Control of Fault Intensive Zones on Hydrocarbon Accumulation: a Case Study of Qijia-Gulong Area in Northern Songliao Basin

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Abstract: The top surface faults of Quantou Formation in Qijia-Gulong area in northern Songliao basin are widely developed and densely zoned, controlling the deposition and accumulation of Fuyu oil layer. To clarify the control role of fault intensive zones, a combination of plane and section is used to analyze the plane and section characteristics of fault intensive zones, analyze their impact on reservoirs and source rocks, and clarify the reservoir control mode. The results show that: (1) The faults of Fuyu oil layer in Qijia-Gulong area are unevenly distributed and densely zoned, the Western intensive zones are NNE direction, and the eastern intensive zones are NW direction; (2) The western part of the fourth section of Quantou Formation in the study area is in the direction of provenance. The same direction fault promotes the sand body to transport into the basin, and the reverse fault blocks the sand body migration. When the fault trend is the same as the direction of provenance, the sand body is dispersed along the fault strike; (3) Oil and gas migrate to the high part of the structure through the fault sand body transport path. In the west of the study area, oil and gas are accumulated in the footwall of the antithetic fault at the boundary of the fault intensive zone, which in the East are mainly enriched in the "concave uplift" structure formed by inversion.

Key words: northern Songliao Basin, Qijia-Gulong area, Fuyu reservoir, Fault intensive zone, Reservoir control

1. Preface

The middle and shallow oil and gas in the northern Songliao basin has very broad exploration prospects [1], in which Qijia-Gulong area and Sanzhao area are rich in residual resource potential [2]. Fuyu oil layer is a tight oil reservoir, including the fourth section of Quantou Formation and part of the third section of Quantou Formation. Its source rock is overlying the first section of Qingshankou Formation mudstone [3]. Qijia-Gulong area is in the west of Daqing placanticline, where many NNE trending secondary sags and nose structures are developed. At present, tight oil has been found around the depression on a large scale, and the exploration degree in the deep sag area is low, which has great exploration potential (Fig 1).

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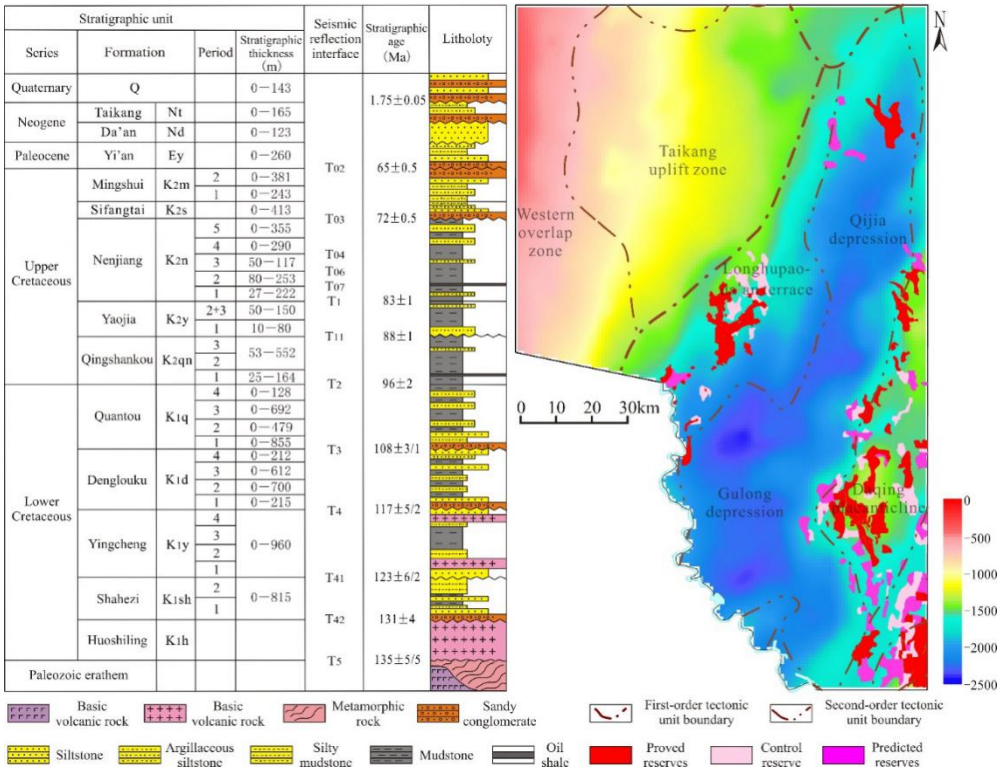

