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Cementation exponent estimate in carbonate reservoirs: A new method

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Abstract

There are two approaches for measuring hydrocarbon saturation: well log interpretation and usually developed formulas. Archie's equation is one of the most fundamental equations used for water saturation calculation. Archie's equation includes three factors: cementation factor, tortuosity and saturation exponent. Archie determines these factors based on lab results in sandstone and provides fixed value for them. Carbonate reservoirs have a variety of textures, shapes and distribution of pores; therefore, the mentioned factors, especially cementation are not considered constant. In this study, the relationship between cementation factor and density log was examined because cementation factor is defined as a parameter that has a close relationship with density. By calculating the matrix density and accordance factor between the matrix density and cementation factor from core's analysis, a log will be generated that can estimate the variation of cementation factor around the borehole. This method is useable for calculating the cementation factor in carbonate rocks.

Keywords: Cementation factor, carbonate reservoir, density, new method, exponents.

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1. Introduction

Geochemistry and geophysics are efficient methods for estimating various types of hydrocarbon reservoirs [1]–[7]. For the purpose of water saturation calculation (Sw) in carbonate reservoirs, the estimation of cementation factor (*m*), which is the porosity exponent, is necessary. The parameter *m*'s value depends on the type and volume (percentage) of the porosity; therefore, it is not a constant, particularly in heterogeneous reservoirs. Significant errors can be caused by an inaccurate estimation of *m* in the calculation of water saturation when using Archie's equation [8] and it can be followed by discrepancies between log interpretations and production test results [9]. The cementation exponent can be determined by the grain and pore shapes and how they are connected [10]. The generally accepted value of '*m*' is 2 where it represents interparticle porosity [8]. Due to the better connectivity for electrical current in fractured rocks, the value of *m* tends to decrease in these rocks [11]. Using parallel dual porosity systems for such rocks is suggested. In rocks with a high percentage of non-touching vugs, the value of *m* tends to be higher than 2 as reported by Lucia [12]. In carbonate reservoirs, porosity has different proportions that change with depth, on account of the fractures and vugs that co-exist with the matrix (intra and interparticle connections). In 2010, Al-Ghamdi et al. improved Aguilera's [13] physical model for triple porosity systems, to account for the presence of matrix fractures and vugs [13].

In this study, well logging and cores analysis data were used for determining porosity type and estimating the relationship between density log and cementation exponent in one of the carbonate reservoirs in the south of Iran. This region is a pioneer in mineral processing activities in Iran [14]–[16].

2. Methodology and programming

Cementation factor can be defined as a parameter that has a close relationship with density. Consequently, when cementation increases between grains of rock, rock density increases too. Change in the lithology and conversion of limestone to dolomite can affect the degree of the cementation factor. Since, in other methods that have been proposed, the effect of these parameters has not been considered, in this study the relationship between the cementation factor and density log will be examined.

For determining a relationship between '*m*' and density log, at first a petrophysical interpretation from a reservoir should be prepared; also, the type and volume of lithology, oil and water zones and matrix density should be determined. Then, the accordance factor between matrix density and the cementation factor is obtained from core analysis by using Equation (1) as follows:

$$\begin{cases} V_{ill}n_{ill} + V_{clc}n_{clc} = N_{oil\ zone} \\ V_{ill}n_{ill} + V_{clc}n_{clc} = N_{water\ zone} \end{cases} \tag{1}$$

In this equation, two types of lithology are considered. In formations with more than two types of lithology, an equation system should be formed with higher degrees. In this equation, n_{ill} is the accordance factor between matrix density and illite, n_{clc} is the accordance factor between matrix density and calcite, V_{ill} is the average volume of illite in each zone, V_{clc} is the average volume of calcite in each zone, $N_{oil\ zone}$ is the accordance factor in oil zone and $N_{water\ zone}$ is the accordance factor in water zone.

The density of rock matrix can be determined from Equation (2) as follows:

$$\rho_b = \rho_{mat}(1-\emptyset) + \rho_f(\emptyset) \tag{2}$$

where ρ_b is bulk density, ρ_{mat} is matrix density, ρ_f is fluid density and $\emptyset$ is porosity.

Now, by replacing ρ_{mat} and the accordance factor in Equation (3), cementation factor can be calculated around the borehole as follows:

$$m = \rho_{\text{b}} + ((\textstyle\sum_{i=1}^{n} n_i v_i) \times \rho_{\text{mat}}) - (\emptyset \times \rho_{\text{f}}) \tag{3}$$

This formula is written in MATLAB as a programme named CEEC.

