The Role of Expulsion Fracturing on the Redistribution of Reservoir Pressure in Niobrara Shale Reservoirs

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The development and preservation of over pressured compartments in unconventional shale reservoirs requires low-permeability seals that inhibit fluid movement of generated hydrocarbons. The Niobrara is composed of interlaminated marl, silty marl and chalky marl with total organic matter (TOC) ranging from 2-8%. Geomechanical data indicates these laminae are relatively weak as compared to other mud rock formations with Young's Modulus ranging from 2.0-2.5 mpsi. As hydrocarbons are generated from kerogen, fluid pressure exceeds the tensile strength of the interlaminae and subsequent hydraulic expulsion fracturing occurs.

Hydraulic expulsion fractures are characterized as near-vertical planes. They are bed or laminae-bound and calcite-filled. They are distinguished by occurring in relatively structurally-flat (<2°) undeformed strata with varying fracture density. They are most common in the organic source rock and the conventional chalk benches superjacent to the source rocks. A higher density of expulsion fractures usually occur in kerogen-rich heterogenic rocks with thin incompetent internal sealing rocks. As the column of rock is buried, the kerogen-saturated column matures and generates hydrocarbons. Carbonic acid produced from this process to dissolves carbonate at a nanno-scale creating enhanced matrix porosities. As net pressure in the reservoir is reduced, CO2 in solution decreases and the dissolved CaCO3 reprecipitates in the open fracture voids. The orientation of these fractures is therefore aligned with the principal horizontal stress field (S_Hmax) at the time of expulsion, which may or may not be the current principal stress orientation.

Because of an absence of thick and strong sealing lithologies with high unconfined compressive stress (UCS) within and overlying the Niobrara rock column, intense expulsion-fracturing occurs allowing reservoir pressure to equilibrate. This generally results in normally pressured reservoirs that are generally found to be sub-economic targets. Typically, these wells will have a high initial production followed by a dramatic decline. The majority of commercial Niobrara shale reservoirs are considered transitional between over-pressured and normal pressure. While hydraulic expulsion fractures are present in these economic shale reservoirs, they occur in lower densities. Because of this, significant pore-pressure has not been redistributed within the system and economic viability is maintained.