Quantitative identification of interlayer in delta phase oilfield

Xinyu Liu¹*, Lin Cong¹, Shizhong Ma¹ and Bin Zheng²
1 School of Earth Sciences, Northeast Petroleum University, Daqing, China
2 Tianjin Branch of CNOOC Limited, Tianjin, China

*Corresponding author e-mail: 6xydtc@stu.nepu.edu.cn

Abstract. It is very difficult to accurately tap the potential of remaining oil in delta phase oilfield, and the analysis of geological origin of remaining oil is particularly critical. This paper analyzes and studies the types and genesis of interbeds and quantitative identification of interbeds in delta phase oilfield. The data analysis shows that: on the basis of the existing data, the core qualitative interlayer identification is carried out first, and the types and causes of the interlayer are studied. Then, the identification standard of interlayer is established to identify logging interlayer. If the coincidence rate is low, it is necessary to modify the identification standard, reestablish the identification standard of rock electrical corresponding interlayer, and carry out logging interlayer identification again. Finally, we must carry out manual inspection, interpretation inspection and rationality analysis.

Keywords: Interlayer, argillaceous, physical property, calcareous, quantitative identification.

1. Introduction
The interlayer of delta facies oilfield is a low permeability or non permeability layer which distributes in the reservoir and divides the reservoir into several independent flow units. It has a very important impact on the heterogeneity of the reservoir. There are many methods for the classification of interbeds, and different types of interbeds have different effects on different types of reservoirs under different structural conditions [1].

2. Types and genesis of interlayer

2.1. Types of interlayer
Interlayer refers to the impermeable layer or ultra-low permeability rock layer which can block the fluid in the reservoir. Generally, according to the origin, it can be divided into muddy interlayer, physical interlayer and calcareous interlayer.

There are two coring wells LD10-1-A21S1 and LD10-1-2 (Fig. 1) in the study area. Core homing and description are carried out respectively, and comprehensive core histogram is established (Fig. 2).
On the basis of core observation, homing and fine description of two coring wells in the study area, the interlayer is identified. A total of 13 interbeds were identified in the coring section of the two wells. It is mainly composed of argillaceous interlayer and physical property interlayer. No calcareous interlayer is identified in coring wells, but a small amount of calcareous interlayer can be identified in logging data of other wells.

2.1.1. Argillaceous interlayer. Argillaceous interlayer is a kind of stratum with high argillaceous content and poor porosity and permeability. The lithology of argillaceous interlayer in the study area includes mudstone, silty mudstone, argillaceous siltstone, etc. Argillaceous interlayer has low permeability and good sealing ability. The logging response characteristics of argillaceous interlayer are close to the baseline of mudstone [2]. Compared with the adjacent reservoirs, the resistivity decreases, the natural gamma increases, and the density increases. The logging interpretation is not permeable. The core depth of ld10-1-a21s1 is 1692.28-1693.26m, and the first member is a typical argillaceous interlayer (Fig. 3).

2.1.2. Physical property interlayer. Physical property interlayer is a kind of stratum whose porosity and permeability become worse because of mud content and grain size change of sediments. It is mainly composed of siltstone and fine sandstone, and also includes fine conglomerate, argillaceous conglomerate and grain supported conglomerate with high argillaceous content. The physical property
interlayer has certain porosity and permeability, but the physical property becomes worse due to the cementation of fine-grained and thin sandstone in the sandstone during deposition, and the transformation of argillaceous mass by metasomatism or recrystallization [3]. The characteristics of logging curve are between argillaceous interlayer and normal reservoir. Compared with adjacent reservoir, it has low resistivity, high natural gamma, high density, low permeability in logging interpretation, and great difference in permeability compared with adjacent reservoir. Many physical property interbeds are identified in coring wells. The first member of LD10-1-2 with core depth of 1667.17-1667.57m is a typical physical property interbed (Fig. 4). The lithology is mainly fine sandstone with gravel, and the physical property is poor.

