Analysis of Oil-water Distribution Law in Gulong Syncline Area of Southern Gulong

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Abstract. In order to find the main control factors that affect oil-water distribution in Gulong syncline, the oil-water distribution law and main control factors of Gulong syncline in Gulong South were analyzed based on comprehensive evaluation. The research shows that Putaohua oil reservoir in Gulong syncline area of southern Gulong is mainly lithologic oil reservoir under structural background, and the distribution law of oil and water is controlled by structure, sedimentation and reservoir physical properties. The distribution characteristics of reservoir physical properties are the main factors that control the distribution of oil and water in this area. This paper optimizes the reserves on the basis of recognizing the distribution of oil and water, and finally delineates the area of the well potential area X.Xkm2.

Keywords: Gulong syncline, Putaohua oil layer, Main control factors, Reserve optimization, Potential area of well distribution.

1. Introduction
Gulongnan Gulong syncline area is located in Zhaoyuan County, Daqing City, Heilongjiang Province, structurally located in the south of Gulong Sag, the central depression area in the north of Songliao Basin, and the main target layer for development is Putaohua oil layer [1-3]. From the current distribution of drilling and submitted proven and controlled reserves, industrial oil flow can be seen in the high part of the structure and syncline center, and there is no difference in productivity, which is contrary to the oil and gas distribution characteristics of conventional oil and gas reservoirs. In recent years, with the continuous improvement of exploration degree, syncline lithologic reservoir has become an important direction of oil and gas production increase [4-6]. In order to clarify the oil-water distribution law and main controlling factors in Gulong syncline area, this paper based on the fine anatomy of sequence stratigraphy, sedimentation, structure, reservoir diagenetic characteristics and oil-water distribution law, laid the foundation for macroscopically clarifying the plane and profile distribution of oil-water and main controlling factors, and optimized reserves to provide guidance for the next exploration and development in this area.
2. Sequence stratigraphic framework and sedimentary characteristics

2.1. Sequence stratigraphic framework
Guided by the theory of high-resolution sequence stratigraphy, according to the principle of “sequence boundary correlation under the control of step by step ‘standard isochronous plane’, the top and bottom boundaries of Putaohua oil layer are controlled by isochronous standard plane, and the minimum isochronous correlation unit is determined by internal cycle correlation. The thin argillaceous sediments formed during the flooding period of Putaohua oil layer are isochronous, which can be used as a good standard layer for controlling isochronous correlation of strata at Putaohua top interface. The electrical logging curve shows the logging characteristics of low-value peak of acoustic time difference and high-value peak of resistivity. Based on the principle of high-resolution sequence interface and lake flood identification, the first member of Yao Formation is divided into three oil layers and eight sublayers by combining well and earthquake, and the sequence stratigraphic framework is established, which lays the foundation for comprehensive geological research.

2.2. Sedimentary characteristics of sand body
During Putaohua reservoir sedimentation, Songliao Basin experienced large-scale lake recession, and the northern delta depositional system and the western delta depositional system both advanced to Gulong and Maoxing synclinal areas. Delta front subfacies and pre-delta deposits. The sand body is mainly composed of microfacies such as underwater distributary channel, distant sand bar and sheet sand, and the associated facies are underwater distributary channel bay and shallow lacustrine mudstone deposits. Putaohua oil layer is characterized by water regression and sand body accumulation. Gulong syncline is controlled by the western and northern provenances. The western provenance supply is strong, mainly sheet sand, and river sand is developed. The main direction is NW, and the river channel width is generally 400-900m. Among them, the upper and middle sandstone formations of Putaohua mainly develop underwater distributary channel and sheet sand, while the lower sandstone formation of Putaohua mainly develops pre-delta sheet sand and shallow lake mudstone.