Fig 1. Division of structural layers and exploration results of Fuyu oil layer in Qijia-Gulong area

2. Characteristics of fault development

More than 2000 faults are developed on the top of Quantou Formation in Qijia-Gulong area, with NNW strike as the main strike, followed by NW and NE (Fig 2). The extension length of the faults is small, with an average of less than 2km. The faults are unevenly distributed and densely banded. The fault intensive zone is a combination of faults with the same or similar strike, which is banded on the plane and has a certain genetic connection. In the study area, 84 intensive zones were identified, the distribution direction of the Western intensive zones are NNE, and the faults in the zone are interlaced combination of NE and NW faults; The intensive zones in the East are NW trending, and the faults in the zone are NW trending faults with similar strike, which are arranged in parallel or echelon [4-6]. The section shows fault terrace, graben horst, "V" shaped and "Y" shaped structure style.

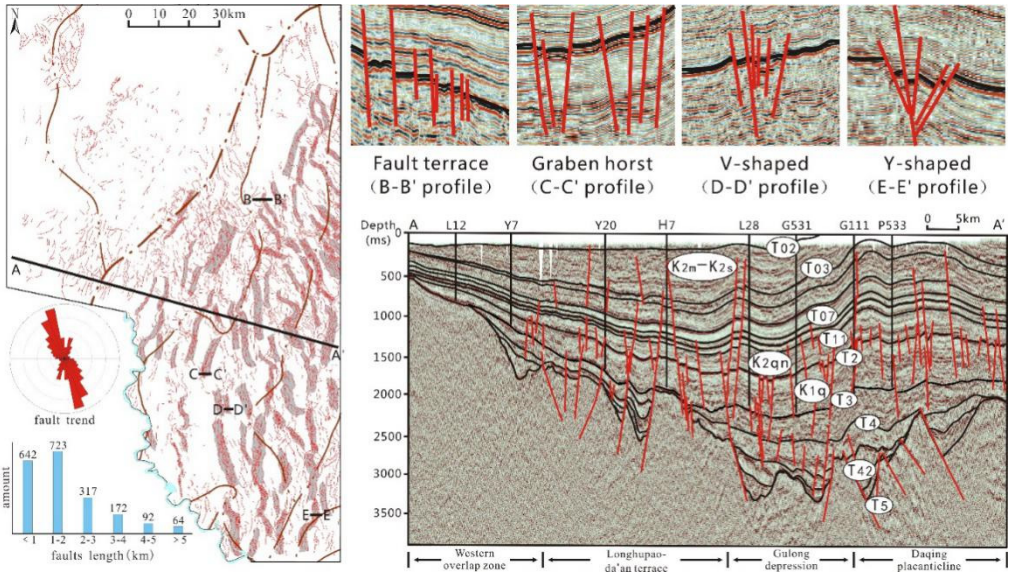

Fig 2. Plane distribution and structural interpretation of faults in Qijia-Gulong area