3. Data

In this study, well logging and cores analysis data from one of the carbonate reservoirs of the South of Iran were used. Fahlian formation is the main reservoir rock of this field that has about 500 m carbonate deposits, gradual boundary over Garou formation and discontinuous boundary under the Gadvan formation. Based on the logs shown in Figure 1, there are four types of lithology in this reservoir: limestone, dolomite, illite and sandstone. The main lithology is limestone.

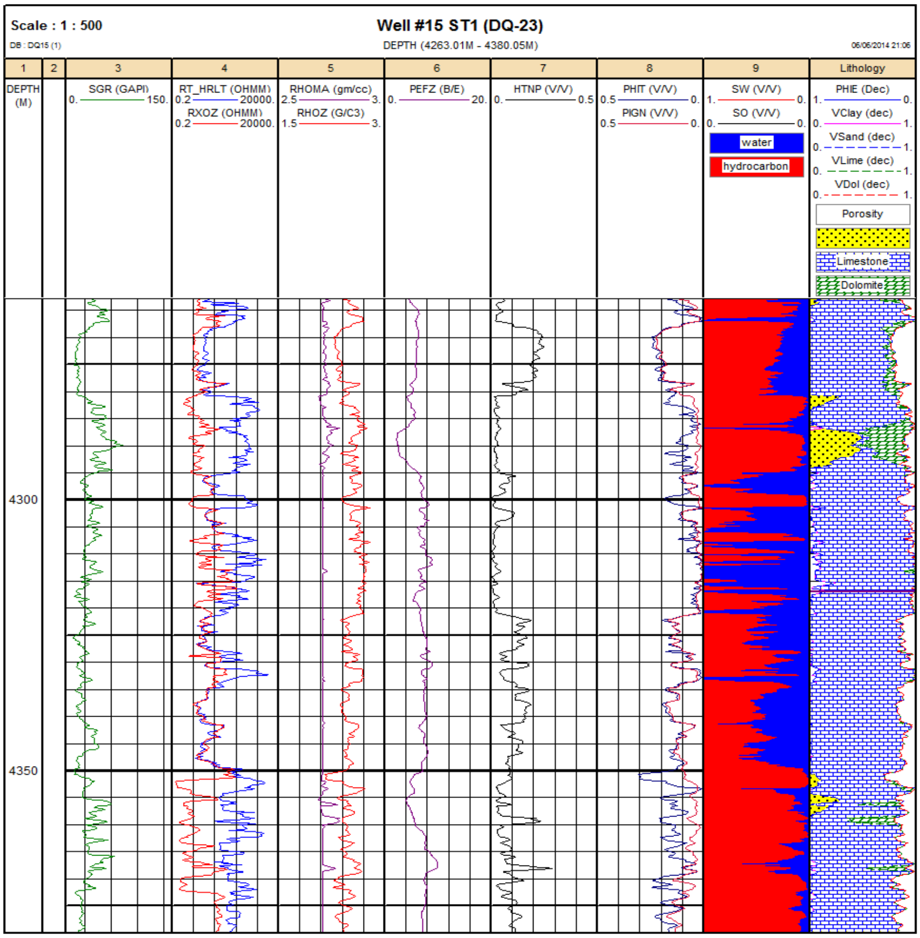

Figure 1. Petrophysical log

4. Results and Discussion

First, by using Equation (2), the density matrix was calculated in the borehole. Then, by cross-plotting *m* versus matrix density, the calibration factor in each of the oil and water zones was determined. The slope of the straight line represents the calibration factor. In Figures 2 and 3, the cross plots in oil and water zones are shown, respectively.

