Hindawi
Geofluids
Volume 2023, Article ID 4273208, 15 pages
https://doi.org/10.1155/2023/4273208

Research Article

Analysis of Oil-Water Distribution Law and Main Controlling Factors of Meandering River Facies Reservoir Based on the Single Sand Body: A Case Study from the Yan $9_3{}^2$ Layer of Y Oil Area in Dingbian, Ordos Basin

Tiaotiao Shi,[1,2] Shengping He,[3,4] Kaitao Yuan,[5] Mingjun Liu,[1] Min Wang,[1] Xingping Tu,[1] and Liwen Chang[1]

[1]*Research Institute of Shaanxi Yanchang Petroleum (Group) Co., Ltd., Xi'an 710075, China*
[2]*Hainan Vocational University of Science and Technology, Haikou 571126, China*
[3]*State Engineering Laboratory for Exploration and Development of Low Permeability Oil and Gas Fields, Xi'an 710018, China*
[4]*Research Institute of Exploration and Development, PetroChina Changqing Oil Field Company, Xi'an 710018, China*
[5]*Dingbian Oil Production Plant, Yanchang Oil Field Co., Ltd., Yulin 718600, China*

Correspondence should be addressed to Shengping He; 443078807@qq.com

Received 31 May 2022; Revised 5 September 2022; Accepted 19 October 2022; Published 18 April 2023

Academic Editor: Dengke Liu

After the oilfield development enters the medium and high water cut stage, the fine three-dimensional description of the single sand body, the distribution rules of the remaining oil, and its main controlling factors have become the focus of research. The premise is to understand the original oil and water distribution characteristics and the important influencing factors of the reservoir. Taking the Yan $9_3{}^2$ reservoir of Y oil area in Dingbian as an example, combined with the meandering river sedimentary model, this paper uses dense well pattern logging data to dissect single sand body on the foundation of the core and logging results. The conclusion shows that, first, Yan $9_3{}^2$ layer is divided into two stages: Yan $9_3{}^{2\text{-}1}$ and Yan $9_3{}^{2\text{-}2}$, which constitute four single sand body superposition configuration modes, namely, type I, type II, type I & II, and type I/II. Second, type I & II is mainly developed in the sand body of the main channel. In the west of the main channel sand body, type I, type II, and type I/II are developed. Only type II is developed in the east of the main channel sand body. Thirdly, sedimentary microfacies, sand body thickness, sand body configuration, and structural characteristics are the key factors influencing the oil-water distribution law of the Yan $9_3{}^2$ reservoir.

1. Introduction

At present, the single sand body is the smallest unit to study the sedimentary layer. Its main characteristics are that the sand body is continuous, and mudstone or impermeable layer is developed on both the upper and lower parts of the sand body. Although some single sand bodies are connected with adjacent layers due to no interlayer, their internal fluid still constitutes an independent reservoir [1–10]. The chief geological factors affecting the distribution of remaining oil include sedimentary microfacies and the configuration relationship of the single sand body, reservoir lithology, physical properties, and heterogeneous characteristics. In essence, the subdivided small layer is still the combination of single sand bodies of different sedimentary origins, and the fine description of the small layer reservoir could not meet the production demand. Therefore, the three-dimensional spatial distribution and connectivity of the single sand body have become the focus of studying the law of oil-water distribution [11–21]. This study starts with the division of the single sand body, reunderstands the internal structure of the sand body, discusses the internal

