m, n) are regarded variables as follows:

(1) m = n =v ***(v =variable)***

This assumption has following limitations :(Freeman and Schlumberger, 1983)

- Uniformity of the invaded mud filtrates through the rock unit.
- Selection of accurate of mud filtrate resistivity (R_{mf}) and the electromagnetic wave transmission time of water.

According to this assumption, equation (2) can be written as:

$$S_{X_0}^{V} = \frac{R_{mf}}{\phi^{V} R_{X_0}} \qquad \text{………………………………..….. (3)}$$

$$V = \frac{Log\left(R_{mf} / R_{X_0}\right)}{Log\left(S_{X_0} / \phi\right)} \qquad \text{…………………………….. (4)}$$

$$\therefore S_{W}^{V} = \frac{R_{W}}{\phi^{V} R_{t}} \qquad \text{……………………………..…….. (5)}$$

Where:

R_W : Resistivity of the formation water.

R_t : Resistivity of the uninvaded zone.

(2) m = v and n =2

Water saturation can be calculated by the following equation:

$$S_{X_0}^{2} = \frac{R_{mf}}{\phi^{V} R_{X_0}} \qquad \text{……………………………………. (6)}$$

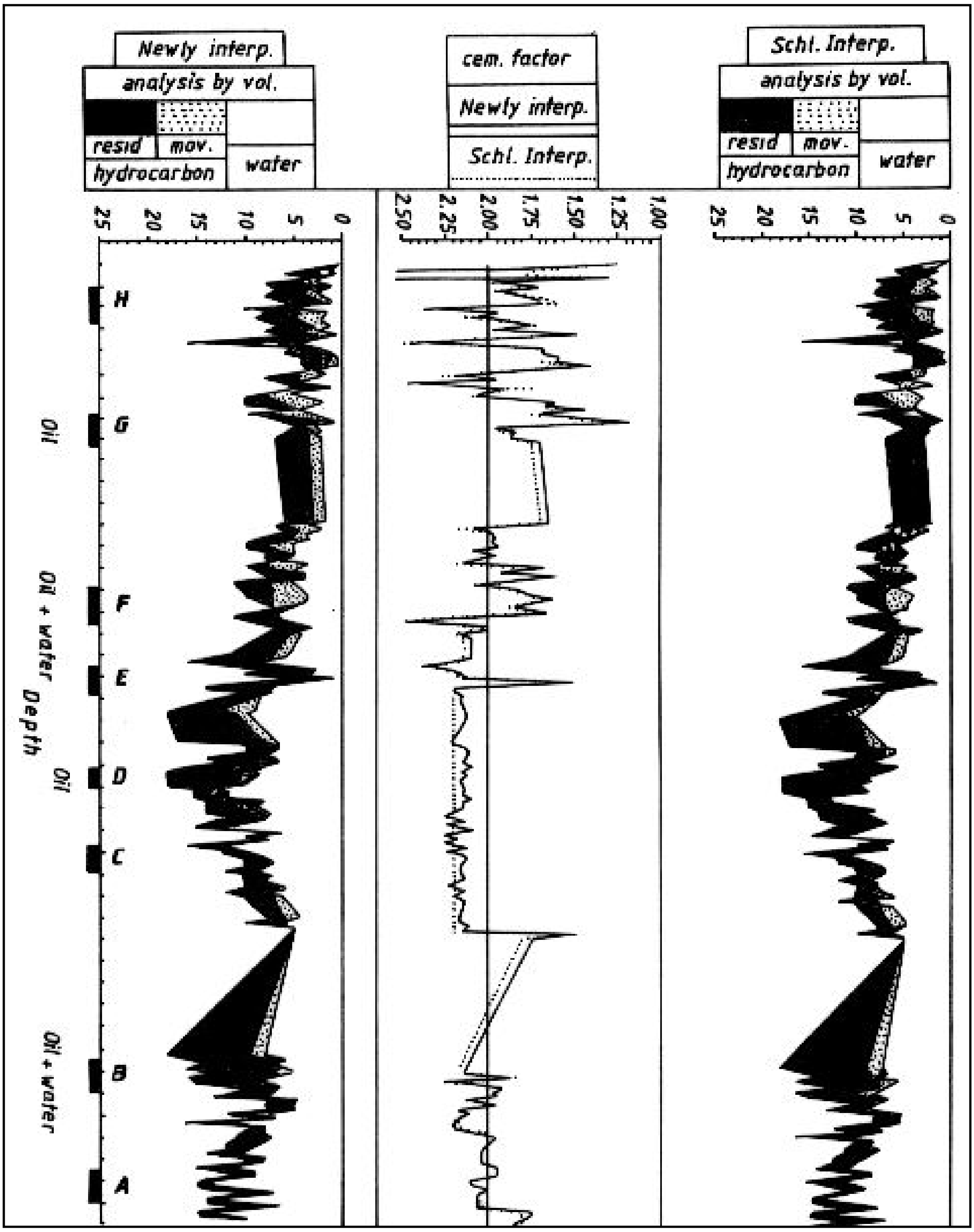
$$\therefore S_{W}^{2} = \frac{R_{W}}{\phi^{V} R_{t}} \qquad \text{………………………………….…. (7)}$$