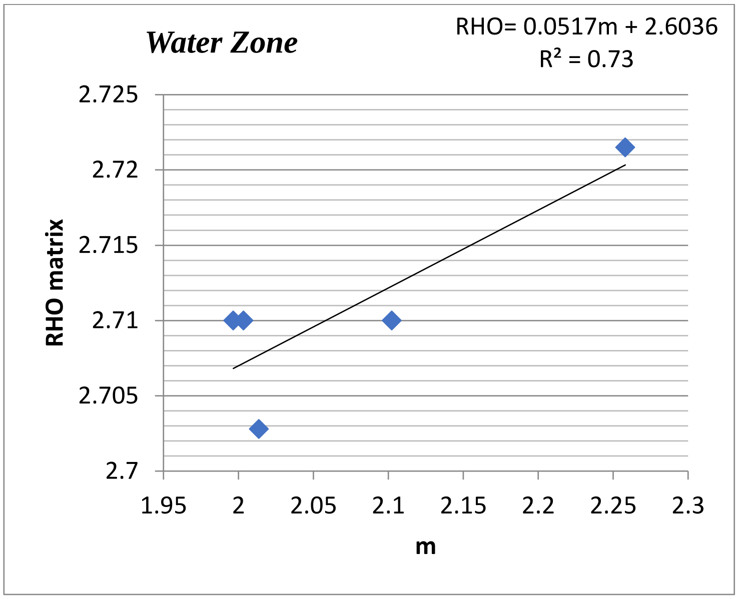

Figure 2. Cross-plot m versus matrix density in the water zone

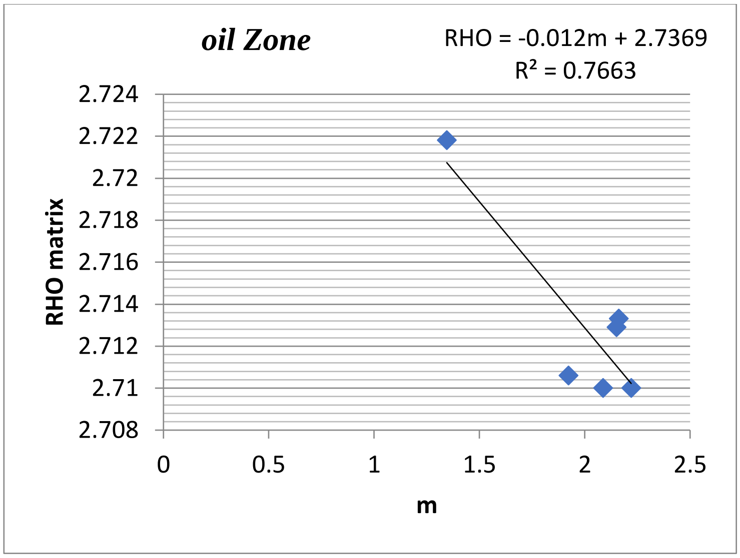

Figure 3. Cross-plot m versus matrix density in the oil zone

Finally, the four-variable system of equations was formed. By solving this equation, the accordance factor can be calculated as follows:

$$\begin{cases} 0.742m_{lime} + 0.021m_{sand} + 0.006m_{dol} = 0.0517 \\ 0.651m_{lime} + 0.002m_{clay} + 0.103m_{sand} + 0.111m_{dol} = -0.012 \\ 0.89m_{lime} + 0.023m_{clay} + 0.002m_{dol} = 0.0517 \\ 0.832m_{lime} + 0.004m_{clay} + 0.006m_{sand} + 0.009m_{dol} = -0.012 \end{cases} \quad (4)$$

In this equation, m_{lime}, m_{clay}, m_{sand} and m_{dol} are the accordance factors between matrix density and limestone, clay, sandstone and dolomite, respectively.

Now, by replacing the matrix density and accordance factor calculated from Equation (4) in Equation (3), the cementation factor of the borehole will be determined. The results are shown in Figure 4.