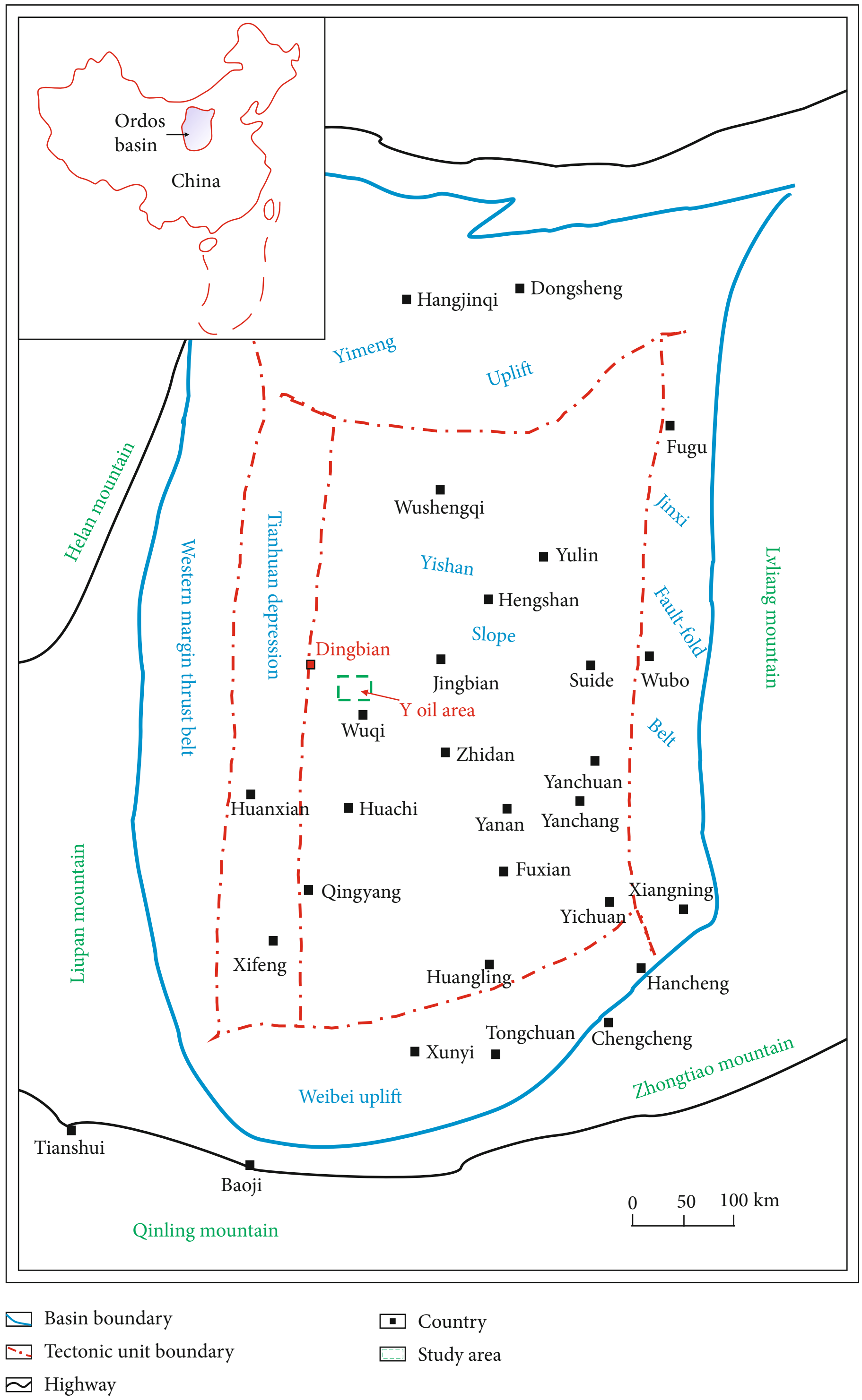
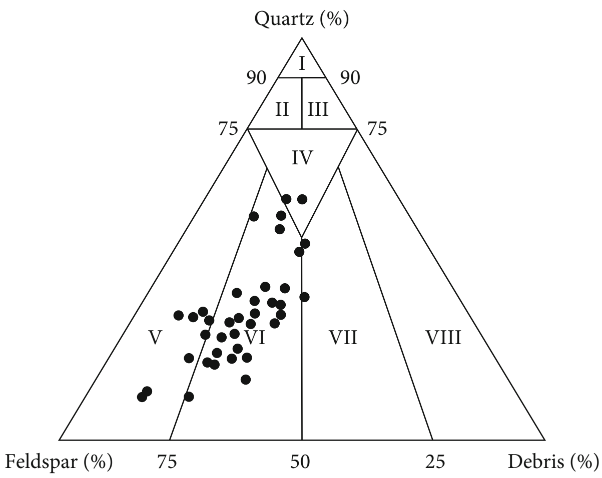


Figure 1: Geographic location map of Dingbian Y oil field in Ordos Basin.

configuration of multistage superimposed single sand body of distributary channel under the control of the meandering river and its control over oil-water distribution, analyzes its main control factors, and analyzes the original oil-water distribution characteristics from the perspective of geological factors, so as to lay a foundation for the production of old oil fields.

