Paleozoic Gas Geochemistry in Northwest Saudi Arabia: Laboratory Simulation Versus Field Observation

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ABSTRACT

The Early Silurian Qusaiba shale gas and Qusaiba-derived gas in the underlying Ordovician Sarah and local Qasim sandstones are two main exploration targets in the northwestern part of Saudi Arabia. A series of hydrous and anhydrous gold-tube pyrolysis experiments were conducted on variably mature (immature to gas window) Qusaiba rocks and kerogen concentrates to simulate the process of gas generation. Full kinetics and isotope fractionation parameters of gas generation were measured, and a new expulsion model was tested based on pyrolysate composition, aiming at helping lower exploration risk in these Paleozoic successions. Fundamental science in gas geochemistry, such as the role of water in primary and secondary cracking, late gas potential, and the magnitude and fate of non-hydrocarbon gases (CO2 and H2S), can greatly benefit from such laboratory simulation. These experiments cannot reproduce the evolution of gas compositions, carbon isotope ratios, and isotopic rollover/reversal with increasing maturation reported in mud gases and well testing gases. The disagreement between pyrolysis results and field observations indicates the complexity of the natural gas system caused by post-generative processes, such as migration, mixing, and alteration. The discrepancy also highlights the simplicity of such experiments that are limited by source rock availability and how representative samples are, as well as differences between laboratory conditions and geological reality (temperature, pressure, water, and mineral catalysis). Data can be reconciled by considering relative differences (e.g., C2/C3 vs. δ12C2-δ13C3, Prinzhofer et al., 2000), rather than direct comparison of absolute values (e.g., %C1 vs. δ13C1, δ13C1 vs. δ13C2). Using this “relative difference” approach, laboratory data shows a good match with field gas data, suggesting that: first, the Qusaiba shale represents a semi-open system with intermediate-to-high expulsion efficiency, and, second, gases in the Sarah and Qasim sandstone reservoirs are mainly products of the late cracking of kerogen and bitumen, as evidenced by the pyrolysis experiments on mature Qusaiba kerogen. Reference Prinzhofer, A., M. R. Mello, L. C. da Silva Freitas, and T. Takaki, 2000, New geochemical characterization of natural gas and its use in oil and gas evaluation, in M. R. Mello and B. J. Katz, eds., Petroleum systems of South Atlantic margins: AAPG Memoir 73, p. 107–119.