3. Tectonic characteristics
Overall, it shows a structural pattern with high periphery and middle depression, with a structural height difference of 175m. The dip angle of the structure is generally 2, the strike is nearly north-south, the fault distance is generally 10 ~ 50m, and the fault planes of Putaohua oil layer are densely banded. According to the seismic profile, three fault dense zones are divided, and the boundary fault of the dense zone is the oil source fault of Putaohua reservoir. The nearly N-S trending faults are consistent with the structural strike, and the matching of faults and sand bodies is conducive to the formation of shielding and fault-lithology and lithologic reservoirs. Under the fault cutting, a pattern of alternating barriers and grabens is formed, which is beneficial to the formation of oil-rich areas (Figure 1).
4. Analysis of oil-water distribution law and main control factors

4.1. Reservoir type and oil-water vertical distribution law
The syncline center area is dominated by pure oil, with high oil productivity, which is mainly > 3t/d, with a small part distributed in 0.5 ~ 2t/d, oil-water interaction or inversion (unconventional reservoir), and lithologic reservoir under structural background. The oil productivity in synclinal slope area decreases, mainly distributed in the interval of < 0.5t/d, and a few distributed in 0.5 ~ 2t/d and > 3t/d, with oil-water interaction, mainly lithologic reservoirs, mostly in the same layer (conventional/unconventional reservoirs). In the nose structure area, the oil and water are obviously different, and the productivity increases, most of them are located in the interval of > 3t/d, and a few of them are distributed in the range of 0.5 ~ 2t/d, mainly forming structural-lithologic reservoirs and micro-amplitude reservoirs (conventional reservoirs) [7-8].

4.2. Oil-water plane distribution law
From the regional plane oil-water distribution, Gulong syncline shows the distribution characteristics of detention area, transition area and gravity differentiation area. According to the logging interpretation, oil testing and mud logging results, the oil-water interfaces of all wells and 69 exploration and evaluation wells in the study area are determined and drawn into isoline maps. After superimposing the zoning marker wells determined by the reservoir profile, it is found that the area surrounded by the marker wells in the detention area and the transition area is nearly consistent with the contour line of -1740m; The area surrounded by the marker wells that demarcate the transition zone and the free flow zone is nearly consistent with the contour line of -1680m, and the study area is located in the detention zone, mainly composed of pure oil layers.

4.3. Analysis of main influencing factors

4.3.1. Good source-reservoir combination relationship is conducive to oil and gas enrichment and accumulation. The source rocks of Qing-1 member have a large distribution area, high abundance of organic matter and strong hydrocarbon expulsion ability, which can expel a large amount of hydrocarbons from the overlying Putaohua oil layer during the reservoir forming period, providing a material basis for the accumulation of Putaohua oil layer.

4.3.2. Oil source fault is the main channel of oil and gas vertical transportation. The faults in Putaohua reservoir are densely zonal in plane. According to the seismic profile, three fault dense zones are divided, and the boundary fault of the dense zone is the oil source fault of Putaohua reservoir. Faults strike near north-south, and matching faults with sand bodies is conducive to the formation of shielding, fault-lithology and lithologic reservoirs, and is conducive to the formation of oil-rich areas.

4.3.3. Underwater distributary channel and main sheet sand constitute high-quality reservoir with rich oil and gas. Gulong syncline area belongs to a large-scale shallow water gentle slope and strong current river-controlled delta front sedimentary system, which is jointly controlled by northern and western provenances. In the western part of the study area, the material source supply is strong, the ratio of sandstone thickness to sand land is large, mainly sheet sand, and the channel sand is developed, with the main direction being NW, the channel width generally being 400-900m, and the fault strike intersects with the channel direction at a high angle.

4.3.4. Reservoir physical properties control oil-water plane distribution. Reservoir physical properties mainly study the porosity and permeability characteristics of reservoirs [9]. From the distribution table of reservoir porosity and permeability, it can be seen that sedimentary environment and buried depth have dual control over reservoir physical properties, and the closer to provenance and the higher the structural position, the better the reservoir physical properties. On the contrary, in the lower part of the
structure, due to the deep burial, the compaction effect is obvious, the porosity and permeability are relatively low, and the physical properties become worse [10]. Therefore, the reservoir physical properties in Gulong syncline area are poor, which reflects the great resistance of fluid migration in this area.