2. Geological Background

The Y oil area of Dingbian is located in the west of the Northern Shaanxi slope near the Tianhuan depression (Figure 1). It has been put into development since August 2007. Three sets of main oil-producing layers have been developed in the study area, which is a typical multilayer



I: silicarenite

II: feldspar quartz sandstone

III: lithic quartz sandstone

IV: feldspar lithic quartz sandstone

V: arkose

VI: lithic feldspar sandstone

VII: lithic quartz sandstone

VIII: lithic sandstone

Figure 2: Rock type diagram of the Yan 9_3^2 layer.

reservoir. Yan 9_3^2 is one of the main oil-producing layers. The Yan 9_3^2 oil layer in this area belongs to meandering river deposition with good sand body continuity. More than ten years of development practice show that the oil-water relationship is controlled by both structure and lithology. The lithology of Yan 9_3^2 members is mainly lithic feldspathic sandstone and feldspathic sandstone (Figure 2). The pore type is mainly intergranular pore. The clastic components are mainly quartz, feldspar, eruptive rock, cryptocrystalline rock, schist, and phyllite (Figure 3(a)). The interstitial materials are mainly kaolinite, illite, and carbonate (calcite, dolomite, and iron-bearing dolomite) (Figures 4 and 3(b)). The porosity is 13.5%(Figure 5(a)). The permeability is $18.3 \times 10^{-3}\ \mu m^2$ (Figure 5(b)).

3. Methods

3.1. Identification of Sedimentary Interface of the Single Sand Body. Experts divide the strata of different grades according to the sedimentary interface. Using the logging data and the theory of continental reservoir hierarchy division, the hierarchy subdivision is carried out from the perspective of sedimentary genesis. In this study, referring to the classification system of the fluvial reservoir configuration interface proposed by Miall and Congjun et al. [22, 23], the Yan 9 oil formation is divided into four levels (Table 1). This study focuses on the level 1 and level 2 reservoir configuration units.

Level 2 sedimentary interface is a mainly argillaceous barrier, mainly a set of argillaceous barriers including mudstone and argillaceous siltstone deposited on the upper part due to the weakening of hydrodynamic force. Level 1 sedimentary interface usually refers to the argillaceous interlayer, calcareous interlayer, and physical interlayer. Argillaceous intercalation is developed in this study area, and calcareous intercalation and physical intercalation are rare (Figure 6).

The argillaceous intercalation reflects that there is a sedimentary discontinuity between sand bodies, which is the most important and common sign for vertical identification. The response characteristics of logging curves are high GR, low AC, and low ILM. Figure 7 shows the logging curve which shows that the curve at 1844.8 m returns obviously, which is determined as an argillaceous interlayer. According to this interlayer, the layer can be divided into two single sand bodies.

3.2. Identification of Configuration Units of Single Sand Body. The single sand body configuration unit of the Yan 9_3^2 layer is mainly the sedimentary unit defined by the interface of level 1 and level 2.

First, the Yan 9_3 layer is subdivided into Yan 9_3^1 and Yan 9_3^2 according to the deposition interface of level 2. According to the core observation, logging facies calibration, and well-connected facies correlation, the Yan 9_3^2 layer has identified three sedimentary microfacies: meandering river subfacies and main channel, channel flank, and interchannel bay (Table 2). With the change of hydrodynamic conditions and paleoclimate, the river channel of Yan 9_3^2 oil layer moves and swings frequently, and the river channel sand bodies are partially cut and superimposed to form relatively continuous composite river channel sand bodies.

Second, the Yan 9_3^2 is subdivided into Yan $9_3^{2\text{-}1}$ (phase I) and Yan $9_3^{2\text{-}2}$ (phase II) layers according to the sedimentary interface of level 1. Due to the development of the argillaceous barrier between sedimentary microphases, there is basically no oil-water exchange between the upper and lower layers after reservoir formation. Oil-water exchange generally occurs in the sand body of sedimentary microfacies, because the argillaceous interlayer can only partially hinder the oil-gas migration of sand body in sedimentary microfacies. Therefore, sedimentary microfacies are the basic unit for analyzing the law of oil-water distribution.

