Re-Exploratory Study Within an Area of the Tahe Oilfield, Western China: From Geological Characterization of Fractured Karst Carbonates to Prediction of the Most Prolific Sweet-Spots*

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Abstract

This article outlines a multidisciplinary study of the very deep fractured karst carbonates of the Ordovician Yingshan Formation, which represent potential hydrocarbon reservoirs in an area of the Tahe oilfield, north of the prolific Tarim Basin, Western China. The complexity in characterizing and predicting irregular karst elements and their relationships with fracture networks, motivates the use of innovative techniques for identifying new sweet spots. This investigation aims to initially determine the distribution of karst elements in carbonates and recognize fracture rock-properties, through the construction of a fracture model that permits to detail the genetic relationship of fracture sets with the karst zones, consequently with reservoirs. In addition, we consider the tectonic features that occurred during the Caledonian and Hercynian orogenies which controlled the karstification processes. Likewise, the low connectivity among karst patterns and the production behavior of wells were evaluated. Using well logs from 163 wells, an average range of effective porosity between 1 - 6% in karst sections was estimated with very low drainage capacity. Also, utilizing borehole image logs analysis, three fracture sets were identified (azimuths: 285°, 355° and 235°). Moreover, Structural dip, Ant-tracking, and Relative acoustic impedance (amplitude) seismic attributes, were used as inputs data on a stratigraphic grid at the interface of unconformities T74-T76 (karsted interval). The lower amplitudes of the seismic attribute conformed suitably to the karst patterns and these, were utilized in the construction of 3D model. From the combination of structural attributes, a discontinuities volume was computed which highlights a major quantity of fracture planes in karsted interval, improving the fractures prediction in area. Subsequently, the fracture sets were extracted from the volume through the automatic fault extraction (AFE) technique and upscaled for the construction of discrete fracture network (DFN). We find that, the modeling showed two important karst patterns distributed irregularly in the area, northwestern and southeastern, where the pathways are aligned with the main striking faults. Additionally, fracture porosity and permeability (Kxx, Kyy and Kzz) models were computed. Finally, the integration of results predicted several sweet-spots along and in tip-lines of strike-slip faults W-E, where the fractured karst patterns that maintain the same orientation of faults and are aligned with the azimuth 355°’s fracture set that have greater aperture between 0.5 - 1 mm. This study also revealed various non-perforated karst segments in the intermediate zone. These are located near the regions with high fracture density and wells with accumulated volumes of oil production between 0.5-1 MMBBL, which may meaningful opportunities for the oil and gas industry.
This study also reveals a great clustering of partially dissolved properties through the construction of a fracture model (mini-model) that studies the fracture distribution in the carbonate reservoir. The fracture model is constructed using the Automatic Fault Extraction (AFE) process. In this procedure, extracted fractures are used to construct a network model that simulates the network and fracture properties. In this study, the AFE process is performed using a multi-disciplinary attribute obtained from the combination of Local Attribute Filter (LAF) and Image Attribute Filter (IAF) for fracture attribute extraction. Subsequently, these discontinuities are extracted in interface of the unconformities T74 - T76 (karstic interval) using the DFN (Discrete Fracture Network) model. Fracture porosity and permeability tensor models are computed in the Geological framework of the study area to determine three fracture sets for the study area in question. The model allows to determine several non-perforated spots essentially in the western area. This work was supported by the National Key Scientific Project (2018YFC0601000, 2018YFC0601006), as well as several other grants. The authors are grateful to the operators for permission to publish this paper.

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Conclusions

- The ability to construct a fracture model for the understanding of the fracture system and the carbonate reservoir is essential for the effective interpretation of seismic attributes.
- The fracture model developed in this paper provides a good understanding of the fracture system and the carbonate reservoir, which is essential for the effective interpretation of seismic attributes.
- The fracture model also allows to determine several non-perforated spots essentially in the western area.
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