2.1.3. Calcareous interlayer. Calcareous interlayer is a kind of stratum with poor porosity and permeability under the later calcareous cementation diagenesis. In the later stage, carbonate cementation diagenesis destroyed the reservoir performance and made the porosity and permeability worse. Calcareous interlayer often developed in the medium coarse sandstone and glutenite with good physical properties in the early stage, and sometimes also existed in the medium fine sandstone. The thickness is generally small, usually less than 2 m, and mainly distributed in the thick sandstone of underwater distributary channel. Calcareous interlayer has low permeability and high displacement pressure. Calcareous cements are generally concentrated in two parts: one is the contact surface between sandstone and mudstone, that is, near the top and bottom surface of sandstone; the other is the medium coarse sandstone with good early physical properties in thick sandstone. If there is a fault in thick sandstone, the solution rich in CO\(_2\) ions is easier to enter the sandstone formation, so the calcareous interlayer is more likely to appear near the fault. The lithology of calcareous interlayer is mainly calcareous cemented fine sandstone and fine medium sandstone with dense lithology and no permeability. Its electrical characteristics are mainly characterized by abnormally high deep and shallow lateral resistivity, showing a peak shape and a larger density curve. The formation of calcareous interlayer is mainly related to the heterogeneity of diagenesis of carbonate sediments. Sporadic distribution and strong randomness, less distribution in the study area, only a few wells drilled. Among them, A23 well - 2577m is typical [4] (Fig. 5).

2.2. Genesis of interlayer
Generally, the interlayer can be divided into two types: sedimentation and diagenesis. Combined with the sedimentary characteristics, core and logging data of the area, it is proposed that the genesis of the interlayer in this area can be divided into four aspects [5-6].
During the flood period, with the rise of lake level and the migration of effective accommodation space to land, the base level rises to the highest value, and the accommodation space is far greater than the sediment supply. The top mud of II oil formation and III oil formation in the study area is pure and dense, with well-developed horizontal lamina, large single layer thickness and good continuity, so it is used as a barrier in this area.

With the weakening of transport hydrodynamic force, a layer of silty mudstone or argillaceous siltstone with relatively small grain size is covered on the glutenite of the channel, which represents the deposition of fine material in the short period from the end of the first stage of channel deposition to the beginning of the next stage of channel deposition. Due to the superposition and cutting effect of multi-stage channel, the strong undercutting and scouring of the channel in the later stage, the fine-grained sediments on the top of the channel in the earlier stage have not been completely preserved, which makes the interlayer thickness locally thinner or even missing, and the distribution is relatively random, with small thickness, more and disordered.

The interlayer in the channel or dam is limited in distribution.

Calcareous interlayer is generally formed in limited, shallow water and evaporation environment, and develops at the bottom of underwater distributary channel. The significance of existence of calcareous cementation indicates that after the development of the first stage channel, the original river bed water is in a non circulating state, and part of the river reaches are in shallow water evaporation environment for a long time, resulting in the formation of calcareous layer.

3. Quantitative identification of interlayer

There are many methods to identify and predict interlayer, among which core identification is intuitive and accurate, and the scale is as small as a few centimeters, which is the most effective method. However, there are few coring well data and many logging data with high resolution, which are generally used as the main way to identify interlayer. There are also many methods for prediction between wells. 3D seismic can be used to identify the interlayer between wells, but the interlayer between wells can not be identified. Geostatistics can be used to predict the distribution pattern of interlayer between wells, which can make the best use of the known information, but can not directly observe the shape of interlayer. When using deterministic modeling and stochastic simulation methods to predict and characterize interbeds, we can intuitively understand the shape and structure of interbeds with high accuracy, but ignore the subtle changes between wells. In addition to the above methods can identify and predict the interlayer, in recent years, a number of new methods with strong learning ability and high accuracy have been produced, such as wavelet neural network model, but the new methods also have some limitations [7].

On the basis of comprehensive investigation of the research status at home and abroad, according to the data of the study area, the core calibration logging method is adopted to identify the interlayer.

3.1. Logging data processing

Statistics of all 99 wells in the study area (including newly completed LD10-1-A23S1 and LD10-1-A49S1) 138 kinds of logging curves of different logging series (Table 1), multiple batches of logging data, GR alone up to 14 kinds. There are 19 types of logging curves in two coring wells LD10-1-A21S1 and LD10-1-2 in the study area, and the logging curves of all wells containing two coring wells are counted. According to the logging curve, it is decided that on the premise of making full use of the core, the conventional logging, such as natural gamma ray (GR), deep laterolog resistivity (RD), shallow laterolog resistivity (RS), thermal neutron porosity (CN), density (Zden), acoustic time difference (DT), photoelectric absorption cross-section index (PE), etc., should be effectively combined with the physical parameters, and the 13 reliable logging parameters identified on the core should be used. The core calibration logging method is used to establish the identification chart of interlayer and quantitatively identify the interlayer.
### 3.2. Establishment of quantitative identification standard for interlayer

According to the characteristics of interlayer and interlayer, based on core identification of core of coring well, considering the factors of logging resolution, number of logging curves and sensitivity of curves to interlayer, the identification template of interlayer is preliminarily determined by using parameters of lithology, electrical property and physical property through optimization of multiple intersection plates. The preferred gamma, resistivity curve and porosity are used for interlayer interpretation (Table 2), and appropriate reference to density and permeability is available as required. Thus, the mud interlayer and physical interlayer are separated [8].

