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Tracing Fluid Provenance and Flow Migration in Sub-Salt Layers of the Red Sea Basin With Geochemical Techniques

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ABSTRACT

As a novel working hypothesis, the reconstruction of hydrodynamic regimes and flow pathways for reservoir water can be transformed into a feasible tool to be used as an analogue proxy to spot potential secondary hydrocarbon migration and trapping. In the present case of the Red Sea Basin, produced water from sub-salt units in selected exploration wells were analyzed by a combination of geochemical techniques. This work is to provide constraints on physico-chemical processes involved in the formation and evolution of reservoir fluids. Conceptual geochemical models are being developed for the provenance of hydrothermal fluids, pathways for fluid circulation and type of water-rock interaction processes. In contrast to the commonly assumed hypersaline composition of the Red Sea Basin brine, recovered water samples are found to be geochemically heterogeneous, ranging from brackish to extremely hypersaline. The presence of an extreme dynamic hydraulic system with infiltration of surface water into sub-salt units during Late Pleistocene, probably related to low sea level stands during the Last Glacial Maximum, is revealed by 14C-radiometric age dating. Strontium radiogenic fingerprinting (87Sr/86Sr) and calcium/sodium (Ca/Na) cationic exchange ratios confirm the partial occurrence of hydrothermal reactions between subsurface brines and the igneous basement, causing host rock albitization with Na depletion and Ca enrichment in circulating fluids. A dynamic convective system along fault structures must have enabled vertical flow migration toward underlying mid-ocean ridge (MORB) basalts. Geochemical ratios (bromine/chlorine (Br/Cl) and chlorine/sodium (Cl/Na)), as well as divergent 87Sr/86Sr ratios between fluids from Al Wajh Formation (Early Miocene) and overlying Late Miocene evaporitic seal layers (Mansiya Formation), exclude the option of brine formation by halite dissolution. The limited interaction between infiltrating surface water with Miocene salt represents a further argument for a double-porosity model with a fault-dominated flow regime. Local geochemical similarities between inter-stratigraphic units suggest hydraulic connectivity between specific wells for the Al Wajh horizon, which could imply lateral reservoir continuity for potential hydrocarbon migration. The interpretation of the regional magnitude of flow migration is still limited by a restricted number of available samples from exploration wells.