Deepening research on the distribution characteristics of interlayers in marine sandstone reservoirs

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Abstract. At present, CNOOC has a large number of bottom water reservoirs developed by horizontal wells in the production oilfields, but the overall geological reserves of the oilfields are relatively low. The biggest problem facing this type of reservoir development and adjustment and tapping is the separation of the reservoir. The identification and quantitative characterization of the development characteristics of interlayer space. Therefore, in this paper, by formulating standards for the identification of barriers and intercalations, in-depth study of the profile and plane distribution characteristics of barriers and intercalations, and carrying out studies on the anatomy and characterization of the distribution of marine sandstone reservoirs. The results of the study show that the distribution of the study area on the profile is mainly composed of interlayers in the southwest and northwest of the legal person of the study area, with good connectivity and continuity. The distribution of interlayers on the plane is mainly muddy. Mainly with mezzanine, the research results in this paper are helpful to improve the accuracy of the anatomy of marine sandstone reservoir stacking relationship and the characterization accuracy of interlayer distribution, and improve the development effect of this type of reservoir.

1. Introduction
At present, CNOOC has a large number of bottom water reservoirs developed by horizontal wells in the production oilfields, with geological reserves of about 720 million cubic meters (accounting for 16%); the calibrated recoverable reserves are 180 million cubic meters, and the recovery rate is low. Among them, the marine sandstone bottom water reservoir has a geological reserve of 370 million cubic meters (accounting for 8%), and the calibrated recovery factor is 25.9%. Most marine sandstone bottom-water reservoirs and single wells are already in the period of high to ultra-high water cut, and the recovery degree of calibrated recoverable reserves is relatively high (>60%), but the overall geological reserves of the oilfield are relatively low (15.6%). There is still great potential, and it is urgent to further deepen the research on the identification and quantitative characterization of the development characteristics of the reservoir interlayer space to improve the recovery rate.

Up to now, the identification of interlayers has mainly relied on logging methods. In 2004, Zhu Dongya [1] first established the distribution of various types of interlayers, and then analyzed the effects of interlayers on remaining oil. In 2013, Cui Jian [2] applied the architecture and analytic hierarchy
method to divide the target interlayer in the high-shallow north area into three levels: "interlayer", "thin interlayer" and "thin interlayer". In 2019, Liu Jianhua and others [3] based on the deterministic three-dimensional sand tracing technology of wellbore data to characterize the interlayer and sand interlayers, used the adaptive channel method to characterize the interlayer within the sand under the control of a single sand body, and applied equivalent characterization. Methods to characterize the physical interlayer.

On the basis of the research results of domestic and foreign experts and scholars, this paper uses the classification description and qualitative division of the types and distribution of the barriers to deepen the study of the profile and plane distribution characteristics of the barriers, and fill in the superposition relationship of marine sandstone reservoirs. Characterization gaps such as fuzzy boundaries, improve the accuracy of the anatomy of the marine sandstone reservoir stacking relationship and the characterization accuracy of the interlayer distribution, and ultimately improve the development effect of this type of reservoir.

2. Classification and causes of interlayer

According to the lithology and physical properties of the entire interlayer in the Pearl River Mouth Basin, and for bottom water reservoirs, based on the analysis of fine geology and development laws, the interlayer in the Panyu Oilfield in the Pearl River Mouth Basin can be divided into two categories: Interlayer and calcareous interlayer [4]. The argillaceous intercalation is mostly silty mudstone and some massive dark mudstone. The calcareous intercalation includes calcareous fine sandstone, calcareous siltstone, and argillaceous silty supporting and cemented sandstone, because the Pearl River Mouth Basin Panyu 4-2/ the environmental water in the target area of Panyu 5-1 oilfield changes rapidly and may be mixed with some calcareous sand and mudstone.

(1) Calcareous interlayer
The lithology of this type of interlayer is mainly calcareous cemented sandstone [5]. Because the fine-grained sediment fills the pores, an impermeable layer is formed. The lithology is relatively dense. Because of its porosity and permeability, it does not reach the lower limit of the effective thickness. So it is also called physical interlayer.