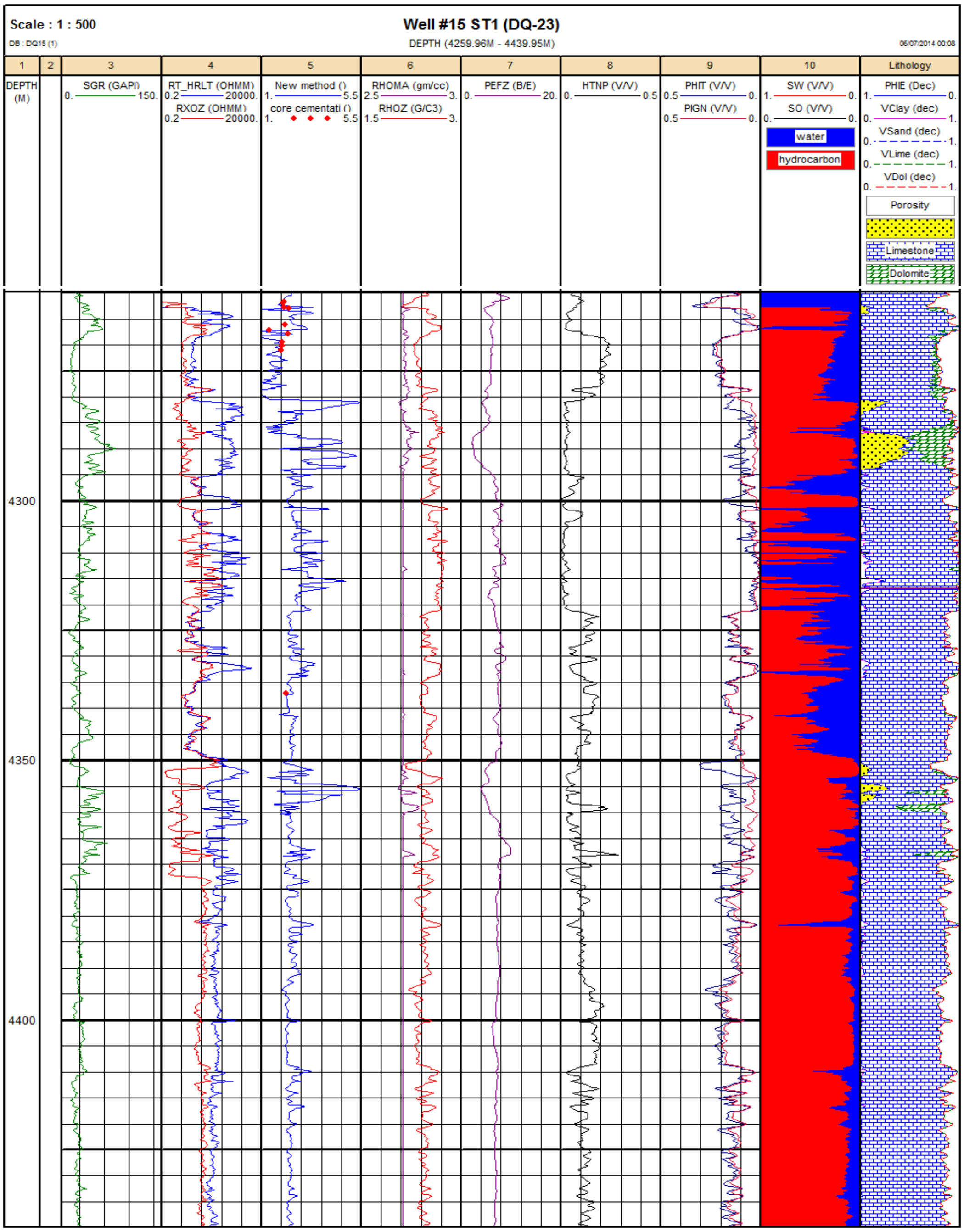

Figure 4. Cementation exponent log generated by the new method

The regression of the calculated values with the core data is 84.09% (Figure 5), which shows this method is practical for the calculation of cementation factor in carbonate reservoirs.

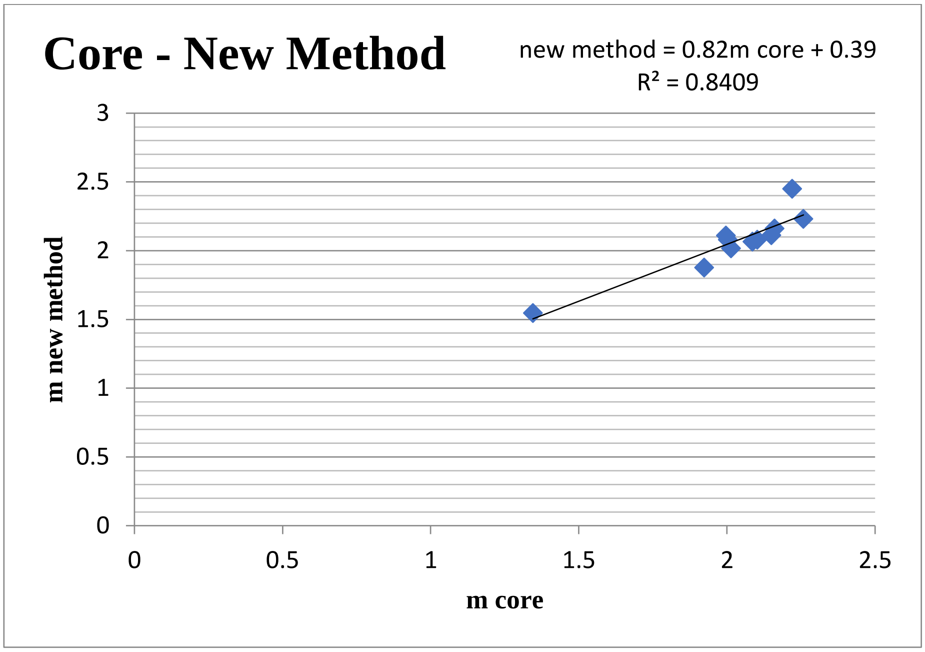

Figure 5. Comparison between the new method and *m* cores

The conversion of limestone to dolomite in some of the zones lead to a cementation factor variation in the range of 3–5.5 and types of porosity in this reservoir included vugy and intercrystalline porosity. Based on the Lucia method, in carbonate reservoirs with vugy porosity, the value of cementation factor increases to around 5.5.

