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Research Advances

Strike-Slip Faults and Their Control on Differential Hydrocarbon Enrichment in Carbonate Karst Reservoirs: A Case Study of Yingshan Formation on Northern Slope of Tazhong Uplift, Tarim Basin

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Objective

Oil and gas are abundant in the Ordovician Yingshan Formation carbonate karst reservoirs on the northern slope of Tazhong uplift in the Tarim Basin, and have extremely complicated oil-gas-water distribution, however. The difference in burial depth of the reservoirs between east and west sides is up to 1000 m. Water-bearing formations exist between oil- and gas-bearing formations vertically and water-producing wells are drilled between oil- and gas-producing wells. Macroscopically, oil and gas occur at low positions, while water occurs at high positiona on the northern slope of Tazhong uplift. The mechanism of differential hydrocarbon enrichment in heterogeneous reservoirs is by far not clarified, which has affected the efficient exploration and development of oil and gas fields in this area. This work is aimed at revealing the mechanism of strike-slip faults and their control on differential hydrocarbon enrichment in carbonate karst reservoirs on the northern slope of Tazhong uplift. We first determined the subsection characteristics and genetic mechanism of northeast-trending strike-slip faults, described strike-slip faults in detail, and identified segmentation of strike-slip faults and their dynamic mechanism. Then, we revealed the fracture development associated with strike-slip faults and transformation of carbonate reservoirs. Finally, we defined the control of strike-slip faults on dominant migration direction of oil and gas and distribution of carrier system.

Methods

The key to understand the differential hydrocarbon enrichment in this area is to use various methods to accurately identify strike-slip faults and link them to carrier systems. Firstly, 3D seismic attribute analysis and high-density sections were used to identify strike-slip faults, aiming at seismic response characteristics of fracture-cave reservoir beds, and optimizing effective seismic attributes, such as maximum absolute amplitude, root-mean-square (RMS) amplitude, peak spectral high-frequency and amplitude variation to assist identifying strike-slip faults. Secondly, Formation Micro-scanner Image (FMI) was used to identify fractures and types as well as fracture occurrence based on different media (rock, fracture, fluid) with different resistivity characteristics. Thirdly, multi-information and multi-parameter statistics, such as seismic attribute inversion, drilling anomaly, core observation, and correlation between wells were integrated to determine transformation of carbonate karst reservoir beds by strike-slip faults. Finally, a carrier framework could be constructed by combination of fault and fracture karst layer, together with production testing and connectivity of fracture-cave system. In this way, it is possible to screen geochemical parameters of oil and gas migration and understand migration direction by horizontal comparison.

Results

Strike-slip faults are characterized by segmentation. New 3D seismic data reveal that the northeast-trending strike-slip faults which are steep and dip generally more than 80° are nearly parallel and generally in 10–15 km spacing developed on the northern slope of Tazhong uplift. Tearing points are located in the place where inclination of faults are reversed, coinciding with intersections of northeast-trending strike-slip faults and northwest-trending Tazhong No. 1 and No. 10 faults.

Strike-slip faults transform carbonate karst reservoir beds obviously. They form associated structural fractures and promote fluid flow and lead to further expansion of existing karsted fracture-cave. According to relevant statistical data such as seismic attribute fracture identification, FMI fracture identification, drilling core

