

Hydrocarbon Leakage through Seal Rocks by Seismic and Core Data: Case Study from the Mauddud Formation in Bahra Field, Kuwait

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ABSTRACT

An effective, low permeability seal is a crucial component of hydrocarbon plays, and as such seal breaching has received less attention in the Middle East although it has a direct influence on hydrocarbon entrapment and retention. Prediction of seal breach has been widely related to faulting, which is often complex since fault (re)activation doesn't necessarily mean fatal seal breaching. Confirmation of fatal hydrocarbon leakage therefore requires additional assessment including core and fluids data that can show the actual consequences on reservoir. Kuwait is located in broken foreland between orogenic front basins, ranging over 1000km from Precambrian Arabian Shield and Red Sea Rift to the west and the compressional Zagros Fold belt to the east. The nature of the basement in Kuwait is poorly known, but there is a documented correlation between a Bouguer anomaly map and subsurface structures in the Kuwait Arch. An unusual signature of a strongly magnetized body with a conspicuous difference from the regional basement in Kuwait is detected, which is interpreted to correspond to a palaeo-high structure in the Palaeozoic. It is overlain by chaotic seismic signals and dislocated E-W faults in the Mauddud Formation E-W faults responsible for structural deflection rather than typical 4-way closure and seemingly controls oil quality distribution across the field. E-W faults extensions are manifest on the surface as the Jal-Azzor escarpment and mud volcanoes. Various sized seismic depressions occurred above the seal of the Mauddud Formation up to ~2km width and with a maximum ~100ms polarity reversal, interpreted to indicate blowout pipes and extensive seal risk. Saddle dolomite occludes fractures dissecting limestone and forms the cement of a tectonic breccia, suggesting ingress of hydrothermal fluids. Abnormally high >20 salinity (wt. %NaCl equivalent) is detected from fluids inclusions, whereas SEM shows salt in micro-vugs along with anhydrite and diagenetic quartz in micro-fractures. Possible exotic igneous minerals such as sodalite are also observed. Saddle dolomite calcite and cements in the Mauddud Formation have crustal $3\text{He}/4\text{He}$, extracted from aqueous fluid inclusions, which were potentially derived from a deep source. A model is proposed that whereby tensional stress led to degassing and eruptive fluid flow from the basement, leading to topical seal breach, and provide an exceptionally example within one of the World's most prolific hydrocarbon provinces.