Multi-scale Assessment of the Middle Eastern Permian–Triassic
Khuff Carbonate: Structural Evolution and its Impact on Reservoir
Properties

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The Khuff Petroleum System Study is a multi-scale, multi-disciplinary analysis that integrates
subsurface and outcrop, rock and fluid samples, and static and dynamic data in order to
characterize the Permian–Triassic Khuff carbonate, one of the major petroleum reservoirs in
the Middle East region. At regional scale, the Khuff carbonate shows a variety of depositional
environments (with facies ranging from coastal plain anhydritic claystone, tidal flat/low-to-
high energy lagoonal deposits to open-marine dolostones alternating with grainy limestones
and high-energy shoal-dominated dolostone/thick grainy limestones) and thicknesses (from
near zero at the pinch-out of siliciclastic facies in Central Saudi Arabia, to more than 400 m
(1,300 ft) in Ghawar Field in northern Saudi Arabia, expanding to 800 m (2,600 ft) in the
North field, Qatar and to nearly 1,000 m (3,300 ft) in the eastern United Arab Emirates.

Local seismic data calibrated to regional well correlations indicate that Khuff thickness,
lithology and facies distributions are strongly controlled by the inherited structural relief and
also by the reactivation of the basement structural fabric related to Permian–Triassic tectonic
events. Therefore according to the tectonic setting, the study area could be subdivided in four
mega-structural provinces: (1) the Arabian Peninsula, (2) Oman, (3) the Zagros region, and
the (4) the salt provinces.

In the Arabian Peninsula, Pre-Khuff basement-related anisotropies are interpreted to have
formed as early as Late Neoproterozoic to Ediacarian time and to follow four main trends: (1)
N-S (Nabitah), (2) NW-SE to WNW-ESE (Najd), (3) NNW-SSE to NW-SE (Mesopotamian).

At the regional-scale the Lower Khuff thickness shows a step-wise increase from fault block
to fault block towards the northeast. This trend is consistent with an
extensional/transtensional reactivation of the NW-SE to WNW-ESE pre-existing basement
anisotropies. During the Middle to Late Permian, the break-up of the Cimmerian terranes was
associated with an azimuth of extension oriented around NNE-SSW implying the Lower
Khuff to represent a syn-rift sequence. During the Early–Middle Triassic, the Cimmerian
blocks made a relatively rapid separation from the Arabian margin, opening the Neo-Tethys
behind. Its evolving active spreading centre exerted a ridge-push progressively stabilizing the
passive margins of the opening oceanic basin. Accordingly, the stress field was re-oriented
with a NE-trending maximum horizontal stress direction allowing reactivation of the N-S and
the NNW-/NW-trending basement fabrics. The resulting pattern of fault-interferences is
interpreted to be responsible for the irregular thickness distribution observed in the Upper
Khuff Member.

Within the salt mega-structural province, the producing fields and discoveries in the Southern
Gulf Salt Basin show a surprising variability in depth, thickness, bulk lithology, average
porosity, reservoir fluids and productivity. At regional scale, the variability in reservoir
properties identified in this study is interpreted to be controlled by different tectonic
structuration and activity such as fault reactivations, by salt diapir-specific growth history
coupled with large-scale burial alteration, deep burial in-situ modification of hydrocarbons in-
place and displacement of hydrocarbons by late non-hydrocarbon charge. Therefore,
understanding the interaction between regional tectonic events, basement lineaments and
sedimentation is a crucial and critical step in order to map paleogeography, thickness distributions, facies patterns and play fairways across the entire Arabian Plate.