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The Mechanism and Enrichment Mode of Tight Sand Oil Formation in the Southwest Ordos Basin

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The high quality source rock widely developed in the area which provides a large amount of hydrocarbon for the large area tight sand oil formation, the delta tight sand widely developed next to the source rock vertically which provides a large amount of reservoir space for the large area tight sand oil formation, and hydrocarbon generation synchronizes with reservoir rock densification process, furthermore, the fault and fracture system which formed during the late Yanshan tectonic movement connected the source rock with reservoir rock, all of these provide the favorable conditions for a large area of tight sand oil formation. The anatomical results of typical hydrocarbon enrichment zones show that high-quality source rocks are in control of oil and gas enrichment, the favorable sand bodies are in control of oil and gas distribution, and the physical properties of reservoir rock are in control of hydrocarbon enrichment, the North-east-east fractures are in control of oil enrichment and high yield. Based on all the above, this paper establishes tight sandstone oil enrichment mode of the southwest Ordos basin edge, that is, "the source rock was next to the reservoir rock, the pressure difference between the source rock and the reservoir rock served as oil-filling driving force, the source rock and the reservoir phase jointly controlled tight sand oil formation, the reservoir phase and the fault-fissure jointly controlled tight sand oil enrichment ".

The high quality source rock widely developed in the area which provides a large amount of hydrocarbon for the large area tight sand oil formation. In recent years, the most scholars agreed that the tight sand oil of Ordos Basin mainly comes from Zhangjiatan shale which often developed in the bottom of the Chang 7 formation other than the Chang 7 formation dark mudstone. Due to the block data limitations, many scholars agreed that Zhangjiatan shale had bad development, preservation and evolution condition in Zhenjing and Bingchang blocks which were located in the southwest edge of the Ordos lake basin, But in recent years the Sinopec`s drilling results indicate that the Zhangjiatan shale are more developed in the blocks of Zhenjing and Binchang which also had high abundance of organic matter, hydrocarbon generation potential, moderate maturity and provided large amount of hydrocarbon for the large area tight sand oil accumulation in these areas. Among these, the Zhangjiatan shale widely distributed in Zhenjing block, in which the shale is more thicker in the northeast part close to the sedimentation centre of the lake basin and is gradually thinning towards southwest part, the thickness of the shale is about 8 to 16 m, and average 10 meters (see Fig 1, black line in Figure 1 was Zhangjiatan shale thickness contour which is on behalf of 10 m). The features of Zhangjiatan shale in Zhenjing block are high amount of potential hydrocarbon, high S2 / S3 Type Index (the value of most samples was larger than 40), high hydrogen index, for short I_H (mainly distributed between 200 and 400 mg/g) and low hypoxic index, for short Io (the value of most samples was less than 5 mg/g), all above indicated that the type of organic materials was mainly as type I; The average value of TOC (Total Organic Carbon) equaled to 8 percent, the value of *R*o(vitrinite reflectance) ranged from 0.7 to 1.0 percent, the value of S_1+S_2 equaled to 53.13 mg/g, all above data showed the Zhangjiatan shale was high-quality source rocks with high abundance of organic matter and high hydrocarbon generation potential. Zhangjiatan shale in Binchang block distributed as well as that of Zhenjing block, which was thicker in the northeast part and became gradually thinner towards southwest, the thickness ranged from 12.5m to 22.5m, with an average value of thickness equalled to 15 meters. The Zhangjiatan shale in Binchang block possessed the similar geochemical characteristics with that of Zhenjing block, namely, high organic matter abundance, mainly as type I, high hydrocarbon generation potential, so it was a set of high-quality source rocks.