3. Structure controls sand body distribution

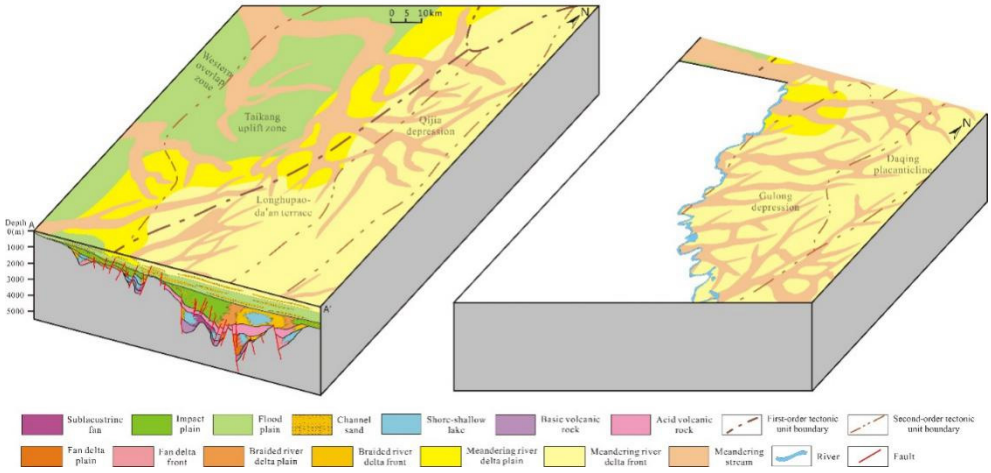

Fig 3. Sedimentary characteristics of Fuyu oil layer in Qijia-Gulong area

The structure controls the shape of the paleotopography, determines the sedimentary characteristics and provenance direction, and the structural shape and faults affect the distribution of sand bodies. The paleotopography of the study area is high in the West and low in the East, so the provenance is mainly from the Western gentle slope, and the river channels are mostly developed from west to East (Fig 3). Due to gravity drive and sedimentary

differentiation, the slope break zone developed in the Longhupao terrace and the delta plain was deposited. In the east of the study area, there is a wide range of delta front deposits, and the scale of sand bodies is developed. Fuyu oil layer has good reservoir space.

Syndepositional faults and slope break zones jointly control the channel strike, thus affecting the distribution characteristics of sand bodies. The sand body distribution direction of Quantou Formation in Qijia-Gulong area is near WE direction. The Western fault of the study area intersects with the channel sand body at a large angle, and the long-term syndepositional fault has a large fault distance, forming a slope break in the gentle slope zone. When the river passes through, if the fault trend is from west to East, the flow will be transported and accumulated into the basin due to gravity when passing through the slope break zone (Fig 4a); If the fault trend is from east to west, when the water flows through the slope break zone, it is obstructed and the sand body transportation is blocked, and the water flows accumulate in the upper part of the slope break zone (Fig 4b). The strike of the eastern fault is NW, which is close to the trend of the river channel. The western slope and fault hanging wall jointly control the direction of water flow. Sand bodies are scattered along the strike of the fault (Fig 4c) [7].

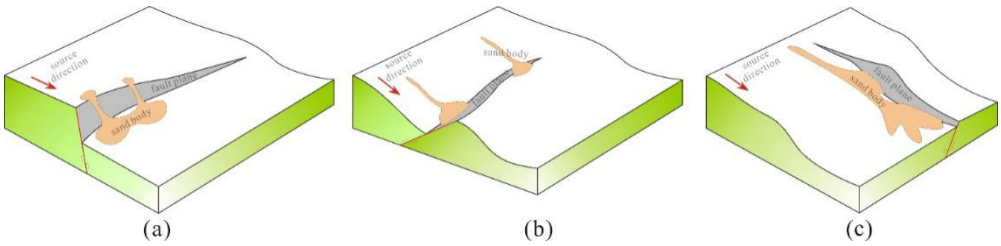

Fig 4. Sand control mode of fault and slope break zone in Qijia-Gulong area

4. Fault controlling reservoir

4.1 Fault intensive zones control hydrocarbon migration and accumulation

The channel sand body of the fourth section of Quantou Formation in the study area is distributed from west to East. Due to the small dip angle of the stratum, the lateral migration ability of the sand body is insufficient, and it is difficult for oil and gas to migrate in a long distance only by the sand body. The fault intensive zone has the effect of lateral shielding and lateral transportation of oil and gas [8]. When the strike of the fault intensive zone intersects with the direction of oil and gas source at a large angle, it plays a role of lateral shielding; When it is close to the direction of oil and gas migration, it mainly shows the role of transportation. Oil and gas migrate to the high part of the structure due to buoyancy, the edge of fault terrace、horst and the "concave uplift" structure formed by structural inversion is the dominant reservoir forming part(Fig 5) [9].

