



Structural controls on karstic development: Seismic analysis involving Tharthar depression and Merjan Oil Field

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ABSTRACT

This study aims to reconstruct a high-resolution structural-karst map of the Tharthar Depression and Merjan Oil Field in central-western Iraq, with assurance on the influence of the N-S Trending Lake Fault System. The work combines regional tectonic mapping, 3D seismic attribute analysis, geochemical information, and fracture-permeability observations to esteem the structural control on karst development.

The results show that the Lake Fault System controlled by both the formation of the Al-Tharthar surface depression and the development of subsurface karst conduit networks beneath the Merjan field. Structural evidence involves fault geometry, variance-attribute karst conduits, and kinematic stress analysis, while rose-diagram analysis indicates a similar strike orientation of about 350° for surface faults and subsurface karst features.

depending on these convergent observations, the study suggests a predictive exploration model with 89% accuracy for distinguishing fault-controlled carbonate reservoirs. The findings indicate that surface fault mapping can be used to help locate structurally controlled karst targets and reduce exploration risk in extensional settings.

1. Introduction

Fault-controlled karst reservoirs represent a significant portion of global hydrocarbon reserves, with carbonate reservoirs accounting for more than 70% of Middle Eastern petroleum resources (Liu et al., 2024; Ali et al., 2025). These reservoirs are an important part of carbonate petroleum systems because faults can enhance dissolution, fracturing, and fluid flow, which create highly heterogeneous reservoir bodies. Recent studies have advanced fault-karst research from simple mapping to integrated characterization using 3D seismic attributes, inversion, core data, image logs, and structural analysis to identify caves, fracture-vug systems, and fault-damage zones (Ma Duan, 2023). However, interpretation remains difficult because these reservoirs are deeply buried, laterally discontinuous, and geophysically ambiguous, and their quality is strongly affected by tectonic reactivation, limited well control, and fluid-rock interaction. Therefore, combining surface structural data with subsurface seismic evidence is still essential for reliable prediction of these reservoirs (Tang et al., 2025; Cao et al., 2021; (Maniscalco et al., 2022).

The study region is exemplifying with Al-Tharthar Depression and Merjan oil field within the central western area of Iraq in the Mesopotamian region. Al-Tharthar Depression is situated between the Jazira and Mesopotamia Plains western the Tigris River and the coordinates of Merjan oil field are 43° 53' 18" E and 32° 14' 39" N within the administrative boundaries of Karbala Governorate about 130 km southwest of Baghdad (Fig. 1).

The central point is on two crucial attributes. The first is Al-Tharthar Depression, a prominent N-S trending topographic law. The second is Merjan Westward Kifl oil field to the southeast.

Since 1970s the 2D-seismic survey is sit in Karbala west Baghdad and detect Merjan Westward Kifl oil fields and in 1980s data interpreted and founded a big mass of stratigraphy under Najmah Formation Upper Jurassic age this mass explained as ancient coral reef and the field that resulted from it is called Merjan this word is Arabic and its meaning in English as coral reef.

The Abu-Jir Fault Zone operating as a premier, deep-seated regional geo-suture that trends NW-SE, the fault serves as the fundamental transitional boundary separating the Stable Platform to the west from

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