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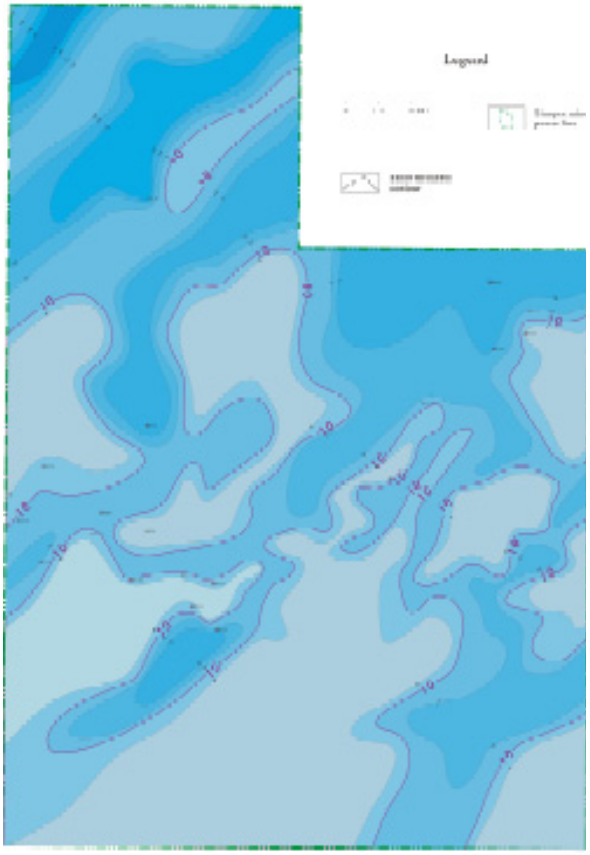

Fig. 1. The overlay map between Chang 81 oil display and Zhangjiatan shale distribution in Zhenjing block.

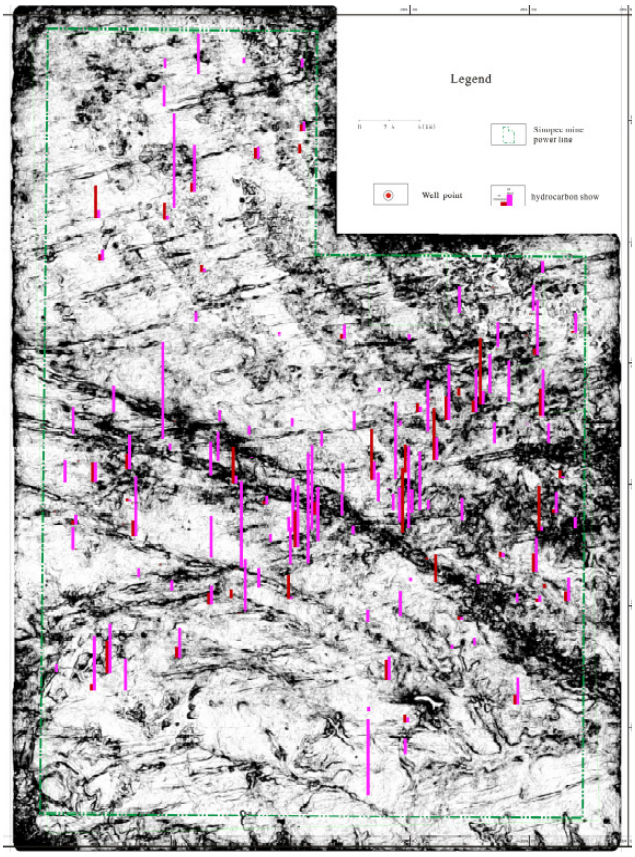

Fig. 2. The overlay map between Chang 81 oil display And T6c (seismic refection event between Chang7 and Chang8 formaiton) coherence in Zhenjing block.