2. Petrophysical core analysis

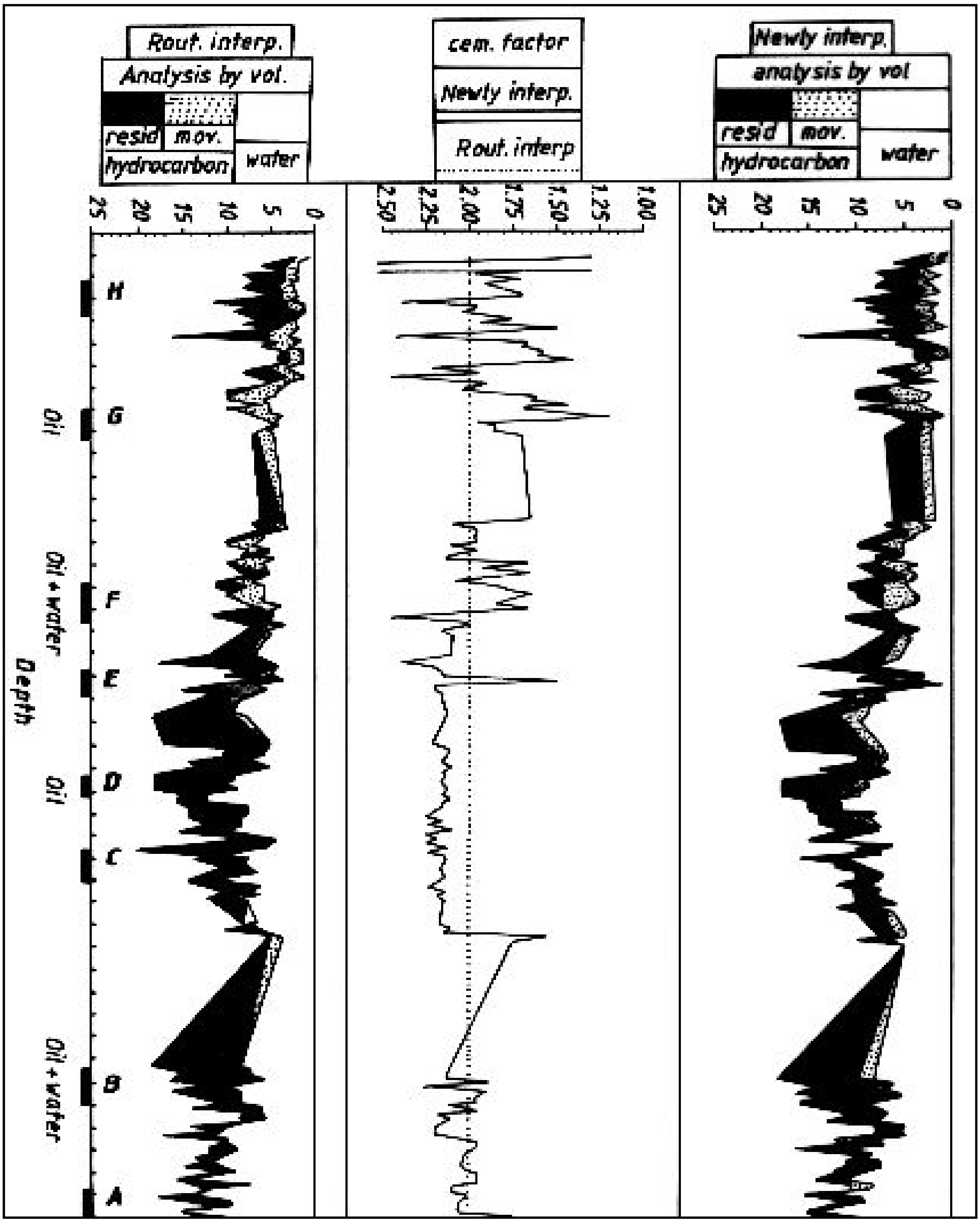
Average values of the petrophysical properties using core analysis is based on reservoir units division, rock type, and results of electrical resistivity were obtained and then substation these values in Archie's equation in order to calculate water saturation of the selected intervals of the studied carbonate formation.

