Analysis of Potential Uncertainties in Opening-Mode Fractures Characterization through the Scanline Technique of Aptian Carbonates, Araripe Basin, Northeast Brasil*

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Abstract

The exploitation of hydrocarbon reserves in naturally fractured reservoirs has drawn considerable attention from the fracture characterization research community due to the importance of fractures in the prediction of fluid flow. Fractures can affect the flow and storage of valuable natural resources. One of the most common methods for rapidly analyzing fracture features is the scanline technique, which generates an approximately quantitative prediction of fracture density and frequency. This method aims to measure the main fracture attributes, such as fracture spacing and aperture. Despite the confidence provided by the systematic use of this method, errors and uncertainties caused by sampling biases exist. The problems caused by these uncertainties can negatively affect the construction of a computational model due to misleading trends. Using Monte Carlo simulations, this study evaluated the uncertainty caused by sampling biases in the scanline data of opening-mode fractures in outcrops of naturally fractured Aptian laminated limestone from the Crato Formation, Araripe Basin, northeastern Brazil. Currently this unit is studied as an analogue of Pre-Salt carbonate reservoir, Santos Basin, Brazil. In this study, errors and uncertainties were grouped into one parameter, termed the coefficient of uncertainty (CU) and defined as the ratio between the errors and uncertainties and the scanline data. We assumed a CU of 30% for measurements of fracture spacing and aperture, which were simulated separately and simultaneously. Thus, the propagation of errors and uncertainties in the scanline data to the coefficients of the corresponding power law was determined. Finally, the proposed statistical analysis of fracture attributes, principally for fracture aperture, showed that the uncertainties can significantly affect the power-law scaling.
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1. INTRODUCTION

The exploitation of hydrocarbon reservoirs in naturally fractured reservoirs has drawn considerable attention from the fracture characterization research community due to the importance of fractures in the prediction of fluid flow. Fractures can affect the flow and storing of valuable natural resources. One of the most common methods for rapidly analyzing fracture features is the scanline technique, which generates an approximate quantitative prediction of fracture density and frequency. The analyzed data were obtained from laminated lacustrine limestone from the Lower Cretaceous Costa Formação of the Araripe Basin, northeastern Brazil (Fig. 1). Currently, this unit is studied as an analog for naturally fractured carbonate reservoirs, including the Pre-Salt of Brazil.

2. OBJECTIVE

The scanline technique aims to measure the main fracture attributes, such as fracture spacing and aperture. Despite the difficulties provided by the systematic use of this method, errors and uncertainties caused by sampling biases exist. The problems caused by these uncertainties can negatively affect the construction of a computational model due to misleading boundaries. This study focused on the evaluation of potential uncertainties caused by reading biases in the scanline data of opening-mode fractures in outcrops of naturally fractured carbonates.

2.1. MONTE CARLO SIMULATION

We applied the Monte Carlo method to produce random variables of the values and to eliminate the uncertainties based on the original scanline data. This data allowed us to extract the fracture density, the aperture, and the radius of the fractures, to calculate the mean and range of the values found in the field (Fig. 5). The coefficient of uncertainty, which corresponds to the ratio of the standard deviation to the mean, was considered to be 35% for each fracture attribute and aperture spacing value (Fig. 5). A total of 1,000 artificial random samples were generated for each aperture and fracture spacing values of the scanline dataset.

3. METHODS

3.1. SCALINE

The first stage of the study was to define the main natural network of fractures present in the limestone unit. Because the Costa Formação was eroded during the Cenozoic, some structures were generated by kaolization. Due to this fact, initially considered only the veins, which represent fractures formed under burial conditions in the limestone unit. After the definition of the main sets of natural fractures used in the study, a series of scanlines were performed in the outcrops. The surveys captured the attributes of the fracture along the scanlines, which were located perpendicular to the strike of the dominant fracture set (Fig. 5).

4. RESULTS

4.1. FRACTURING ANALYSIS

The main fracture type identified in the laminated limestone unit of the Lower Cretaceous Costa Formação is the opening-mode fracture, and we also observed stylolites (Fig. 5). The opening-mode fracture strikes in two main directions, NNW-SSW (set 1) and NE-SW (set 2).

4.2. UNCERTAINTY SIMULATION

The analysis of the scanline form is a set of previously described openings in the Costa Formação of the Araripe Basin, northeastern Brazil (Fig. 6). The uncertainty analysis of the opening-mode fracture set (Fig. 7) is based on the scanline technique. The uncertainty analysis was performed using the Monte Carlo method, which involved the generation of random variables for fracture density and aperture.

5. CONCLUSIONS

The scanline technique was efficiently adapted to access the fracture attributes of natural fracture systems in laminated lacustrine limestones of the Araripe Basin in northeastern Brazil, which is an area used as an analogue for carbonate reservoirs in the offshore region. Identifying the opening-mode fractures documented in studied outcrops are classified as veins filled by calcite. We described two main populations of opening-mode fracture: a set 1, striking NNW-SSW, and set 2, striking NE-SW (Fig. 7). The results of this study showed that in general, the variability of the measurements performed on the scanline dataset make it possible to propagate and observe a specific variability in the coefficients of the power law. Statistical analysis revealed that the uncertainties can affect the power law exponents. Furthermore, the analysis of the results of the modeling led to the conclusion that the data must be interpreted based on the defined "natural" portion of the dataset, with the exclusion of the biased data. As these coefficients are used in the process of modeling of anti-symmetric patterns of fractured reservoirs, such as the permeability field, the determination of a confidence interval for the data obtained from analogues and wells is very important to reduce the costs and problems associated with the uncertainties (Fig. 8).

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