1 Introduction

The oil reservoir formed by Quan3 and Quan4 tight sandstones, also called Fuyu oil layer, in the Sanzhao sag, northern Songliao Basin, contains "sub-source" tight oil, which sourced from the overlying Qing1 lacustrine mudstone that acts as the caprock of the Fuyu oil layer, with the Quan3 and Quan4 tight sand bodies of fluvial-shoal water delta sedimentary system as reservoir bed, constituting a "upper source and lower reservoir" type source-reservoir-caprock assemblage. By far, about 5.38×10^8 t conventional oil in place has been proved in the Fuyu oil layer, and good exploration results have been achieved.

The remaining resources in this study area are dominated by tight oil in tight sandstone reservoirs, which is characterized by low resource quality, low single-well output and unclear potential and distribution characteristics of remaining tight oil resource. Therefore, in this paper, based on the geological characteristics and exploration maturity of the Sanzhao area, tight oil targeted methods (e.g. small bin volumetric method, resource abundance analogy method and EUR analogy method) are used for tight oil assessment in the study area, to point out the sweet zones of tight oil. Moreover, key parameters involved in these methods are analyzed, which can provide reference for the assessment of the same type of tight oil resource in the future.

2 Methodology

2.1 Small bin volumetric method

As to the fundamental principle of small bin volumetric method, the assessment area is divided into a number of grid units; the resources of each small bin is figured out one by one based on the parameters like the area, net pay thickness, net porosity and oil saturation of each grid unit; and then, the resources of the whole assessment area are obtained by adding the resources of all small bins together. The key parameters required in the small bin volumetric method include net thickness of reservoir, porosity, oil saturation, petroleum fullness coefficient, oil density and volume coefficient.

The sandstone thickness of Fuyu oil layer in the Sanzhao sag is generally 5.8-14.4 m; the maximum thickness of single sand body is 8.8 m, and generally 2-5 m. The net reservoir porosity generally ranges in 4-15%, 9.5% averagely, and the air permeability generally ranges in 0.1-2.0 mD, 0.78 mD averagely, showing poor physical property. After combining the oil saturation values of the proved blocks, the oil saturation of Sanzhao sag is taken as 30-50% averagely. Since conventional oil and tight oil coexist in the Fuyu oil layer of Sanzhao sag and the distribution of tight oil "sweet zone" is limited, the petroleum fullness coefficient is taken as 70%. Based on the data of blocks with their reserves booked, the surface crude oil density of Fuyu oil layer in the Sanzhao sag is 0.87 g/cm³, and the volume coefficient is 1.06.

Because conventional lithologic reservoir and tight oil reservoir coexist in the Fuyu oil layer of Sanzhao sag, whereas the proved reserves and proved area of conventional oil in the target zone of the study area booked over recent years are 5.38×10^8 t/km² and 1265.6 km² respectively, after the proved area of conventional oil is subtracted from the area of 5533 km² of the whole study area, the tight oil assessment area used for small bin volumetric method is obtained as 4267.4 km².

Based on the calculation results of the small bin volumetric method, the geologic resources of tight oil in the Sanzhao sag is 60278.8×10^4 t, and the average resource abundance is 14.1×10^4 t/km². The assessment area is divided into three types of resource abundance areas: high...
abundance area (Type A), medium abundance area (Type B) and low abundance area (Type C) (Fig. 1). The resource abundance is more than $25 \times 10^4$ t/km$^2$ for Type A area, less than $25 \times 10^4$ t/km$^2$ but more than $10 \times 10^4$ t/km$^2$ for Type B area, and less than $10 \times 10^4$ t/km$^2$ for Type C area. Based on calculation, the area of Type A, B and C is 1029.5 km$^2$, 441.2 km$^2$ and 2796.7 km$^2$ respectively.

Referring to the recovery factor data of tight oil provinces both at home and abroad, e.g., the Williston Basin of North America, west Canada Sedimentary Basin and Gulf of Mexico Basin (4%-12%), and the scale region in the Zhaozhou oilfield (13.5%), and combined with the calculated recovery factor values of 26 single wells in this study area, the recovery factors of high, medium and low abundance areas in the Sanzhao area are determined as 13%, 7.5% and 4% respectively. Then, the resource abundance of the study area are estimated as follows: for Type A area, the geologic resources and recoverable resources are 46039.3×10$^4$ t and 5985×10$^4$ t respectively; for Type B area, the geologic resources and recoverable resources are 7517.2×10$^4$ t and 563.8×10$^4$ t respectively; and for Type C area, the geologic resources and recoverable resources are 6726.3×10$^4$ t and 269×10$^4$ t respectively (Table 1).

