Formation Conditions and Exploration Potential of Tight Oil in the Kong2 Member, Cangdong Depression

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To study the sedimentary environment, source rock, reservoir characteristics and distribution, symbiotic relationship between source and reservoir, the old wells and well area reexamination, experimental data were involved in the analysis, guiding by the theories and methods of petroleum geology, mineralogy, organic geochemistry, geophysics. The potential targets were predicted for future exploration, and provided a fundamental basis for future exploration and development of tight reservoirs. The main achievements and findings are as follows:

1. There was a humid subtropical climate during the deposition period in Kong2 member of Cangdong depression. The high quality source rock is broadly distributed, depositing in the closed deep lake or semi-deep lake. The terrain extends east to west from the Yesanbo to the Shenusi and south to north from the Wumaying to the Kongdian. The source rock, the cumulative thickness of which can be greater than 50m, is at 1800-3800m burial depth. So the source rock provided the basis of materials for the formation of tight reservoirs and became the stable regional cover.

2. Laterally, the source rock has maximum abundance of organic matter in the Fenghuadian - Wangguantun - Duanliubo area, which is characterized by the the curved distribution for the east wide west narrow, and the highest value gradually declined towards all around. The distribution of the highest value of organic carbon overlaps with the thickness of shale. Vertically, the dominating source layers with high organic matter abundance are the lower part of the $E_k^2$, the $E_k^2$ and $E_k^2$. The average TOC for those layers are 5.16%, 5.47%, 5.27% respectively.

The organic type mainly consists of I-II1, and the kerogen type of organic matter is predominantly sapropelic. The organic matter, including telalginite or lamalginite, show strong yellow fluorescence. The liptodetrinite and the abundant botryococcus braunii can have strong potential of hydrocarbon generation. The type I kerogen mainly distributes in the Fenghuadian area of Cangdong depression and the north and west part of the Wangguantun in Nanpi depression. The average value of type index is between 75 and 90 and the average value of HI typically between 550 and 750 mg/g.c by microscopic examination. However, the data of the atomic ratio of H/I are sparse, only two wells have data analysis, 1.44 and 1.49 respectively. The type II1 kerogen has wide distributions, the estate is bond to north by the Zao29 well area, to the south by the Wumaying area, to the east and west by the sedimentary margins. Each of these regions develop the mudstone, and the thickness exceed 50m. The average value of type index is between 40 and 70, the average value of HI typically between 350 and 650 mg/g.c, and the atomic ratio of H/I between 1.25 and 1.40.

The mature threshold depth is 2600m, and the depth of the top of the Kong2 member exceed 2600m except in Kongdian uplift, so most of the source rocks have came into maturity threshold. The Kong2 member is characterized with high maturity and better type of organic matter, and the depth of expulsion of hydrocarbons is less than 2600m. The “double peak” of thermal evolution of the source rocks are characteristic with increased depth. The source rocks enter into the oil generation threshold less than 1900m, with hydrocarbon generating and discharging early. In other words, the source rocks can generate hydrocarbon in low mature stage (Fig. 1). The value of the vitrinite reflectance is between 0.5% and 1.1% with rather moderate thermal evolution, owing to hydrocarbon-generating peak of the source rock in the high maturity stage.

(3) The category of rock types and the reservoir space of the tight reservoirs are various. The main kinds of rocks include shale, tight sandstone, dolomite and mixing rocks. The dense rock vary greatly laterally. The reservoirs in Kong2 member contain high contents of brittle minerals including quartz, calcite, dolomite, pyrite and analcime, which is favorable for the formation of natural or manual fractures. The porosity of the reservoir is mainly 10%, and

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the permeability is less than $1 \times 10^{-3}$ μm$^2$. There was no correlation between the porosity and the permeability, exhibiting strong heterogeneous. The reservoir space is mainly intergranular dissolved pore and various fractures distributed as a whole-block, providing reservoir space condition for tight oil and gas accumulation (Fig. 2).

(4) The Nanpi slope belongs to the inherited slope. The reservoirs in the lower slope areas and the lake basins are mainly delta-front subfacies and semi-deep lacustrine subfacies with huge areas of the delta-front sheet sand, dolomite, shale and dark gray mudstone assembled in the flake structure. It can form the tight oil reservoir with source in reservoir, and the high quality source rock are widely distributed in Kong2 member are configured organically forming a layered continuous distribution (Fig. 3). The Kongxi slope, Kongdong slope and Yaoguantun slope belong to the inverted slope. The lower parts of the slope is rich in sand and the middle-higher of the slope formed the tight oil reservoir with source in reservoir are favorable for formation and accumulation of tight oil and gas reservoirs (Fig. 4). Two groups of reservoir formation, that is, inner source included group and upper source widely distributed model, which are mainly controlled by source depressions. Vertical distribution of oil is in the $E_{k2}^{1}$ and $E_{k2}^{3}$ formations which are interbedded the source rocks. The source rocks may serve as the reservoirs which belong to the sediments of in-source and short source. The proved oil and gas is mostly found in the source or above the source which belong to source and reservoir in the same bed pattern and the lower generation and up per-storage pattern. So the hydrocarbon generating center control the petroleum formation and distribution, and the oil reservoir

![Fig. 1. Thermal history.](image1)

![Fig. 2. Photomicrograph of GD14.](image2)

(a), 3198.37m, micritic dolomite, lamellar asphalt; (b), 3190.94m, micritic dolomite, structural fracture filled by asphaltum; (c), 3185.67m, micritic dolomite, dolomite intracrystalline pores filled by asphaltum; (d), 3189.53m, micritic dolomite, striped algae
distributes chiefly at hydrocarbon generating center or around it.

(5) Based on the study of the sedimentary environments, strata and structure in conjunction with the analogy, overlaying and synthetical technology, we predict favorable oil and gas distribution zone according to the distribution of high quality source rocks, the favorable tight reservoirs and the fracture. The main reference index of the distribution of the tight reservoirs in Cangdong depression are as follows: high abundance of organic matter (TOC $\geq$ 3%), proper organic matter maturity ($R_o \geq 0.5\%$), reservoir buried between 2000 and 4000m, slope zone, few faults (growth index $< 1.5$), transgressive systems tract, delta front far bar and semi-deep lacustrine environments. with the standard listed above, we ensure the favorable tight reservoirs distribution zone is in the $E_k^1$, $E_k^2$ and $E_k^3$. The middle-higher of the inverted slope (Kongxi slope, Kongdong slope) and the lower of the inherited slope (Nanpi slope) are considered to be the favorable exploration area of tight reservoirs.