(2) Mud interlayer
The argillaceous interlayer is mainly silty mudstone and argillaceous siltstone in the target area of Panyu 4-2/Panyu 5-1 oilfield in the Pearl River Mouth Basin. The muddy interlayer is mainly characterized by mudstone on the logging curve. The microelectrode curve has a low stable amplitude, a significant decrease in deep lateral resistance, a high natural gamma value, a high acoustic time difference, and a significant expansion of the well diameter curve.

According to the formation time of the interlayer, 11 stages of muddy interlayer can be divided in the 16.8 formation. The muddy interlayer is mainly deposited during the period when the supply of detrital sources decreases and the sea level rises[6].

![Figure 1. Logging histogram of BO16.80 interlayer division in Well B19H](image-url)
3. Interlayer identification

3.1. Basis for the formulation of interlayer standards
Interlayer is an ineffective layer between oil and gas display layers. It is mainly manifested by relatively poor physical properties. The physical properties of oil layers between wells of various sedimentary sand bodies vary greatly. Therefore, it is necessary to determine the physical property value standards of various types of interlayers. According to the core data, single-layer test well section data and logging data of the marine sandstone reservoirs of the 16.8 strata in the Panyu 4-2/Panyu 5-1 oilfield in the Pearl River Mouth Basin, after physical property analysis of the logging data of each 16.8 strata, according to The upper and lower limits of its effective thickness determine the division standard of the 16.8 stratigraphic marine sandstone in the study area.

3.2. Interlayer identification standard
The subdivision of barriers and intercalations in this area is determined on the basis of core observations [7]. According to their physical properties, the response characteristics of various barriers and intercalations on logging curves are found, and typical sections are established by rock types, and these typical sections are regarded as undertaken. The core well uses logging data to determine the basis for the interlayer.

(1) Calcareous interlayer
The calcareous interbeds in the 16.8 formation of the Panyu 4-2/Panyu 5-1 oil field in the Pearl River Mouth Basin are mostly carbonate rocks that fill pores and metasomatize clastics. They are mostly formed during diagenesis, and the conductivity is poor due to high calcium content. Among them, the porosity and permeability of the calcareous intercalation are higher than that of the argillaceous intercalation, but because it is distributed in the hydrocarbon-bearing interval, that is, the reservoir, it is often the lowest average value of the hydrocarbon-bearing interval in the 16.8 formation.

(2) Mud interlayer
The muddy interlayer of the 16.8 strata in the Panyu 4-2/Panyu 5-1 oil field in the Pearl River Mouth Basin is dominated by shale. The lithology is mostly silty mudstone, which is reflected by the obvious mudstone characteristics on the logging curve. The horse, electrical resistivity, and acoustic time difference are all relatively high. The natural gamma curve value is generally above 102.6 API; the resistivity is above 1.6Ω·m, and the density (DENE) is above 2.3g/cm³. Poor, porosity is less than 1.74%, permeability is generally less than 0.015x 10⁻³μm².

Table 1. Electricity Identification Standard Table of 16.8 Stratum Interlayer in Panyu Oilfield

| Interlayer classification  | GR/API | Rt/Ω·m | DENE/g*cm⁻³ | POR/% | PERM/mD |
|---------------------------|--------|--------|-------------|-------|---------|
| Calcareous interlayer     | <72.7  | >1.6   | >2.3        | <6.91 | <0.15   |
| Mud interlayer            | >102.6 | >3.3   | >2.5        | <1.74 | <0.15   |

4. Distribution characteristics of interlayer profile
Based on the identification and statistical verification methods of the 16.8 formation barriers and interlayers in Panyu Oilfield mentioned above, 53 wells in the study area were identified and calculated for the types of barriers and intercalations and their thicknesses were corrected. The space exhibition has been studied in detail.

The A07H1-B19H-B13H section is a northwest-south east section that traverses the 16.8 strata in the study area in the vertical provenance direction. The profile shows that the 16.80 strata in the southwestern part of the study area was mostly interlayer spread during the 16.8 period and had good connectivity and continuity. The uneven distribution of intervals and interlayers in other periods has a greater impact on the physical properties of the reservoir.
The A17H-A13H-B11H profile is a northeast-southwest profile that traverses the 16.8 strata in the study area in the vertical provenance direction. This section shows that the 16.80 strata in the northwest of the study area developed in the direction of the provenance in the 16.80B and 17. Multi-layer spreading and good connectivity and continuity. Interlayers in other stages also developed, but most of them have poor connectivity and continuity.

