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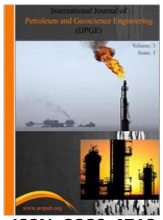

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Investigation of Porosity Effect to Determine Uncertainty in Archie's Water Saturation Water Saturation Equation Parameters, Case Study: Two Reservoir Formations from an Iranian Oil Field

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Abstract

Keywords:

Cementation Factor,
Monte-Carlo method,
Porosity,
Uncertainty analysis.

Formation A and Formation B are main reservoir intervals in one of the Iranian oil fields which were considered for uncertainty study. Uncertainty in calculated water saturation has a direct economic impact on both exploration and development projects, yet is rarely quantified by petrophysicists.
Cementation factor (cementation exponent) is one of the most important parameters in saturation equation to determine the water or hydrocarbon saturations. It acts as a power of porosity in the most of saturation equations which increases the importance of this parameter.
Monte-Carlo Simulation and @Risk software was used for uncertainty analysis. Four different scenarios were assumed and different models were run for each zone. The results show that cementation factor is highly important in saturation calculations and small variation in cementation factor values can affect the results of water saturation determination considerably. Also in high porosity zone Shell formula is a suitable equation for calculation of cementation factor (m), but in low-porosity zone using a constant value for cementation factor is better than using Shell formula.

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1. Introduction

Based on our understanding of the rocks and the petrophysical measurements of logs and core experiments, an assessment of the uncertainty in the derived petrophysical properties (Water saturation) can be estimated [1]. This may be achieved using a calculation technique and assumptions of the uncertainties in the measurements and parameters used in the calculations.

The purpose of this study is to evaluate uncertainty in water saturation in zone A and Zone B reservoirs in one of the Iranian oil-fields.

Based on petrophysical and geological properties, there are 2 reservoir intervals (zone-2 of Interval A and zone-1 of Interval B) in each well. The reservoirs were clean carbonate so Archie's equation was used for water saturation calculations.

Archie established a relationship between porosity, water resistivity, formation resistivity and water saturation in clean formations [2]. Archie's method has the ability of continuous determinations of saturation through whole reservoir interval [3]. The equation is as follows:

$$S_w^n = F\frac{R_w}{R_t} \quad (1)$$

Where Rw is the formation brine resistivity, Rt is the true formation resistivity (rock pores filled with brine water and hydrocarbon) and F is the formation resistivity factor which F factor can be calculated by the following equation:

$$F = \frac{a}{\varphi^m} \quad (2)$$

Where a is tortuosity factor, φ is porosity and m is cementation factor (cementation exponent).

In above equations porosity and Rt can be determined based on well log data. Rw is calculated from appropriate tables using brine salinity and reservoir temperature. At last a, m and n should be calculated based on special core analysis data. Since special core lab data are not available in all reservoir studies, a number of methods developed to determine these parameters but still core lab measurements are the most accurate one. Shell formula is a famous common correlation which is widely used in petrophysical studies (such as this study). The equation for Shell formula is as follows:

$$m = 1.87 + \frac{0.19}{\varphi} \quad (3)$$

Another experimental relation is Boraei formula (proposed for Abu Dhabi carbonates, [4]):

$$m = 2.2 - \frac{0.035}{\varphi - 0.042} \quad (4)$$

Figure 1 shows calculated cementation factor (m) using these experimental methods. As illustrated in this picture, in low porosity values, m increases in Shell formula while decreases in Boraei formula.

In order to illustrate the uncertainty and the relative importance of each factor, a Monte-Carlo simulation is run for the following cases in A and B Formations (Reservoir zones). For each reservoir, four different scenarios and Monte-Carlo simulation methods have been applied to evaluate the water saturation uncertainty and P5, P50 and P95 have been considered as possible, probable and proved Sw values.

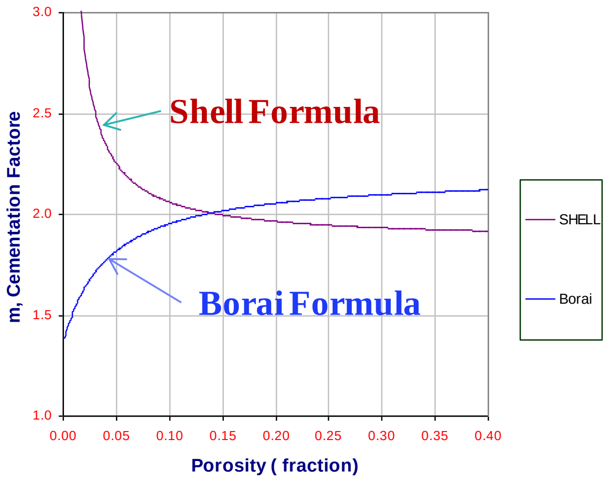

Figure 1: Calculated m using experimental methods.

