Analysis of reservoir-forming conditions of Beidong sub-sag in Beier Sag

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Abstract. Beier Sag is the main oil-rich sag in Hailar District basin. This paper analyzes the structure, source rock, relationship of source and reservoir, and deeply studies the reservoir-forming characteristics of Beidong sub-sag in Beier Sag. The study shows that the structure pattern of the bei-dong sub-sag in Beier Sag is characterized by "concave and uplifted interchangeably", the present basin pattern is quite different from the prototype basin, develops northeast-east and north-east fault depressions in the Nantun formation during the sedimentary period. After three-stage tectonic transformation, it changes into the north-northeast direction, develops the palaeo-structure and has the geological conditions of reservoir formation. The dark mudstone of Nantun formation in Beidong sub-sag is thick, the abundance of organic matter is higher, and Type II is the main type; it is the medium-good source rocks with favorable conditions for reservoir formation. There are three sets of reservoir-forming assemblages in Beidong sub-sag, forming multi-type reservoirs. The succession of palaeo-structure is the main controlling factor of oil and gas accumulation, the favorable oil-bearing structures, such as reverse fault block and mid-concave uplift, are developed.

1. Introduction

Beier Depression is located in the southwest of Hailar District Basin. The area studied in this paper is Beidong sub-sag in Beier Sag; its total area is approximately 1850 km². The exploration level in Beidong Sag is relatively lower, and there are 15 exploratory wells in the SAG. Among them, there are one industrial oil well and eight wells in which oil and gas readings are found. The exploration target strata are mainly Nantun formation, Tongbomiao formation and bedrock. At present, no proved reserves have been submitted in the SAG of this area. After the exploration and research of many years, the predecessors have a certain understanding of the geological conditions in this area, but due to the low degree of research and complex petroleum geological conditions in this area, the amount of resources calculated by the earlier resource evaluation is relatively small, less than 10 million tons, therefore, the area has been neglected for a long time, and the study of Petroleum Geology as a whole is lacking. Recent exploration results show that dark mudstones of certain thickness are also developed in the sub-troughs of the Beidong area, especially in the southern member, which has a high abundance of organic matter and is entering a mature stage, which is a prerequisite for oil and gas generation, therefore, the area has the value of further exploration and evaluation[1-6] (Fig. 1).
2. Characteristics of tectonic evolution
Consistent with the tectonic activity of Hailaer basin, there have been three regional tectonic movements in Beidong area of Beier Sag since early Cretaceous. They are the end of Nantun formation, the end of Yimin formation and Qingyuangang formation. At the end of the Nantun formation, most of the Beidong Sag was uplifted and eroded due to the regional compressive stress field, especially in the Huoduomoer structural belt and the Sudeerte structural belt, followed by the Beidong trough group. During the deposition of Damoguaihe formation and Yimin formation, the control of boundary faults on the stratum is relatively weak. The study area is controlled by left lateral strike slip stress field, forming fault depression basin. At the end of Yimin formation, the whole area is uplifted and eroded by regional compressive stress. At the end of the deposition of Qingyuangang formation, the area was transformed by weak extension and compression, and inversion occurred in some areas, which was obvious in bei60 trough and Beidong sub sag. Vertically, it can be divided into three structural layers: fault depression structural layer, fault depression transition structural layer and depression structural layer. The structural evolution has experienced fault basin, fault depression transition basin and depression basin (Fig. 2 and Fig. 3).
Figure 2. Seismic profile of depression structure (horizontal)

Figure 3. Seismic profile of depression structure (longitudinal)

3. Characteristics of source rocks
The residual thickness of strata in Beidong area during the fault depression period is relatively large, and the thickness is controlled by the paleo-tectonic background during the fault depression period. In the paleotopography trough area, the thickness is larger. The thickness of dark mudstone in the first member of Nantun formation in Beidong Sag is generally between 100m and 350m, and the maximum is 550m. The areas with the largest thickness of dark mudstone are distributed in bei18 and bei52 depressions, with an average thickness of 450m, which is an important hydrocarbon generation center; the thickness of dark mudstone in other depressions is relatively thin, generally between 50-300m. The thickness of dark mudstone in the second member of Nantun formation in Beidong area is generally 500~250m, and the maximum is 300m. The areas with the largest thickness of dark mudstone are distributed in bei60 and bei6 depressions, with an average thickness of 200m; the thickness of dark mudstone in other depressions is relatively thin, generally between 50-150m.