RESULTS AND DISCUSSION

Figures (1) and (2) show the results of using the new approach of the studies parameters and it's comparison with Schlumberger results. It's clear that the result of the present work is greatly identical to Schlumberger results.



(Fig.1) Comparison between results of oil saturation and cementation factor with those of newly and Schlumberger interpretations



(Fig.2) Comparison between results of oil saturation and cementation factor with those of newly and routine interpretations

There is an agreement between the computed values of the petrophysical constant obtained by core description ranged (m = 1.1 – 1.57, n = 1.15-4.5), (Table -1), and the same values determined by core analysis which classified according to units classification (Table-2).

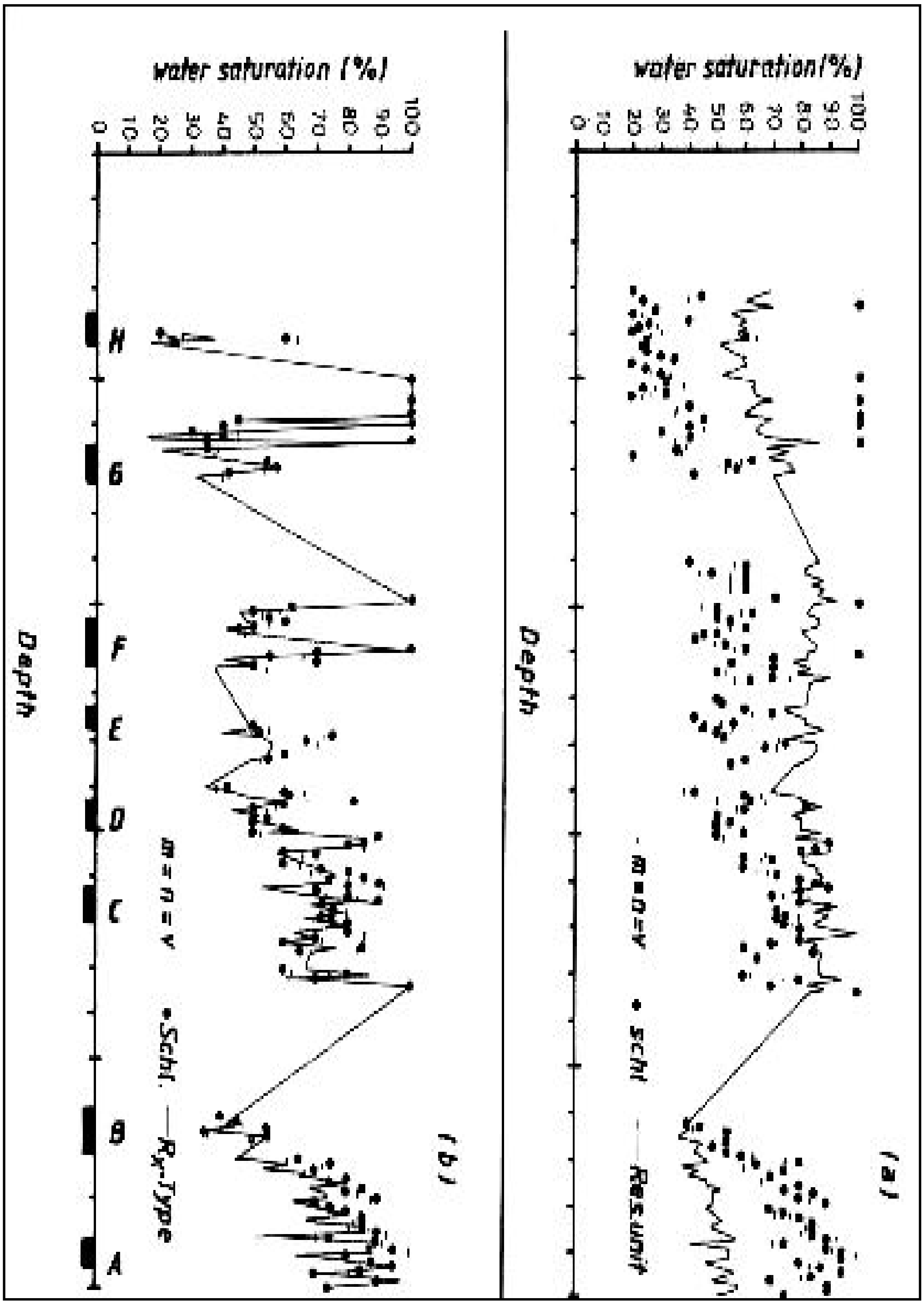
(Table-1) Core description of the studied well according to rock type of the selected carbonate reservoir, (Oil Exploration Company, 1989), (South Oil Company, 1978)