2. Uncertainty in Formation A

In the studied oil field, formation A is divided into 3 zones which only A-2 is a reservoir zone. Fig. 2a shows status of porosity, saturation and Fig 2b shows histogram of PHIE just in A-2 zone. The available petrophysical data from A-2 zone is used for uncertainty analyses using Monte-Carlo method.

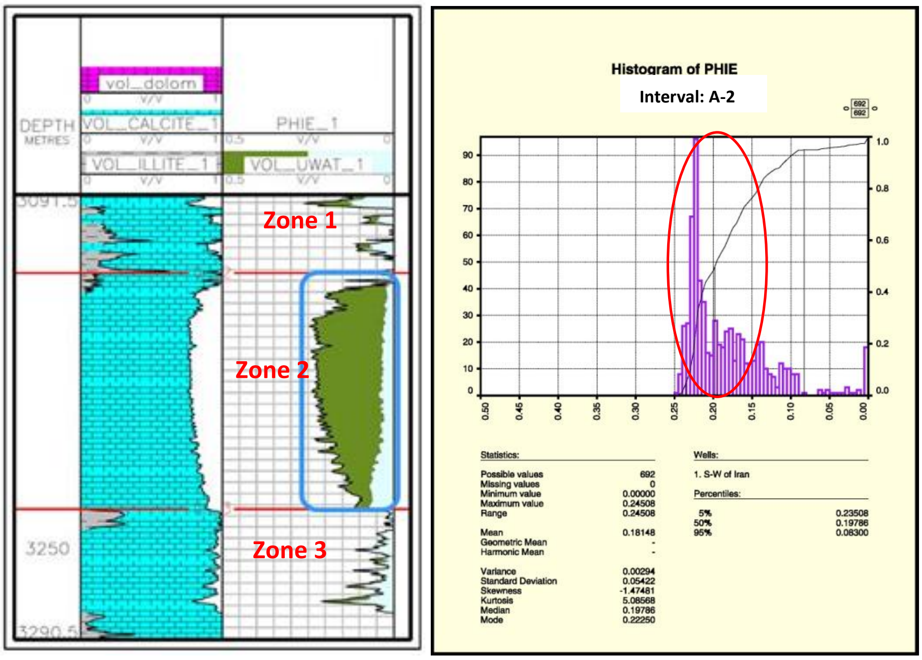

Fig. 2: (a) Porosity and saturation in 3 zones of Formation A; (b) histogram of PHIE just in A-2 zone.

Based on Monte-Carlo method, uncertainty in result is due to uncertainty in input parameters [5,6]. For saturation water (Sw) calculation, input parameters are porosity, Archie parameters and resistivity of formation and water. Triangle distributions were determined for porosity, water resistivity and formation resistivity (Fig 3-a, b and c). For m and n parameters two kinds of distribution were determined separately: triangle and distribution obtained and fitted on values from shell formula (Fig. 4-a and b**Error! Reference source not found.**).

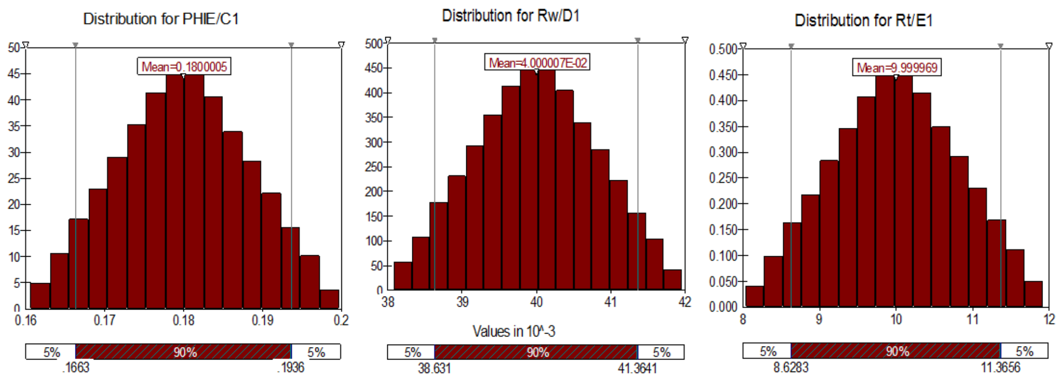

Fig. 3: Triangle distribution for (a) porosity, (b) water resistivity, and (c) formation resistivity.

