

Depositional and Diagenetic Characteristics of a Complex Ediacaran Carbonate Reservoir: The Khufai Formation of the East-Central Sultanate of Oman

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Abstract

The Ediacaran-aged Khufai Formation includes one of the oldest commercially-proven petroleum plays in the world. This complex fractured and vuggy carbonate reservoir is part of the Nafun Group (ca. 550-635 Ma), which also includes prolific source rocks (Khufai carbonates and underlying Masirah Bay Formation siliciclastics) and an efficient top seal (Shuram Formation mudstones). Abundant subsurface and outcrop data from the east-central Sultanate of Oman have enabled the characterization of the complex depositional and diagenetic settings of the Khufai dolomitic reservoir. Integration of seismic and well data with outcrop data – involving seismostratigraphic interpretation; well-to-outcrop correlation (wireline logs, borehole images, and core and outcrop sedimentological descriptions); and detailed petrographic analysis of drill cuttings, side-wall cores, core plugs and outcrop samples, reveal that Khufai reservoir effectiveness can vary significantly both laterally and vertically. This requires robust characterization and modelling to support ongoing exploration, appraisal, and development activities.

The Khufai Formation deposition in east-central Oman occurred during highstand progradation of a distally- steepened, microbially-influenced carbonate ramp. Lithofacies generally comprise outer- and mid-ramp mudstones to packstones with some siliciclastic influxes and rare breccia; ramp-crest grainstone shoals; and wide inner-ramp with microbially-dominated peritidal carbonates. The interplay of carbonate ramp architecture, siliciclastic sediment input, and pre- and syn-sedimentary tectonics played an important role in depositional facies variation across the Khufai ramp.

The Khufai dolomitic reservoir has undergone several post-depositional deformation events. The diagenetic overprint includes micritization, cementation, dissolution, fracturing and compaction. Multiple phases of hydrocarbon charge have led to a mix of oil and bitumen occurrences – the latter often occluding pore spaces. Hydrocarbon charge often appears to be relatively late and is associated with deep burial events. The reservoir is characterized by very low matrix permeabilities (0.01-20 mD) and porosities (0.1-10%). The reservoir quality is, however, often enhanced by intense fracturing and dissolution (mouldic and vuggy), resulting in a dual-porosity system. Both processes of fracturing and dissolution have occurred several times through a long geological history. Dissolution porosity in the Khufai forms a significant proportion of the open pore space: reservoir effectiveness typically relies on connection of vugs through low wavelength conductive fracture systems.