Zones	Depth Intervals	Core description	M	N
A	Interval (1) Interval (2)	Compacted limestone	1.57	1.15
B	Interval (1) Interval (2)	Compacted limestone contains shale fragments, low hardness, Stylolitic, vuggy and sometimes contains Oolite.	1.21	3.62
C	Interval (1)	Compacted limestone of moderate hardness, contain Pyrite, calcareous cement and some clay zones.	1.21	1.76
D	Interval (1) Interval (2) Interval (3)	Porous limestone with low hardness, vuggy and contain calcareous cement, fossiliferous and recrystallization can be observed.	1.37	3.6
E	Interval (1) Interval (2) Interval (3) Interval (4)	Compacted limestone of low hardness, highly fractured and contain vuggys filled by calcareous cement, Stylolitic, Pellets and fossils can be observed.	1.43	2.14
F	Interval (1) Interval (2) Interval (3)	Compacted limestone with moderate hardness, vuggy, porous and Stylolitic	1.1	4.5

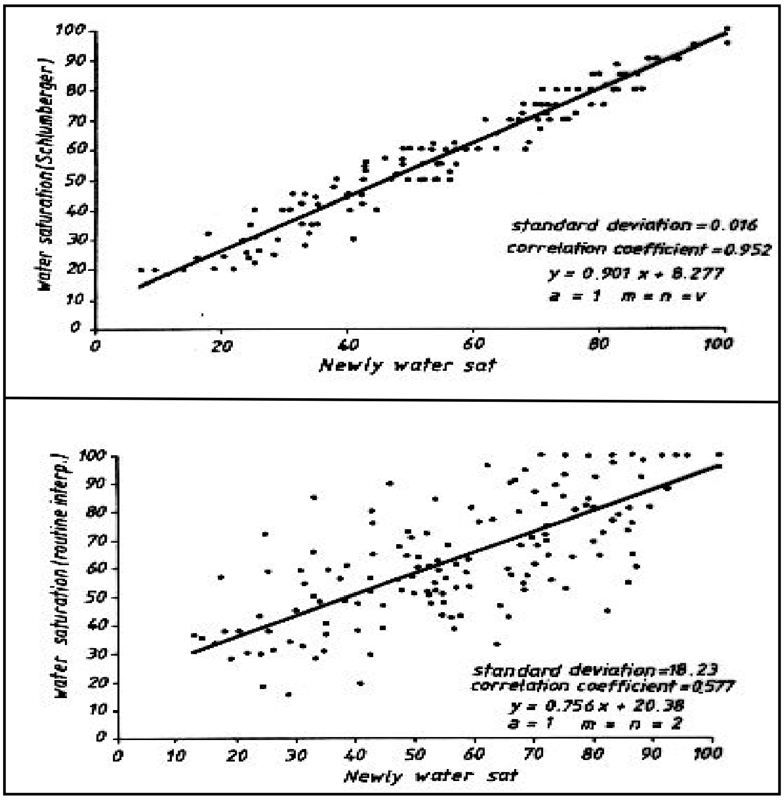
(Table-2) Petrophysical constants obtained from the core analysis according to reservoir units classification of the selected well, (South Oil Company, 1978)

Reservoir Units	**Petrophysical constants obtained from the core analysis**		
	m	**n**	**a**
Unit A	1.463	5.614	1.280
Unit B	1.596	4.689	1.715
Unit C	0.847	3.500	1.050

The present study results by using (EPT) log and assuming that both (m) and (n) values are variables were compared with Schlumberger interpretation and production test of the studies well. As appeared in figures (3) and (4), there is a close agreement between the above results. This indicates that assumption of taking (m) and (n) as variables are more reliable in calculating water saturation.



(Fig.3) Comparison between newly and Schlumberger interpretations with (S_w) calculations according to it's: (a) reservoir units (b) rock type