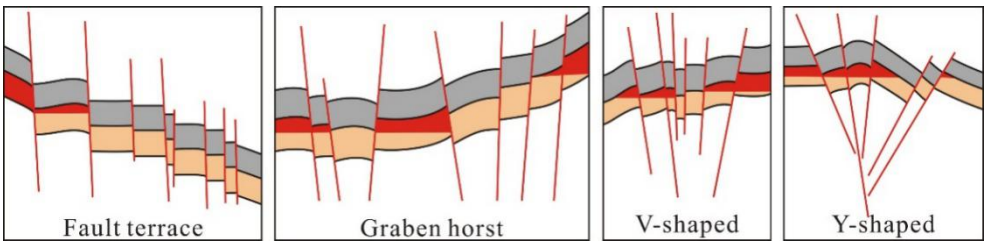

Fig 5. Dominant reservoir forming positions of fault intensive zone in Qijia-Gulong area

4.2 Reservoir forming characteristics in the study area

The last stage of Mingshui Formation is the accumulation stage of large-scale migration and accumulation of oil and gas [10]. The source rocks generate and expel hydrocarbon on a large scale. The NNW trending fault in the study area is reactivated and opened by extension, and the fault and sand body can communicate effectively and play a role of transportation [11]. NNW trending faults are mainly developed in the east of the study area. Qijia-Gulong sag has developed "concave uplift" formed by structural inversion on the East and West boundaries, which is conducive to oil and gas enrichment. Industrial oil reservoirs and low production reservoirs have been drilled in the study area.

The trend of the faults in the west are mostly NNE, which are closed by the compressive stress field at the end of the Mingshui Formation and play a role of shielding. Oil and gas migrate through the NNW fault-sand transport path in the intensive zone. During the migration process, they are blocked by the NNE faults, which are shown on the profile as antithetic faults (the fault trend is opposite to the formation trend) at the boundary of the intensive zone. The sand body is butted with the mudstone of Qingshankou Formation in the hanging wall of the fault, and oil and gas accumulate and form reservoirs in the footwall of the fault [12-14]. The well Y20 encountered an industrial oil layer in Fuyu oil layer, and the oil test results showed that the daily oil production could reach 7.7t(Fig 6).

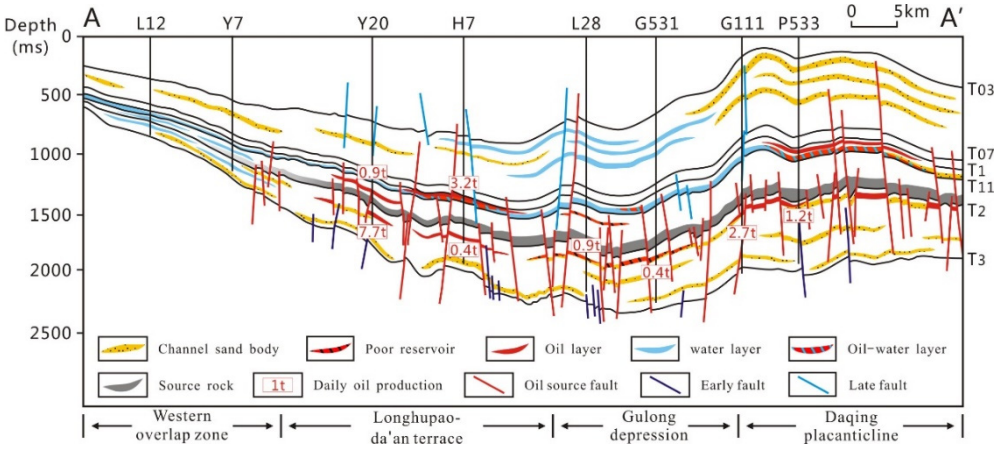

Fig 6. Reservoir profile in Qijia-Gulong area

5. Conclusion

(1) The faults of Fuyu oil layer in Qijia-Gulong area are unevenly distributed and densely zoned. The distribution direction of the western fault intensive zones are NNE, and the eastern fault intensive zones are NW.

(2) The sand body of the fourth section of Quantou Formation is developed from west to East, and syndepositional faults affect the sand body distribution. The same direction fault promotes the sand body to transport into the basin, while the antithetic fault blocks the sand body migration. When the fault direction is the same as the source direction, the sand body is dispersed along the fault trough.

(3) Oil and gas migrate to the high part of the structure through the fault-sand body transport path. In the west of the study area, oil and gas are accumulated in the footwall of the antithetic fault at the boundary of the intensive zone, while in the East, they are mainly enriched in the "concave uplift" structure formed by inversion.

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