From these 8 interlayer profiles, it can be seen that in the 16.8, 16.80B, and 17 layers, No. 1 and No. 2 and No. 11 mud interlayers are thicker, appear more frequently, and have stronger distribution connectivity and continuity; The muddy interlayer in the small layer has a large change in layer thickness, unstable distribution, and often does not have good connectivity and continuity.

5. Plane distribution characteristics of interlayer

According to the above division of single wells and interlayers and the distribution characteristics of interlayer interwell profiles, it is found that there are 11 sets of obvious interlayers developed in the study layer of BO strata in the Zhujiang Formation, which are indicated by numbers 1-11 from bottom to top. Among them, the 1, 5, 6, 7, and 8 interlayers are developed in the BO17, BO16.8d, BO16.8c, BO16.8b and BO16.8a formations, respectively; the 2, 3, and 4 interlayers are developed in the BO16.8B formation; the No. 9, 10, and 11 barriers are developed in the BO16.8 formation.

Interlayer 1 in the study area is developed in the BO17 formation, mainly distributed in the central-northern well area of the study area, and is distributed in a large area in the central and northern part. The southern and central-southern well areas are distributed in dots and thinner. Interlayer 2 is developed at the bottom of BO16.8B formation, mainly distributed in the middle well area of the study area, and the whole is mainly distributed in block. Interlayer 3 is developed in the middle of the BO16.8B strata and is widely distributed in the study area. The middle-north is distributed in large areas, and the south and west are distributed in blocks. Interlayer 4 is developed on the top of BO16.8B formation, and the whole is mainly distributed in a large area, mainly distributed in the north, central and southern well areas, and the thickness of the interlayer is relatively large. Interlayer 5 is developed in the BO16.8d stratum, mainly distributed in dots, and only distributed in blocks in the middle of the study area. Interlayer 6 is mainly developed in the BO16.8C formation, which is mainly distributed in dots in the study area, and only in blocks in the southern well area, with relatively small thickness. Interlayer 7 is
developed in the BO16.8b stratum, with a point-like distribution as a whole, with a thickness below 3m and a relatively small distribution area. Interlayer 8 is developed in the BO16.8a stratum, and is distributed in dots as a whole. The thickness of the interlayer is small. Most of the interlayers are not connected and are distributed in isolation. Interlayer 9 develops at the bottom of the BO16.8 formation, and the whole is distributed in blocks with a relatively large distribution area. Interlayer 10 is developed in the middle of the BO16.8 formation, mainly distributed in the middle, middle-southern and southern well areas of the study area. The whole is massive and has a large distribution area. The barrier 11 is developed on the top of the BO16.8 formation and is distributed in a large area, mainly in the A13H Dang well area and the central-south well area in the study area.

Figure 4. Plane Distribution of Interlayers of the Zhujiang Formation in the Pearl River Mouth Basin
Based on the above research on the 16.8 strata interlayer plane of the Zhujiang Formation in the study area, there are 11 sets of obvious barriers developed in the target layer of BO strata in the Pearl River Formation. Among them, barrier 1, barrier 2, barrier 3, barrier 4, barrier 9, barrier 10, and barrier 11 are distributed in blocks. The area is wide, the thickness of the barrier is large, and the continuity of the barrier is good; the barriers 5, 6, 7 and 8 are mostly distributed in dots, and the distribution area and thickness are relatively small and the continuity is poor. Mostly distributed in isolated dots.

6. Conclusion
The southwest and northwest of the study area are mostly interlayer spread with good connectivity and continuity. Interlayers in other stages also developed, but most of them have poor connectivity and continuity.

There are 11 sets of obvious barriers developed in the target layer of the BO strata in the Pearl River Formation. Among them, the barriers 1, 2, 3, 4, 9, 10, 11 are distributed in blocks, with a wide distribution area, a large thickness, and Layer continuity is good; barrier layers 5, 6, 7, and 8 are mostly distributed in dots, with relatively small distribution area and thickness, and poor continuity.

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