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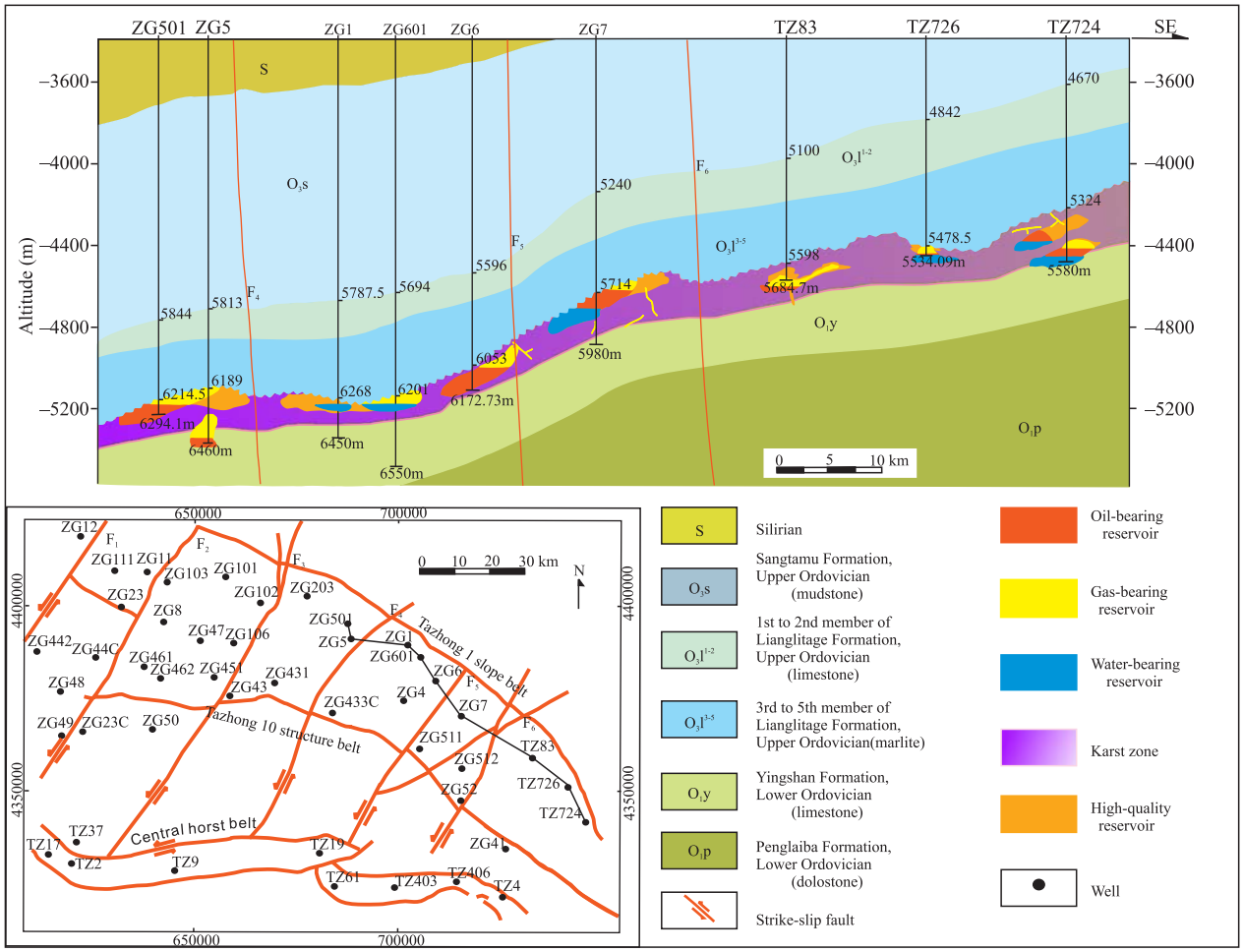

Fig. 1. Ordovician reservoir of wells ZG501-TZ724 on northern slope of Tazhong uplift, Tarim Basin.
F_1 is Zg12 strike-slip fault. F_2 is Zg8 strike-slip fault. F_3 is ZG10 strike-slip fault. F_4 is ZG5 strike-slip fault. F_5 is ZG6 strike-slip fault. F_6 is TZ82 strike-slip fault.

fracture observation, drilling break and overflow size, the farther the fracture is away from the faults, the lower the density of fracture is. Fracture-cave karst reservoirs are mainly within 4.5 km from strike-slip faults.

Strike-slip faults lead to blockwise enrichment of oil and gas in the Yingshan Formation karst reservoirs. The northeast-trending strike-slip faults and northwest-trending thrust faults cut the Yingshan Formation karst reservoirs into several blocks. Oil and gas entered the tearing points of strike-slip faults, migrating vertically and accumulating in high positions of the block. Due to several separation of the nearly 300 m thick dense beds (high-resistivity layers) in the karst zone, oil and gas show layered occurrence in several blocks. Oil-gas-water distributes normally in each block, and oil and gas are enriched in high positions near strike-slip faults.

Conclusions

(1) The northeast-trending strike-slip faults on the northern slope of Tazhong uplift are nearly parallel, featured by segmentation. The fault inclination is reversed on both sides of tearing point, coinciding with the intersection of strike-slip fault and thrust fault

(2) The transformation of carbonate karst reservoir beds by strike-slip faults is characterized by the formation of associated structural fractures and further expansion of karsted fracture-cave. Oil and gas reservoirs controlled by faults are generally within 4.5 km from strike-slip faults.

(3) Strike-slip faults and thrust faults cut the Yingshan Formation karst reservoirs into several blocks. Oil and gas entered the tearing points, migrating laterally in the block, and formed an independent and normally distributed oil-gas-water system.

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