As shown in Figure 4, the generated log is in good accordance with the density log. So, it can be derived that the cementation factor and density log have a similar variation.

5. Conclusion

The variation in cementation between grains rock, type of lithology and cement leads to the variation of density log. Therefore, by using density log and determining the relationship between the cementation factor and density log, the variation of the cementation factor in the borehole can be estimated. In this study, by determining the matrix rock and the accordance factor between density and the cementation factor from the core, a relationship can be achieved that can estimate the cementation variation in the borehole. The regression of the calculated values with the core data is 84.09% that shows this method is useable for calculation of cementation factor in carbonate rocks.

References

[1] A. Shirazy, M. Ziaii, A. Hezarkhani, and T. Timkin, ``Geochemical behavior investigation based on k-means and artificial neural network prediction for titanium and zinc, Kivi region, Iran,'' *Bull. Tomsk Polytech. Univ. Georesour. Eng.*, vol. 332, no. 3, pp. 113--125, 2021.

[2] S. Alahgholi, A. Shirazy, and A. Shirazi, ``Geostatistical studies and anomalous elements detection, Bardaskan Area, Iran,'' *Open J. Geol.*, vol. 8, no. 7, pp. 697--710, 2018.

[3] A. Shirazi, ``Remote sensing studies for mapping of iron oxide regions, South of Kerman, Iran,'' *Int. J. Sci. Eng. Appl.*, vol. 7, no. 4, pp. 45--51, 2018.

[4] A. Shirazi, ``Geostatistics studies and geochemical modeling based on core data, sheytoor iron deposit, Iran,'' *J. Geol. Resour. Eng.*, vol. 6, pp. 124--133, 2018.

[5] A. Shirazy, ``Geochemical and geostatistical studies for estimating gold grade in tarq prospect area by k-means clustering method,'' *Open J. Geol.*, vol. 9, no. 6, pp. 306--326, 2019.

[6] A. Shirazy, ``Geophysical study: Estimation of deposit depth using gravimetric data and Euler method (Jalalabad iron mine, Kerman province of IRAN),'' *Open J. Geol.*, vol. 11, no. 8, pp. 340--355, 2021.

[7] A. Shirazy, ``Geostatistical and remote sensing studies to identify high metallogenic potential regions in the Kivi area of Iran,'' *Minerals*, vol. 10, no. 10, p. 869, 2020.

[8] G. Archie, ``The electrical resistivity log as an aid in determining some reservoir characteristics,'' in *Proc. Dallas Meeting*, Dallas, TX, USA, 1941, pp. 54--62.

[9] M. Hasanigiv and M. Rahimi, ``New correlations for porosity exponent in carbonate reservoirs of Iranian oil fields in Zagros Basin,'' Tech. Rep., 2008.

[10] H. S. Salem and G. V. Chilingarian, ``The cementation factor of Archie's equation for shaly sandstone reservoirs,'' *J. Petroleum Sci. Eng.*, vol. 23, no. 2, pp. 83--93, 1999.

[11] J. Rasmus, ``A variable cementation exponent, M, for fractured carbonates,'' *Log Analyst*, vol. 24, no. 6, 1983.

[12] F. Lucia, ``Petrophysical parameters estimated from visual descriptions of carbonate rocks: A field classification of carbonate pore space,'' *J. Petroleum Technol.*, vol. 35, no. 3, pp. 629--637, 1983.

[13] A. Al-Ghamdi and R. C. R. Aguilera Clarkson, ``Cementation exponent estimation for complex carbonate reservoirs using a triple porosity model,'' in *Proc. SPE/DGS Saudi Arabia Sect. Tech. Symp. Exhib.* OnePetro, 2011.

[14] R. J. Doodran, ``Minimalization of ash from Iranian gilsonite by froth flotation,'' *J. Minerals Mater. Characterization Eng.*, vol. 9, no. 1, pp. 1--13, 2020.

[15] S. Khakmardan, ``Evaluation of chromite recovery from shaking table tailings by magnetic separation method,'' *Open J. Geol.*, vol. 10, no. 12, pp. 1153--1163, 2020.

[16] S. Khakmardan, ``Copper oxide ore leaching ability and cementation behavior, mesgaran deposit in Iran,'' *Open J. Geol.*, vol. 8, no. 9, p. 841, 2018.