JOURNAL OF PETROLEUM GEOMECHANICS
(JPG)

Extended Abstract

Examining Key Factors Influencing the Accuracy of Water Saturation Calculations in Carbonate Reservoirs: A Case Study of Kangan and Dalan Formations in the Western Persian Gulf

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Received: 30 November 2023; Accepted: 14 January 2024

DOI: 10.22107/JPG.2024. 427939.1221

Keywords

Rock type, electrical efficiency, Archie parameters, heterogeneity management, water saturation, electrical conductivity, Dalan and Kangan

Abstract

Evaluating the characteristics of carbonate reservoirs, given their significant heterogeneity, is always accompanied by challenges and high uncertainties. Water saturation is a crucial parameter in assessing these reservoirs, and the Archie equation is commonly used for water saturation estimation. Moreover, the effect of water saturation on the mechanical behavior of rock is recognized as an important phenomenon in geotechnical engineering. The accuracy of water saturation calculated through the Archie equation depends on the precision of its parameters, including cementation exponent, saturation exponent, and tortuosity exponent. The heterogeneity of carbonate reservoirs significantly affects the Archie equation coefficients and, consequently, water saturation calculations. In this study, various methods, including the electrical efficiency, current zone indicator, and Winland method, were employed to manage reservoir heterogeneity. Subsequently, Archie parameters were calculated for each category, and water saturation was determined and compared with Dean-Stark water saturation. Furthermore, the influential parameters on the accuracy of water saturation were discussed and examined. To achieve the study objectives, 157 Dean-Stark water saturation data, 57 core plug samples for formation resistivity factor (FRF) determination, 20 core plug samples for measuring formation resistivity index (FRI), 1114 porosity and permeability measurements from core plug samples and 1368 thin sections were utilized from an exploration well in the western Gulf of Persian. Our findings highlight the significance of exploring electrical behavior characteristics and pore throat radii as crucial elements influencing the precision of water saturation calculations. As per the results, employing constant Archie parameters leads to an overestimation of water saturation and, consequently, an underestimation of hydrocarbon reserves. Our analysis illustrates that effectively managing reservoir heterogeneity through the electrical efficiency method significantly improves the accuracy of predicted water saturation compared to other approaches. Conversely, the Winland method exhibits the highest uncertainty in predicting water saturation.

1. Introduction

Accurate evaluation of petrophysical properties of carbonate rocks has always been a major challenge in the oil industry due to their pronounced heterogeneity. The accurate calculation of water saturation in hydrocarbon reservoirs during initial stages is crucial for reliable reservoir evaluation and reduction of economic uncertainties in field development [1,2]. Furthermore, the investigation of water saturation can assist us in studying the mechanical behavior of rocks and the extent of water's impact on rock parameters such as compressive strength, coefficient of fracturing, and permeability [3]. Therefore, understanding the behavior of rocks and assessing the amount of oil reserves relies heavily on determining reservoir water saturation. The Archie equation [4], is the most common

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relationship for indirectly calculating water saturation. Categorizing carbonate rocks based on common characteristics can improve the accuracy of Archie parameter calculations and consequently enhance water saturation estimation. The objective of this study is to evaluate and investigate the most effective approach for managing reservoir heterogeneity in calculating water saturation. The calculated water saturations using different approaches for managing heterogeneity were compared and evaluated against core data from Dean-Stark water saturation measurements.

2. Methodology

The dataset includes 57 data points of formation resistivity factor, 20 data points of formation resistivity index, 157 data points of Dean-Stark water saturation, 1114 data points of porosity and permeability, and 1368 thin section data. These data were selected from an exploratory well in a gas field located in the Western Persian Gulf region to achieve the study objectives. The methods used to determine the rock types studied in this research include the Winland method [5], the current zone indicator [6], and the electrical efficiency [7]. After calculating water saturation using both the Dean-Stark method and the Archie equation for different rock types, water saturation was also determined using the constant Archie coefficients (1-2-2). Afterwards, the water saturation obtained from different methods was compared and evaluated with the Dean-Stark water saturation, and the influence of various parameters on water saturation was studied.

3. Results and Conclusions

The average water saturation calculated in different categories of electrical efficiency method is lower compared to other methods for determining rock types (Fig. 1). This indicates the success of this method in managing reservoir heterogeneity for water saturation prediction, considering the electrical behavior of rocks. Among the studied methods for determining rock types in this research, the winland method has shown the highest difference and uncertainty in predicting water saturation (Fig. 1).

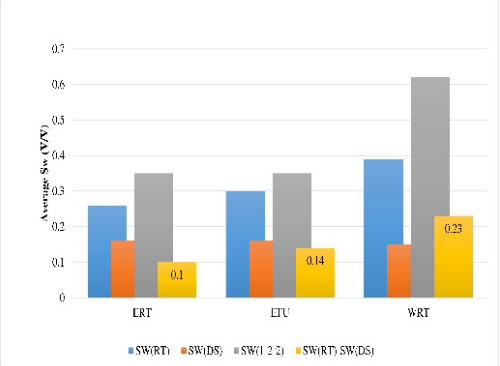

Fig. 1. The difference in water saturation calculated in each of these methods and the Dean-Stark saturation can be observed.

The results show that managing reservoir heterogeneity through the electrical efficiency method leads to more accurate calculations of Archie parameters and, consequently, a reduction in the difference between calculated water saturation and Dean-Stark. The results indicate that managing reservoir heterogeneity through the electrical efficiency method leads to more accurate calculations of archie parameters and consequently reduces the difference between calculated water saturation and Dean-Stark. After using the electrical efficiency method, determining rock types using the current zone indicator method, taking into account the electrical radius of the rocks, increases the accuracy of predicting archie parameters. As a result, it leads to an increase in the accuracy of estimating water saturation. Determining rock types using the Winland method has resulted in the greatest difference between calculated water saturation and Dean-Stark. Therefore, managing reservoir heterogeneity using the Winland method is associated with greater uncertainties compared to the electrical efficiency and current zone indicator methods.

4. References

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