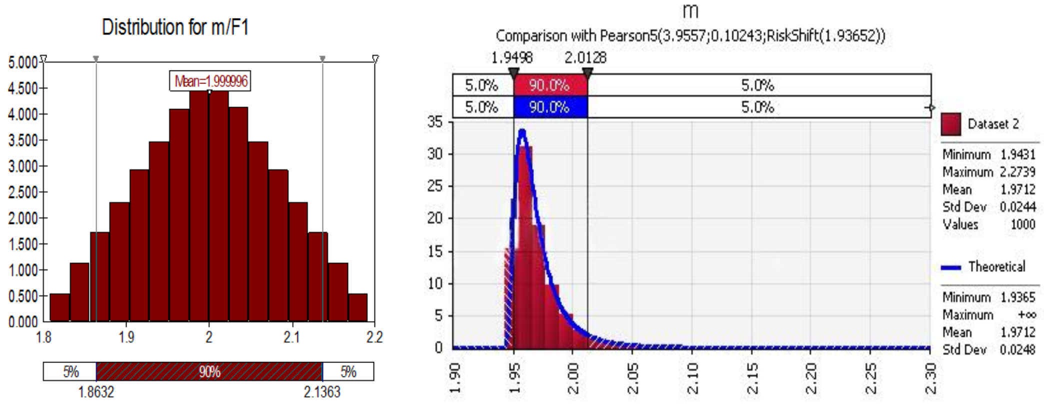

Fig. 4: (a) Triangle distribution for cementation factor; (b) Fitted curve on distribution obtained from Shell formula.

In A-2 zone four different cases were modeled in @Risk software (Iteration=1000). Table 1 shows input values in this modeling. The results of Monte-Carlo modeling in @risk software for case A-2_A are shown in Fig 5, and it can be said that the most important factors affecting the uncertainty in the calculated water saturation in this case are PHIE and Rt.

Also model was run for other cases which the tornado charts of them are shown in Fig 6. As shown in this figure, in cases 2 and 3 (m=2) cementation factor is the most important parameter in Sw calculation.

Furthermore a sensitivity study was done on different cases. Fig 7 shows the mean, +/- std deviation and range of 5%-95% of calculated Sw in different scenarios. As a result, the best case for calculation of Sw in Formation A in this field is fourth scenario. It means calculated m using Shell formula is acceptable and useful.

Table 1: Summary of uncertainty input in A-2 zone.

Case	□	Rt	Rw	m	n
A-2_A	0.18+/- 0.02	10 +/- 2	0.04 +/- 0.002	Shell formula	2 +/- 0.05
A-2_B	0.18+/- 0.02	10 +/- 2	0.04 +/- 0.002	2 +/- 0.05	2 +/- 0.05
A-2_C	0.18+/- 0.02	10 +/- 2	0.04 +/- 0.002	2 +/- 0.05	Shell formula
A-2_D	0.18+/- 0.02	10 +/- 2	0.04 +/- 0.002	Shell formula	Shell formula

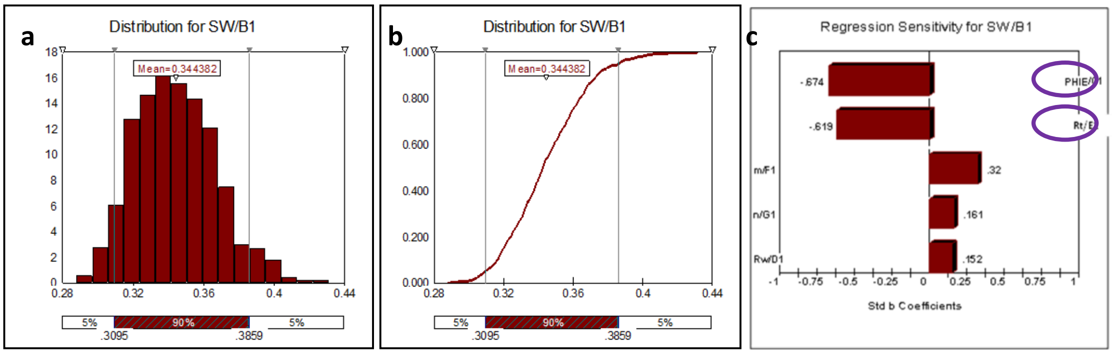

Fig. 5: The result of Monte-Carlo modeling in Case A-2_A: (a) Distribution of calculated Sw; (b) Cumulative distribution of calculated Sw; (c) Tornado chart; Factors with the greatest impact on Sw.

