Oxygen Stable Isotopes Help Explain Distinctive Pore Architecture in a Tight Carbonate Reservoir Rock

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Abstract

Carbonate rock textures are controlled by depositional and diagenetic processes. Identifying major diagenetic events and their paragenesis, as well as their impact on reservoir quality are crucial for the understanding of porosity evolution in carbonate reservoir rocks. This paper outlines the use of oxygen isotopes to interpret how diagenesis affected pore structure in a tight carbonate reservoir from an onshore field in the Middle East. Oxygen isotope values of bulk carbonate core plug samples were used to decipher cementation temperatures, which can provide clues to the burial depth. The samples have been studied using conventional core analysis to quantify porosity and permeability. The same samples were studied using scanning electron microscope (SEM), mercury injection porosimetry and Quantitative Evaluation of Minerals by SCANning electron microscopy (QEMSCAN) to understand the porosity network in the tight carbonate at different scales and dimensions. The reservoir characterization part of the study showed that effective porosity is interparticle porosity between micrite particles and can be up to 25%. Permeability does not exceed 3 mD. Additional porosity (up to eight porosity units), which is isolated and thus not contributing to fluid flow, was recognized using the SEM and QEMSCAN. This isolated porosity includes intraparticle pores inside microfossils such as foraminifera and coccoliths. Oxygen isotope data suggest that most cementation occurred at shallow burial depths (a few hundreds of meters). Due to this initial shallow burial and cementation, most microfossils remained intact and were not mechanically crushed. This was not the case in the entire reservoir, but at certain depths, where higher argillaceous contents are present; pressure dissolution occurred and minimized this isolated porosity. Moreover, this process occluded inter-micrite porosity leading to lower reservoir storage capacity. The use of oxygen isotopes to explain reservoir characteristics has not been yet been fully integrated into reservoir studies. This work here helps explained the stage at which cementation occurred in the burial history of a carbonate reservoir and helps explain the preservation of isolated porosity.