Evaluation and Characteristic Analysis of Shale Mode I Fracture Toughness Based on Logging Data

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Introduction

The fracture toughness of rock is of great significance for quantitative evaluation of the fractureability of shale reservoirs. However, the rock samples in the deep part of the stratum can only be obtained by a small number of drilling cores, so it is impractical to measure the fracture toughness of the whole well section by conventional methods. In addition, direct testing of rock fracture toughness is costly and has a long period, and the cost of drilling core is high, the number of cores is limited. Therefore, it is necessary to analyze the characteristics of the shale mode I (opening-mode crack) fracture toughness and establish a method to predict the fracture toughness of deep formation rocks.

Methodology

Studying the relationship between fracture toughness and other available parameters, and establishing a prediction model is an effective method to predict the fracture toughness of deep formation rocks. The geophysical well logging data continuously distributed throughout the well section can characterize the stratum properties of the tested strata. Therefore, the relationships among the mode I fracture toughness, the density, the acoustic time, the attenuation coefficient and the shale content are analyzed, and using density, acoustic time and shale content as fitting parameters, the shale mode I fracture toughness prediction model based on logging data is constructed. The research object is the Longmaxi Formation shale which selected in the southern Sichuan Basin, and the mode I fracture toughness of the Longmaxi Formation shale samples is measured by the cracked chevron notched brazilian disc(CCNBD) method.

Results and Discussion

The distribution of the mode I fracture toughness of the Longmaxi Formation shale is 0.4744MPa·$m^{1/2}$～1.0607MPa·$m^{1/2}$, and the average value is 0.7817 MPa·$m^{1/2}$, which indicates that the Longmaxi Formation shale mode I fracture toughness has significant anisotropy. The relationships among the mode I fracture toughness of the Longmaxi Formation shale, the acoustic time, the attenuation coefficient and the shale content are shown in Fig. 1 to Fig. 3. The fracture toughness obtained by the graphs decreases with the increase of the acoustic time and the attenuation coefficient, while the fracture toughness increases with the increases of the shale content. The relationship between the predicted fracture toughness value and the measured fracture toughness value is shown in Fig. 4. The predicted fracture toughness value is well correlated with measured fracture toughness value.

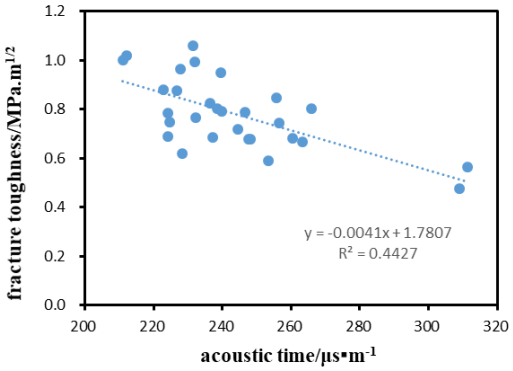

Figure.1 The relationship between fracture toughness and the acoustic time

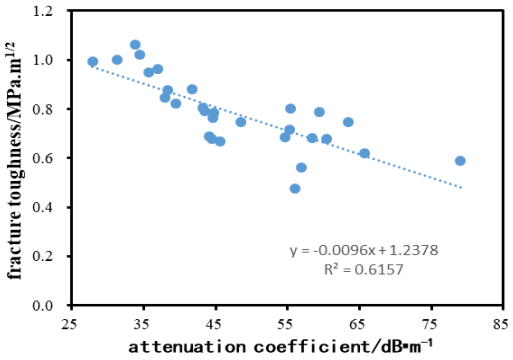

Figure.2 The relationship between the fracture toughness and the attenuation coefficient

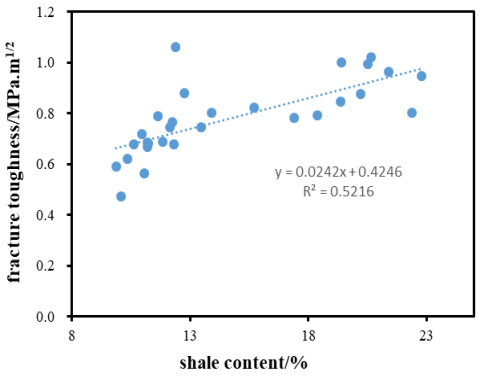

Figure.3 The relationship between fracture toughness and the shale content

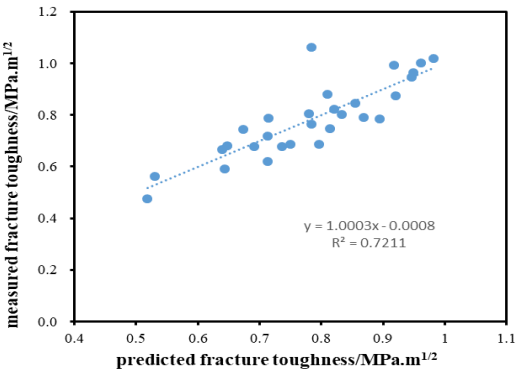

Figure.4 The relationship between the measured fracture toughness value and the predicted fracture toughness value

Conclusion

The established fracture toughness prediction model successfully predicted the continuous value of shale mode I fracture toughness. The model can provide fracture toughness full wellbore continuous data for on-site fracturing operation, and contribute to the exploration and development of oil and gas reservoirs.

Keywords: rock mechanics, Longmaxi Formation shale, cracked chevron notched brazilian disc(CCNBD), mode I fracture toughness, prediction model

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