The dark mudstone of Nantun formation in Beidong sag is thick, and the type of organic matter is mainly type II, which is evaluated as medium-good source rock and has good oil generating conditions. The type of organic matter in each trough in Beidong area is similar, mainly type II, locally develops kerogen named type I , distributed in the calcium bearing mudstone of the lowerpart of the first member in the Nantun formation. This set of mudstone was encountered in the lower part of the first member in the Nantun formation of bei18 and bei60 depressions. The thickness of the mudstone is 55-80m. This set of mudstone is the high-quality source rock in Beier Sag, and the upper and lower
parts are the most abundant oil and gas reserves. At present, bei60 well in Beidong area has been drilled and coring has been carried out. The core observation is black and grayish black mudstone, which develops micro fractures, fills with calcite, and has the characteristics of fracture oil-bearing, with oil spots on the fresh surface.

The dark mudstone in Beidong area is in mature stage, with hydrocarbon generation threshold of 1800m and relatively shallow maturity threshold. Compared with Beixi sub sag and Beizhong sub sag, the depth of 0.5% Ro maturity of dark mudstone in Nantun formation in Beidong area is 1050m, and the depth of 0.7% Ro maturity is 1800m. The high-quality source rock is calcareous argillaceous rock of the fifth sand formation in the lower part of the first member in Nantun formation, which is widely distributed on the plane, and is speculated to be distributed in all depressions in the Beidong area, with a thickness of 40-80m. The thickness and lithology of Beidong, Beixi and Beizhong are the same, which are deposited in the brackish water environment during the maximum flooding period of the first member of the South member.

4. Analysis of hydrocarbon accumulation process

Beidong area is characterized by strong structural transformation and complex hydrocarbon accumulation process, which can be divided into five stages: source reservoir filling stage of the first member of the Nantun formation, formation and finalization stage of paleostructure at the end of the second member of the Nantun formation, stable subsidence stage of Damoguaihe formation, hydrocarbon migration and accumulation stage of Yimin formation, and structural inversion stage of Qingyuangang formation. The Tongbomiao formation and Nantun formation are the fault depression period. The basin is filled with thick sediments. The thickness of the first member of the Nantun formation is the largest, which is the most important material basis. The process can also be divided into two levels: firstly, the prototype basin was formed on the basis of the deposition of Tongbomiao formation, which was generally in the transgressive stage; secondly, the local water uplift was formed at the end of the first member of the Nantun formation, which was eroded and reformed (Fig.4).

Figure 4. Sedimentary filling stage evolution map of the first member of the South member of hydrocarbon accumulation in Beidong area.
After the late reformation of Nantun formation in Beidong area, three favorable reservoir forming areas, named slope zone, mid sag uplift and buried hill, were formed. Among them, structural reservoir was mainly formed around the structural uplift, while structural lithologic reservoir was formed in the mid sag uplift. Four typical reservoir forming models were established, namely, strong reformation in the late paleouplift of the central trough and reverse fault terrace slope zone Late reformation, central paleo uplift reverse fault terrace slope complex and deep fault connect source reservoir buried hill reservoir. At present, the top of the second member of the Nantun formation of well Beix64 has been found in industry, and the first member of the Nantun formation has also seen a thick oil-bearing display (Figure 5).

Figure 5. Model map of late reformed reservoir in reverse fault terrace slope zone of Beidong sub sag
5. Conclusion
Beidong area has a structural pattern of "alternating depression and uplift". The present basin pattern is quite different from the prototype basin. During the sedimentary period of Nantun formation, NEE and NE fault depressions were developed. After three stages of structural transformation, NNE fault depressions were developed, and paleostructures were developed, which provided the geological conditions for hydrocarbon accumulation. The residual trough group still develops thick dark mudstone and has good hydrocarbon generation index. It is in mature stage and has favorable conditions for reservoir formation. Three sets of reservoir forming assemblages are developed to form multiple types of reservoirs. The inherited development of paleostructure is the main controlling factor of oil and gas accumulation. The favourable oil-bearing structures such as reverse fault block and uplift in sag are mainly developed.

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