Under the dual control of provenance and structure, the reservoir physical properties in the high part of short axis provenance direction and nose structure in the west are better, and the reservoir physical properties in the low part of syncline area are getting worse gradually. The average porosity and permeability of the whole region are 13.2% and 1.57mD; respectively. It belongs to low porosity and ultra-low permeability reservoir (Table 1).

Through the study of reservoir physical properties, it is found that the reservoir permeability in the central part of Gulong syncline area is basically within 1.0mD, and its physical properties are poor, so it is a pure oil area, and its physical properties become better in the surrounding slope areas. Transition to oil-water zone, and oil-water distribution is in good agreement with reservoir physical property changes.

### Table 1. Distribution of porosity and permeability

| Structural position     | Porosity/average | Permeability/average |
|-------------------------|-------------------|----------------------|
| Nose structure of Xinzhao| 10-23/15.5        | 0.3-99.2/11.3        |
| Nose structure of Xinzhan| 13-19/15.2        | 0.1-10/2.1           |
| Nose structure of Aonan  | 14.8-21.2/17.5    | 0.18/43.8/13.4       |
| Gulong syncline         | 9-17/13.2         | 0.1-3/1.57           |
| Maoxing syncline        | 10-15/13.5        | 0.3/3/1.5            |

The average porosity is 14.9% and the average permeability is 1.77mD in the center of syncline, and 15.2% and 3.39mD in the syncline slope. Through comparative analysis, the production in the syncline center area with poor reservoir physical properties and relatively high thickness is higher, and the reservoir physical properties at the syncline slope become better, the thickness decreases and the production decreases.

In the central area of Gulong syncline, the oil and gas generated by the source rock migrated along the oil source fault to Putaohua oil layer. This area is the intersection area of delta front water system with fine lithology and high shale content. Due to the poor reservoir physical properties, the syncline central area is deeply buried, and the reservoir is diagenetic and then filled with oil and gas. The capillary force is large, and there is almost no movable fluid. The oil and gas are detained and the oil-water differentiation is poor, which conforms to the syncline reservoir forming mechanism [11-12].

### 5. Optimization of favorable well distribution areas and classification results

According to the above research results of oil-water distribution law, the application of new seismic data in the syncline pure oil area is favorable for structure and sedimentation, with developed sand bodies and reservoir thickness greater than 2.8m. Under the condition of fully considering faults, the favorable area is delineated as X.Xkm2, and the geological reserves are XXX×104t.
Figure 2. Preferred results of favorable areas

6. Conclusions
(1) Putaohua oil reservoir in the study area is a lithologic oil reservoir under structural background, and the distribution of oil and gas is controlled by structure, sedimentation and reservoir physical properties. Pure oil area is distributed in the syncline area in the middle of the study area, and oil-water layer area is distributed in the slope area.

(2) Sedimentary (subfacies) environment and buried depth have dual control over reservoir physical properties, and reservoir physical properties and thickness control oil and gas production.

(3) The center area of Gulong syncline is the intersection area of delta outer front water system with fine lithology and high shale content, which is beneficial to the formation of good caprock. Due to the poor physical properties of the reservoir, the syncline center area is buried deeply, and the reservoir is diagenetic first and then filled, with large capillary force, almost no movable fluid, oil and water difference, and oil and gas retention and accumulation.

(4) The reservoir types and reservoir-forming models are clarified by analyzing the main controlling factors of reservoir-forming, and the oil-water distribution law is implemented by fine dissection of reservoirs in the enrichment area.

(5) According to the above research, the pure oil area with effective thickness greater than 2.8m is selected to delineate the favorable area of X.Xkm², and the geological reserves are XXX×10⁴t.

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