#### Table 2. Standard table for well logging identification of interlayer

| Identification parameter | Argillaceous interlayer | Physical property interlayer |
|--------------------------|-------------------------|-----------------------------|
| Natural gamma (API)      | >100                    | 85-125                      |
| Deep lateral resistivity (Ω·m) | <9          | 3.5-27                      |
| porosity/%              | <20                    | 20-30                       |
| permeability/10⁻³μm²    | ≤60                    | 40-70                       |
| Density (g·cm⁻³)        | >2.17                  | 2.1-2.17                    |

### 3.3. Interlayer identification and its effect

The interlayer identification standards of LD10-1-A21S1 and LD10-1-2 should be used to interpret the interlayer of other coring wells in the study area, and the identification quantity, type and thickness of interlayer should be compared with the core data to verify the identification accuracy. However, there are few coring wells in the study area, which can only be verified by reinterpretation of known coring wells. Through the comparative analysis of logging identification results and core observation results, it can be seen that the accuracy of interlayer number identification can reach about 89% (Fig. 6).
3.4. Interpretation of interlayer in development well

According to this interpretation standard, 87 wells with stratification data (LD10-1-A23S1, LD10-1-A28S1, LD10-1-A30, LD10-1-A30S1, LD10-1-A31, LD10-1-A39S1, LD10-1-A42, LD10-1-A49S1, LD10-1-C23H, LD10-1-C24H, LD10-4-1D, LD10-4-1H1-no stratification data) in the 99 wells in the study area were interpreted (FIG. 7). A total of 1340 mudstone interbeds and 122 physical interbeds are interpreted, and a total of 1462 interbeds are interpreted.

4. Conclusion

Through the study of the interlayer in the study area, the identification method of single well interlayer is summarized. On the basis of previous research results, core data, logging data and logging data, the
core qualitative interlayer identification is carried out, and the types and causes of interlayer are studied. Then, the identification standard of interlayer is established to identify logging interlayer. If the coincidence rate is low, it is necessary to modify the identification standard, reestablish the identification standard of rock electrical corresponding interlayer, and carry out logging interlayer identification again. Finally, we must carry out manual inspection, interpretation inspection and rationality analysis.

References

[1] Luo Weiping, Xiao Chengwen, Chen Weizhong, et al. Study on high resolution processing of well logging data and identification of interlayer: a case study of Donghe sandstone in Hudson oilfield [J]. Progress in geophysics.

[2] Hu wangshui, Gan Yongnian, Zou Xiaopeng. Study on reservoir modeling in 1-1 area of No.1 structure in dongnanpu sag of Hebei Province [J]. Science, technology and engineering, 2012, 12 (7): 1611-1614.

[3] Dou Songjiang, Jiling, Wang Haibo, et al. Study on the interlayer of Mesozoic thick oil layer in wangguantun oilfield [J]. Petroleum geology and engineering, 2008, 22 (1): 48-51.

[4] Li Jianping, Xiong Lianqiao, Huang Tao, Liu Ziyu. Sedimentary characteristics and interlayer identification of Lower Cretaceous oil sands in Alberta basin, Canada [J]. Offshore oil and gas in China, 2019, 31 (5): 30-41.

[5] Wang Haiyun, Li Changsheng, Liu Yang, et al. Fine logging evaluation of interlayer in block Q of Liaohe Basin [J]. Journal of Yangtze University (self SCIENCE EDITION), 2018, 15 (11): 24-2.

[6] Bloch S, Lander R H, Bonnell L. Anomalously high porosity and permeability in deeply buried sandstone reservoirs:origin and predictability[J]. AAPG Bulletin, 2002, 86(2):301-328.

[7] Lian zhanggui, Li Jun, Wang Xiao, et al. Comparison between deterministic modeling and stochastic modeling of interlayer in clastic reservoir development [J]. Xinjiang Petroleum Geology, 2019, 40 (5): 605-609.

[8] Luo X R, Hu C Z, Xiao Z Y, et al. The effects of carrier bed heterogeneity on hydrocarbon migration[J]. Marine and Petroleum Geology, 2015, 68(12): 120-131.