

Fracture Identification in Carbonates Using Borehole Image Log and Digital Rock Physics

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Abstract

Fracture identification and characterization is becoming increasingly important to understand flow behavior in fractured carbonates. Macro-scale fractures can be identified and characterized using borehole image logs and well data. However, it is significantly more challenging to identify and characterize micro fractures, which are an important component of the flow network. In this study, an integrated fracture characterization approach combining borehole image log, 3D X-ray tomography based digital rock physics and core was used to improve the understanding of a complex fracture network system in a carbonate unit. The fracture density computed from borehole image log data showed the presence of highly fractured rock. Two sets of fractures were identified on borehole images, one striking NE-SW and the other NW-SE. Other well data, including conventional log interpretation and drilling data (e.g., rate of penetration, lost circulation), corroborated the borehole image log based fracture interpretation. The orientation and vertical extent of fractures was determined by borehole images with core data. Micro fracturing was identified using high resolution 3D X-ray micro-computed tomographic images. Fractures were identified on borehole image logs and micro fractures were observed on tomograms, however because flow characteristics of fractured rocks are strongly dependent on their interconnectivity, it was critical to assess connectivity. From the 3D images, we were able to directly identify the connectivity of the pore space. A 3-D model of porosity was created by subtracting the as-received state image from the registered saturated with X-ray contrast brine image. The connected porosity model suggested that the majority of flow occurred through the micro-fractures. Identification and characterization of both macro and micro scale fractures is necessary to understand flow behavior. The study results underscore the importance of micro fractures in controlling flow in fractured carbonates. However, identification and characterization of micro-fractures cannot be done effectively using conventional logs alone or even together with borehole image logs. Effective fracture network characterization requires an integrated approach that uses borehole imaging with 3D X-ray tomography.