The large areas delta tight sand which was adjacent to the high-quality source rock widely developed in the study area. The main geological features of the Ordos Basin were simple construction, gentle structure and stable subsidence in Late Triassic, the multiple source mainly deposited in the form of delta system around the basin, which controlled the development and distribution of reservoir rocks. Sinopec Exploration areas including Zhenjing, Binchang and other blocks were subject to the southwest-oriented and the south -oriented source depositional system in. The main oil-bearing series in Zhenjing block consisted of Chang 8^1, Chang 9^1 and Chang 6^2 oil reservoir group. Taking Chang 8^1 sub-oil reservoir group as an example, the lower limit of effective oil-reservoir properties was $\Phi \geq 7\%$ (porosity being equal to or greater than 7 percent), $K \geq 0.1$ md (permeability being equal to or greater than 0.1 millidarcy), while the reservoir properties limits of oil testing production capacity which achieves economies was generally $\Phi \geq 10\%$, $K \geq 0.3$ md, thus, effective reservoir could be divided into two categories, the type I reservoir was considered as "reservoir sweet spot" which was favorable for oil reservoir and production, the type II reservoir was considered as effective accumulation and production reservoir. Drilling wells statistics show that the effective reservoirs of Chang 8^1 sub-oil group in the region widely developed and contiguously distributed. The sand bodies whose total effective thickness was more than 20m consisted of 4-5 main sand belts and mainly distributed in Chuankou, Daijiaping and Zhongyuan area. And superimposed sand area was accounted for more than 2/3 of the total area of the block so that it provided significant reservoir conditions for forming a large area of lithological reservoirs.

The fault-fracture forming during Yanshan tectonic movement improved the reservoir rock and communicated the hydrocarbon source. The Coherent and Curvature properties of Loess Tableland 3-D seismic data in Zhenjing and Binchang area clearly showed a series of north-west and north-east to linear traces (Fig. 2), among them, part of traces had been identified as obvious vertical fault throw fracture according to seismic data. The 3-D seismic data revealed the fracture direction was almost north-east-east, only in the central of Zhenjing area there existed north-west larger fault fracture zone. These faults' occurrence was steep in the vertical profile and straight in the horizontal section, moreover the vertical and horizontal fault throw was small. Most of faults broke up

to Cretaceous formation, part of them could be broken down to Paleozoic formation. All of the above showed the faults were the characteristics shear fault under the action of the horizontal stress field and close relationship with late Yanshan tectonic movement. According to the drilling well and the oil-field test data analysis, Zhenjing and Binchang block logging display or logging interpretation of oil and gas reservoirs had a close relationship with the fracture (Fig. 2), especially upper part of Yanchang formation and Jurassic Yanan formation relatively were far from Zhang Jiatan shale vertically, reservoirs mostly distributed in the high points of the structure near the faults. According to faults & occurrence of fissures and speculation of some scholars, the faults and associated fractures mainly formed during Yanshan tectonic movement, which improved sandstone reservoir's physical property, and well matched with the key oil accumulation period, directly connected source rock with reservoir rock, constituted an effective channel for oil and gas migration, and promoted oil migration and accumulation.

The oil enrichment was jointly controlled by "high quality source rock-the favorable reservoir belt-fracture well developed" in southwest of Ordos Basin. The exploratory drilling statistics showed that the areas where Zhang Jiatan shale well developed and evolved had more oil and gas shows in the plane, such as the centre and north of Zhenjing block, the north and east of Binchang block. However, there was no exact relationship between the thickness of the shale and reservoir oil-bearing. It indicated that oil enrichment was controlled by high-quality source rock in macro-scale. Oil saturation statistics based on exploration well-log data also showed that reservoir oil saturation gradually decreased with the vertical distance between reservoir rock and the Zhangjiatan shale increasing. It showed that effective source rock not only played a leading role in formation of large area lithological reservoirs, but also controlled the layer of oil enrichment. The oil enrichment was controlled by " the favorable reservoir belt ", for there was good relationship between reservoir oil-bearing and reservoir physical property which was mainly controlled by sedimentation and diagenesis, particularly "reservoirs sweet spot" caused by the interaction between sedimentation and diagenesis, was an important exploration and development target. Exploration & exploitation practice in the southwest of Ordos basin, especially large-scale horizontal drilling wells, proved that the fracture developing zone based on sand bodies was favorable for oil enrichment and high productivity. Production data indicated the oil show thickness and grade (ranging from oil immersed to oil spot) of exploratory wells near the reservoir area where NEE-trending faults and associated fractures developed were better than matrix reservoir developed area, the daily output of horizontal wells was also 2.21 times that of the matrix area, and the water content reduced by 20.0 percent.