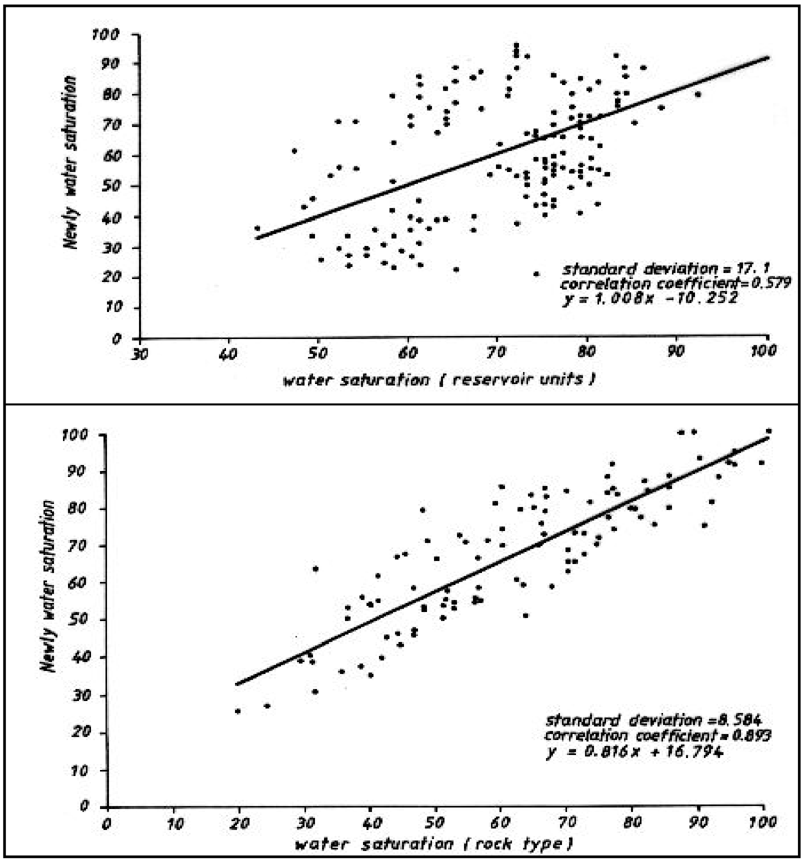
(Fig.4) Relationships between newly computed values of (S_w)
and Schlumberger, routine interpretations

In order to verify the various interpretation results, they have compared with step production test of the selected well. It appears that there is a good agreement between the present study and Schlumberger results (Table -3).

(Table-3) Comparison of (S_w) values obtained by various interpretations with the results of production tests of the selected well, (South Oil Company, 1979)

Perforating depth	% (S_W) obtained by using Pet. Constants as :			Production test results
	Variables from :		Constant by routine Interp.	
	Schl. Interp.	Sugg. Interp.		
A	70-95	66-100	70-100	Water flow
B	35-60	35-60	37-76	Oil flow with (20-30)% water
C	72-90	72-88	55-92	No test
D	50-60	49-55	48-68	Oil flow
E	42-52	37-56	39-85	No test
F	42-70	40-65	43-100	Oil flow with (10-25)% water
G	20-62	17-53	56-90	Oil flow
H	20-60	22-68	18-38	No test

Figure (5) shows the comparison between water saturation from the new approach and the results of core analysis according to two classifications, the first is based on reservoir units and the second is based on rock type. The obtainable results related to a rock type refer to clear improvement in water saturation calculation and the closeness of the results with the new approach, the above results were compared with the production tests of the studies well and a good agreement between the new approach and core analysis according to rock type was noticed (Table- 4).



(Fig.5) Relationship between newly interpreted water saturation values with those obtained from laboratory analysis (rock type and reservoir units)

(Table-4) Comparison of (S_w) values obtained by various interpretations with the results of production tests of the selected well, (South Oil Company, 1979)

Perforating depth	% (S_w) obtained by:			Production test results
	Core analysis according to :		Suggested Interp.	
	Reservoir unit	Rock type		
A	47-58	63-95	66-100	Water flow
B	30-46	35-64	35-60	Oil flow with (20-30)% water
C	83-100	64-92	72-88	No test
D	78-91	51-67	49-55	Oil flow
E	69-86	36-58	53-72	No test
F	77-90	39-50	40-65	Oil flow with (10-25)% water
G	66-77	31-40	17-53	Oil flow
H	52-61	20-31	26-64	No test

CONCLUSIONS AND RECOMMENDATION

1. By comparison of the suggested approach with schlumberger results and production test, it's clear that they were not in agreement because of using the petrophysical constants obtained from core analysis according to reservoir units regardless the rock type.
2. As a result, final values of (S_w) would be erroneous if the petrophysical parameters regarded as constants.
3. To obtain a good accuracy, (EPT) log should be runned to enhance water saturation calculation.
4. It is the best to determine the petrophysical constants according to lithological classification instead of reservoir unit classification.
5. The new results can be used successfully in calculation the oil reserve of the calcareous reservoir.
6. The same principles of the suggested method can be applied on the clastic reservoir.
7. The new results can be used in well completion at well development stage because of it's accuracy in determining the performance intervals stimulation technique type.

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