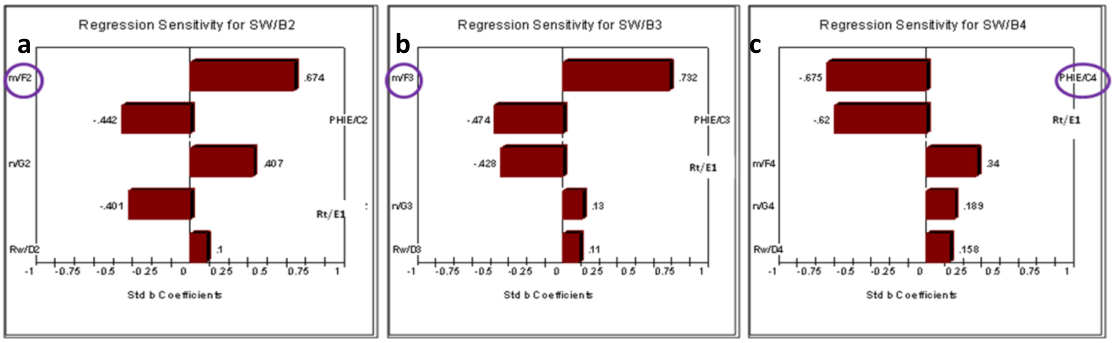

Fig. 6: Tornado chart : (a), (b) and (c) Factors with the greatest impact on Sw in Case A-2_B, A-2_C and A-2_D respectively.

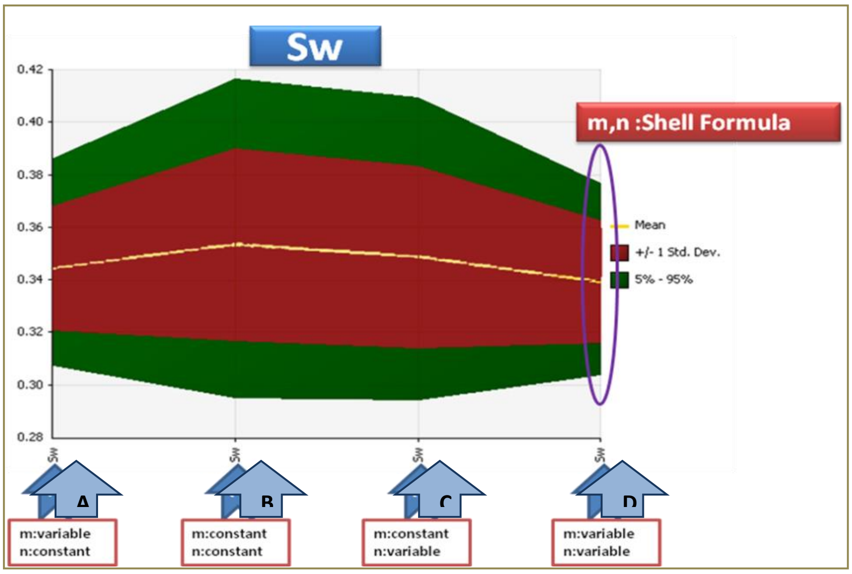

Fig. 7: Summary Graph of Different Scenarios in A-2.

3. Uncertainty in Formation B

Formation B in studied oil field is divided into 6 zones which zone 1 and 5 are reservoir zones. Fig. 2 shows status of porosity and saturation and Fig 8b shows histogram of PHIE just in B-1 zone which was considerated for uncertainty study.

