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Unlocking Stranded Oil in a Tight Carbonate Field VIA CCUS: IRM as an Enabler for CO_2 Enhanced Oil Recovery

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Abstract

Following an extensive CCUS screening study for CO_2 Enhanced Oil Recovery (EOR) across PDO's Block 6 concession, a tight carbonate field was identified as the most prospective candidate. Located in the north of Oman, the field comprises a robust structural high and covers a total area of over 100 km^2, with oil discovered in the Cretaceous Upper and Lower Shuaiba Formations. The Upper Shuaiba has been appraised and piloted for waterflood, however initial performance was characterised by poor water injectivity and depletion causing intermittent production. The Upper Shuaiba oil resources were therefore classified as 'stranded', awaiting a viable development concept through CCUS.

The Upper Shuaiba is part of a laterally-extensive, shallow water carbonate platform complex of Aptian age that forms a progradational system. The stratigraphy alternates between clean carbonate and argillaceous units within a series of clinoforms, capped by the Nahr Umr shale. As the system progrades in a SE direction, the Upper Shuaiba carbonates transition from high quality grainstones and rudist-rich facies on the platform margins to lower quality microporous facies in distal parts. The tight carbonate field sits in this distal setting and is dominated by thin (3-5 m) but laterally continuous microporous units with good porosity (20-35%), low permeability (< 5 mD) and a thick (> 40 m) transition zone.

To successfully model and predict the production performance of the field under CO_2 injection, an Integrated Reservoir Modelling (IRM) workflow was developed. The structural model incorporated three individual Upper Shuaiba clinoform units (BB, AA and C), a set of NW-SE trending faults and a complex, stepped Oil-Water Contact (OWC) due to regional tilting in the area. The correct choice of saturation height function, derived from MICP data and calibrated to log-interpreted oil saturations, was crucial to accurately predict areas of highest STOIIP density and place horizontal line drive development patterns. Dynamic models were built at the pattern scale which forecasted significant production performance improvements vs. waterflood due to greater pressure support and the enhanced miscibility between CO_2 and oil.

A CO_2 injection pilot was carried out in 2023-2024, successfully demonstrating both excellent injectivity and improved, continuous production, ground-truthing the modelling results and paving the way to unlock the oil reserves. From a sustainability perspective, the carbon footprint of the produced oil is significantly reduced due to a proportion of the injected CO_2 remaining in the reservoir, resulting in a net abatement of CO_2 over the lifetime of the project. In this way, CCUS delivers a double benefit of both enhanced oil production and CO_2 storage in the Upper Shuaiba reservoir.