2.2 Resource abundance analogy method

The Zhaozhou oilfield in the south of Sanzhao sag is selected as a scale region for analogy. Referring to the assessment results of small bin volumetric method, the Sanzhao sag is divided into Type A, B and C areas to conduct analogy with the Zhaozhou scale region. The analogy results show that the analogy coefficients of Type A, B and C areas of the Sanzhao sag are 1.077, 0.862 and 0.677 respectively. Based on analogy assessment, the geologic resources and recoverable resources are 46039.3×10$^4$ t and 5985×10$^4$ t for Type A area, 7517.2×10$^4$ t and 563.8×10$^4$ t for Type B area, and 6726.3×10$^4$ t and 269×10$^4$ t for Type C area (Table 2).

2.3 EUR analogy method

There are a total of 26 horizontal and vertical wells in the assessment area. Because only a few wells are put into production and their distribution range is restricted, the mean well controlled area is taken. Based on the data provided by the oilfield, the single well controlled area is calculated as about 0.5 km$^2$.

Three kinds of production decline methods like exponential decline, logarithmic decline and power exponent decline are used to match the production data and estimate the EUR values of every single well under different situations. Overestimated value, medium-estimated value and underestimated value are obtained appropriately. At the time of calculating the resources, based on the actual productivity situation, the probability for each estimated value to occur is given, and then the possible EUR probability distribution value of the single well is obtained.

It is discovered through statistics and matching of EUR values that the EUR values of producers of Fuyu oil layer in the Sanzhao sag can be divided into 3 classes: for Type A area, the maximum value, median value and low value of EURs of single well are 2.1×10$^4$ t (10%), 1.93×10$^4$ t (50%) and 1.6×10$^4$ t (90%) respectively; for Type B area, they are 1×10$^4$ t, 0.76×10$^4$ t and 0.6×10$^4$ t respectively; for Type C area, they are 0.5×10$^4$ t, 0.36×10$^4$ t and 0.12×10$^4$ t respectively. The EUR probability distribution of the 3 types of areas is shown in Fig. 2.

The calculation results of EUR analogy method show that the geologic resources and recoverable resources are
21013.6×10^4 t and 2731.8×10^4 t for Type A area, 5797.7×10^4 t and 434.8×10^4 t for Type B area, and 21709.4×10^4 t and 868.4×10^4 t for Type C area. The geologic resources and recoverable resources of tight oil of the whole Sanzhao area are 48520.7×10^4 t and 4035×10^4 t respectively (Table 3).

Based on understanding on the tight oil accumulation conditions and resource potential of the Sanzhao sag, the aforesaid 3 methods are integrated to calculate the tight oil resource potential of the area. Because only a few data can be used for EUR method, its weighted value only takes 0.2; whereas the weighted values of small bin volumetric method and resource abundance analogy method take 0.4 respectively; and the final integrated calculation results show that the expected geologic resources are 55856.7×10^4 t (Table 4), the recoverable resources are 5851.2×10^4 t, and the recoverable coefficient is 10.5%.

### 3 Conclusions

The integrated calculation of above 3 methods shows that the tight oil geologic resources of Fuyu oil layer in the
Sanzhao area are $55856.7 \times 10^4$ t, the recoverable resources are $5851.2 \times 10^4$ t, the resource abundance is $13.1 \times 10^4$ t/km$^2$, the recoverable resource abundance is $1.37 \times 10^4$ t/km$^2$, and the recoverable coefficient is 10.5%. The migration and accumulation coefficient depends on the ascertainment of the total hydrocarbon generation volume of this area. Because the parameters like the thickness of source rock, area, hydrocarbon potential and organic matter hydrocarbon generation transformation ratio of the Sanzhao area have been ascertained, based on the computational formula of hydrocarbon generation volume, the total hydrocarbon generation volume of tight oil in this area is calculated as $98.8 \times 10^8$ t; based on $55856.7 \times 10^4$ t geologic resources, the migration and accumulation coefficient is calculated as 5.7%. They represent the key parameters of tight oil resource assessment of sub-source hydrocarbon accumulation type in Songliao Basin.

References