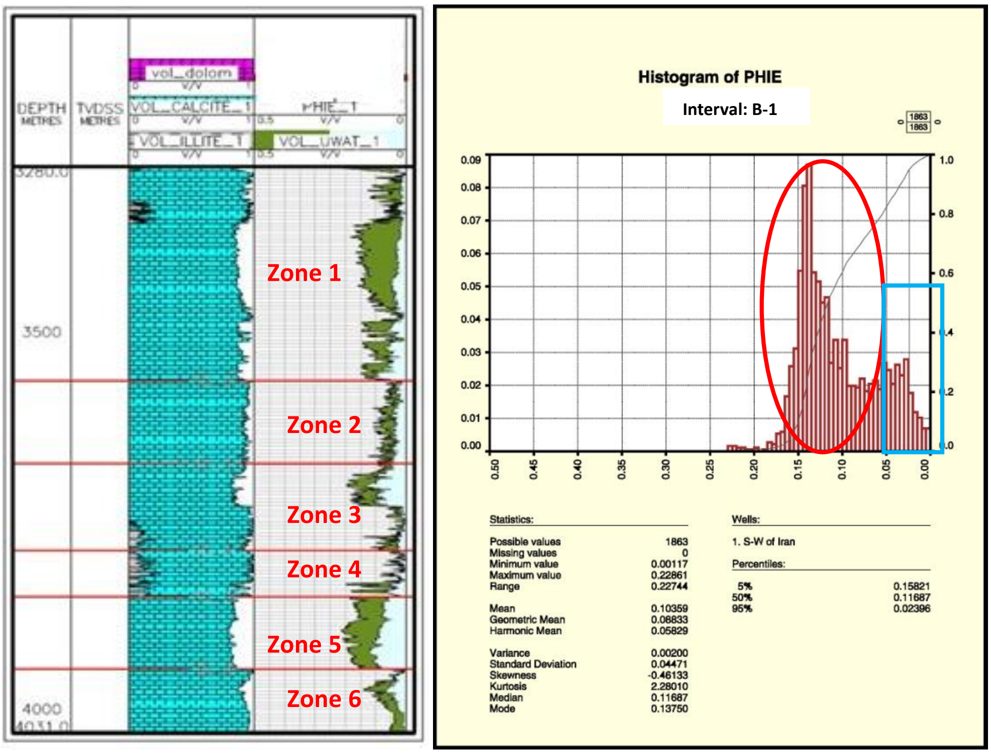

Fig. 8: (a) Porosity and saturation in 6 zones of Formation B; (b) histogram of PHIE just in B-1 zone.

Based on porosity this zone divided to two cases as B-1 low porosity and B-1 high porosity. Input values for these cases are represented in Table 2 and 3.

Summary graph of different scenarios in B-1-low porosity and B-1-high porosity are shown in Fig 9 and 10 respectively. Based on these figures it can be concluded that in low porosity reservoirs, a constant value for cementation factor (2nd and 3rd scenarios) is beter than using Shell formula but in high-porosity reservoirs use of variable values for cementation factor show beter results.

Table 2: Summary of uncertainty input, B-1-low porosity.

Case	□	Rt	Rw	m	n
B-1-low por_A	0.06+/- 0.02	155 +/- 45	0.04 +/- 0.002	Shell formula	2 +/- 0.05
B-1-low por_B	0.06+/- 0.02	155 +/- 45	0.04 +/- 0.002	2 +/- 0.05	2 +/- 0.05
B-1-low por_C	0.06+/- 0.02	155 +/- 45	0.04 +/- 0.002	2 +/- 0.05	Shell formula
B-1-low por_D	0.06+/- 0.02	155 +/- 45	0.04 +/- 0.002	Shell formula	Shell formula

Table 3: Summary of uncertainty input, B-1-high porosity.

Case	□	Rt	Rw	m	n
B-1-high por_A	0.13+/- 0.02	23 +/- 5	0.04 +/- 0.002	Shell formula	2 +/- 0.05
B-1- high por_B	0.13+/- 0.02	23 +/- 5	0.04 +/- 0.002	2 +/- 0.05	2 +/- 0.05
B-1- high por_C	0.13+/- 0.02	23 +/- 5	0.04 +/- 0.002	2 +/- 0.05	Shell formula
B-1- high por_D	0.13+/- 0.02	23 +/- 5	0.04 +/- 0.002	Shell formula	Shell formula

