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Inorganic Origin of CO2 and Its Indication for Sweet Spots in Tight Formations, North West Saudi Arabia

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ABSTRACT

Gas tested from Lower Paleozoic tight sandstones of the Sarah and Upper Qasim formations in Northwest Saudi Arabia is generally observed to be sourced from marine Type II organic matter of the Qusaiba shale. Gas from wells with high initial production (IP) in the area share common characteristics of high gas dryness and relatively heavy carbon isotopic composition (δ13C) for methane. Regional variations of gas composition and distribution appear to reflect regional maturity control of the Qusaiba source rocks. Isotope rollovers with wetness and partial reversals against their carbon number have been identified in gases with high IP from these tight formations. Some low IP wells, however, also possess high gas maturity, with isotope rollover/reversal profiles, suggesting that other factor(s), possibly related to reservoir quality, should be considered for seeking gas pay zones. A distinctive feature we found — other than gas maturity, dryness and isotope rollovers/reversals — was concentrations and carbon isotopic composition of carbon dioxide (CO2). The concentrations of CO2 in total gas are higher from high IP wells (9% to 15%), compared to low IP wells (< 9%). The δ13C of CO2 in these tight sandstones, as well as the overlying Qusaiba shale, are all heavier than -10‰, suggesting an inorganic origin. Mineralogical and petrographic associations in these tight sandstones, such as etching and dissolution of carbonate cements, e.g., siderite, suggest CO2 derivation from carbonate dissolution/decomposition. In contrast, the δ13C of CO2 generated from gold-tube pyrolysis of Qusaiba kerogen concentrates averages around -30‰, providing further evidence for the inorganic origin of CO2 in the tight sands. Upon pyrolysis, large volumes of CO2 were generated, which could provide a precursor for carbonate cementation in the tight sandstones. Later dissolution and/or thermal decomposition of carbonate cements — as a response to changes in geochemical equilibrium or abnormal geothermal events — would create secondary porosity to trap more gas and enhance the well deliverability. The inorganic CO2 and high gas maturity synergistically can provide a practical tool for the identification of sweet spots in tight formations. Future work will consider kinetics of the source rock and thermodynamics of the reservoir to understand CO2 generation and distribution in the subsurface and to integrate CO2 as a critical factor in reservoir quality models.