Active Arabian Plate Fracturing: Patterns, Driving Factors, and Impact on Hydrocarbon Resources

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ABSTRACT

Natural fractures in the sedimentary sequences in the platform basins of the Arabian Plate show repetitive occurrence of two episodes; an older early diagenetic episode and a later tectonic episode. This is evident from studies conducted by the current author over the last few decades covering different basins in the Arabian plate from the highly attenuated high folds zone of the Zagros-Taurus to the mildly deformed Arabian platform of Saudi Arabia (Ameen, 1991a, b, 1992, 1995, 2002, 2014, 2016, Ameen and Hailwood, 2008 and Ameen et al., 2010). The early episode of fracturing is a manifestation of mainly gravity tectonics and includes seismites, injectities, slump structures, and natural hydraulic fractures related to burial history or fluid chemistry etc. These fractures have distinctive orientations in their affinity to local paleoslopes, underlying basement-fault escarpments which controlled the basin topography and the fold/fault structures. Characteristically such fractures are limited in their extent and least abundant therefore have no major influences on hydrocarbon resources. The later episode caused mainly tectonic natural fractures including nearly vertical to moderately dipping extension fractures, faults, and tectonic stylolites. They comprise more than one set of fractures predominantly systematic relative to the current day plate tectonic stresses (nearly parallel to or bisected by the maximum horizontal compressive stresses) and they are rarely influenced by local structures (folds and faults). Therefore they are considered as regional tectonic fractures primarily driven by the Arabian Plate tectonic stresses, which have been active since the Cretaceous. Stress-criticality of these regional fractures varies according to the current day in-situ stress regime and the fractures' aperture type. Closer to the Arabian Plate boundaries stresses are higher and criticality is evident from seismological evidence. Further away from the boundaries stress criticality becomes less evident. Stress sensitivity however depends on aperture type so hairline barren fractures tend to be highly stress sensitive compared to partly mineralized fractures with channel type apertures. Within the spectrum of the late fracturing episode the latest dominant set of tectonic fractures imprint the older sets, this reflects the progressive counter clockwise rotation of the Arabian Plate and related remote stresses. The plate rotation resulted in shear rejuvenation of older fractures that are suitably oriented in compressional, extensional strike-slip, compressional strike-slip, and thrust modes. The degree of mineralization of the tectonic fractures varies across the sedimentary section of the Arabian Plate depending on the rock type, fluids chemistry, pressure, temperature and burial history. A considerable number of these fractures are open hairline or partly mineralized fractures facilitating fluid flow. The occurrence of these fractures resulted in part from the increase in pore pressure that coincided with the hydrocarbon generation in the source rocks and facilitated the expulsion from the source rocks. In addition locally in parts of the Arabian Plate the placement of igneous bodies facilitated the increase in pore pressure, and fracturing and maturation of any potential source rock/unconventional reservoirs. Subsequent hydrocarbon placement in reservoirs, cracking both within source rocks and reservoirs enhanced the development of this episode of fracturing. These plate tectonics related fractures play an essential role in enhancing permeability in both conventional and unconventional oil and gas reservoirs with both desirable and undesirable consequences. In addition their systematic strike relative to the current day maximum horizontal in-situ stresses makes them a factor that enhances the stimulation efficiency of unconventional and tight gas reservoirs.