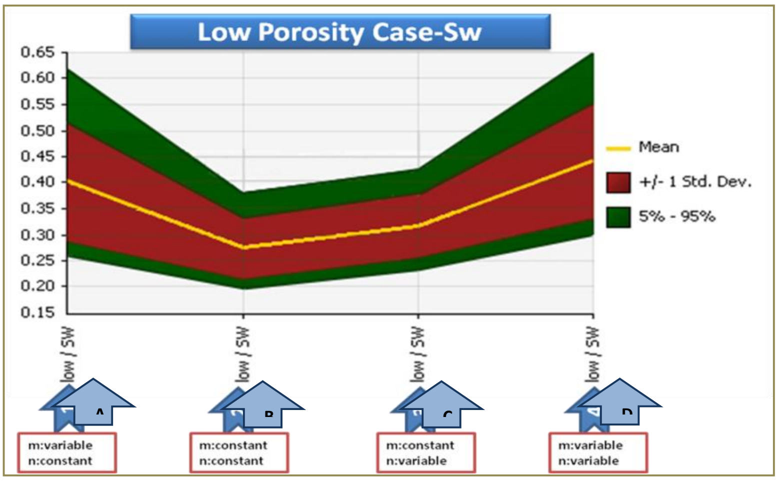

Fig. 9: Summary Graph of Different Scenarios in B-1-low porosity.

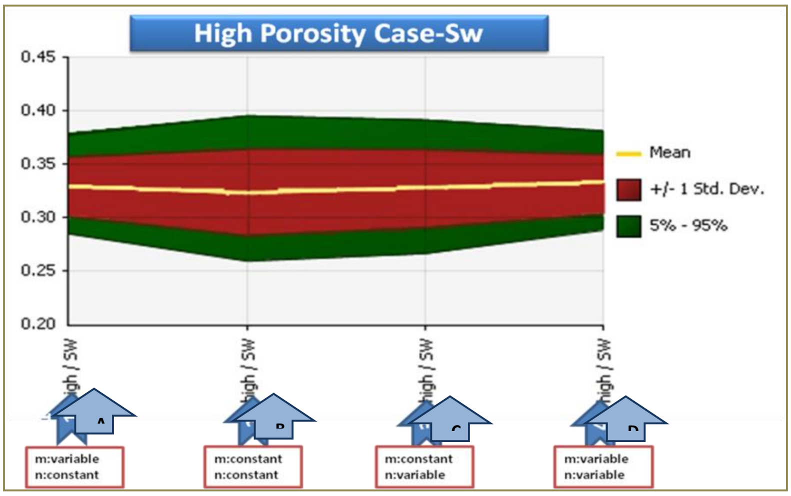

Fig. 10: Summary Graph of Different Scenarios in B-1-high porosity.

3. Conclusion

In this study, calculated petrophysical parameters (porosity and saturation) are used to evaluate uncertainty of water saturation (Sw) in reservoir intervals. The uncertainty of water saturation is dependent to the uncertainty of all petrophysical parameters which are used for calculations. As mentioned in the text based on distribution of input parameters, 4 different scenarios were assumed and different models were run for each zone.

The results show in high porosity zones (such as A-2 and B-1-high-porosity intervals), using a constant value for cementation factor (m) in saturation water equations may cause large errors and uncertainties in hydrocarbon saturation determination, so Shell formula is a suitable equation for calculation of cementation factor (m), but in low-porosity zone (such as B-1-low-porosity) using a constant value for cementation factor is better than using Shell formula.

Reference

[1] Hamada G.M., Al-Awad M.N. Alsughayer. Variable saturation exponent effect on determination of hydrocarbon saturation. SPE Asia Pacific Oil & Gas Conference and Exhibition, Melbourne, Australia, 2002, SPE 77887.

[2] Salem H.S. Derivation of the cementation factor (Archie's exponent) and Kozeny-Carman constant from well log data, and their dependence on lithology and other physical parameters. 1993, SPE 26309.

[3] Hamada G.M., Al-Awad M.N. Evaluating uncertainty in archie's water saturation equation parameters determination method. SPE Middle East Oil Show, Bahrain, 2001, SPE 68083.

[4] Boraei A.M. A new correlation for cementation factoring low-porosity carbonates. SPE Annual Technical Conference and Exhibition held in Las Vegas, 1985, SPE 21316.

[5] Liu N., Oliver D.S. Evaluation of Monte Carlo methods for assessing uncertainty. SPE Annual Technical Conference and Exhibition, New Orleans, 2003, SPE 84936.

[6] Wadsley A.W. Markov chain Monte Carlo methods for reserve estimation SPE International Petroleum Technology Conference, Doha, Qatar, 2005, SPE 10065.