3.3. Determination of Channel Boundary of Single Sand Body. The river channel boundary of the single sand body is mainly identified by the following four characteristics.

3.3.1. Change of Lithology. Interchannel mudstone is an obvious sign to identify the boundary of channel sand bodies at different positions on the plane, especially in the pinch-out reservoir on the side edge. It is mainly because the hydrodynamic force of the same period becomes weak, the sediments are gradually unloaded, and the fine-grained argillaceous sediments are deposited on the upper part in the same period. Laterally, there are many single channels in the same small layer, and fine-grained argillaceous sediments will be developed in the middle (Figure 8).

3.3.2. Change of Logging Curve Shape. For sand bodies of different sedimentary origins, due to the change of lithology and particle size, they vertically reflect the combination of

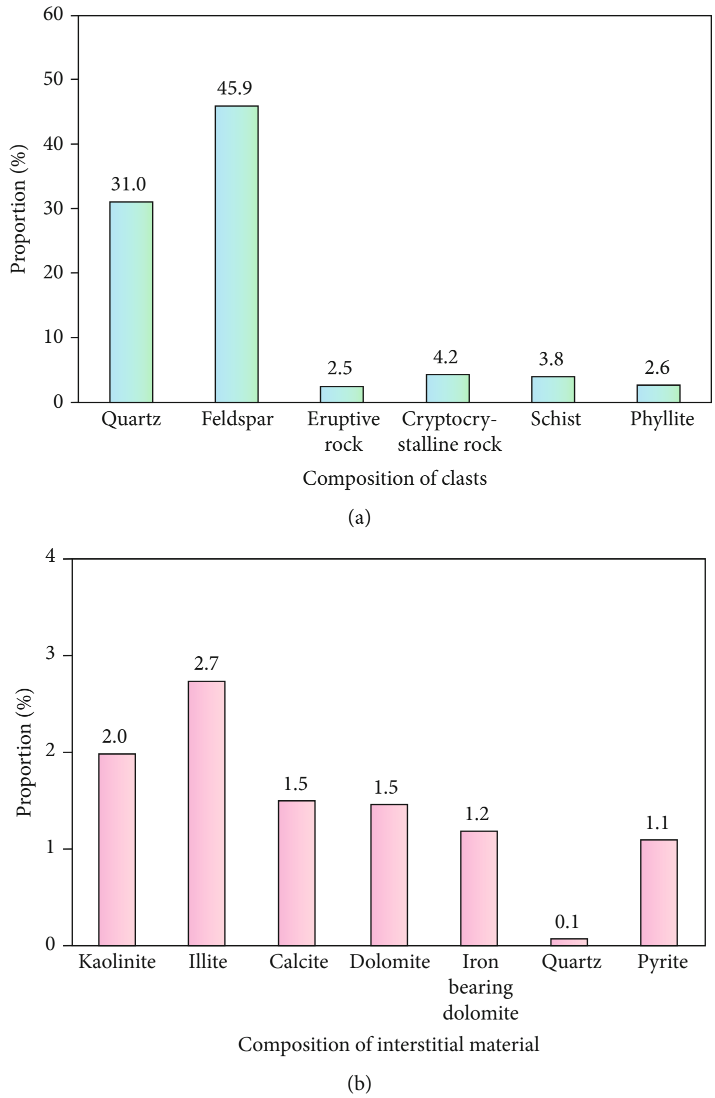


Figure 3: The composition of (a) clasts and (b) interstitial material of the Yan 9_3^2 layer.

different lithology and particle sequences. Therefore, according to the difference of logging curve shape, single sand bodies of different periods can be judged (Figure 9).

3.3.3. Variation of the Transverse Thickness of the Sand Body. The thinning and thickening of the channel sand body generally indicate the beginning of another phase of the channel, rather than the continuation of the previous phase of the channel. The thickness of the sand body from the main channel (D4420-1, D4420-2) to the channel flank (D 4401-2 and DZ4438-3) becomes thinner (Figure 10).

3.3.4. Change of Sand Body Height. Affected by the difference of river diversion or abandonment time, the top position of sand body deposited on the bank of distributary channel in different stages changes, which can be used as a boundary mark (Figure 11).

3.4. Model of Single Sand Body Configuration. According to the depiction results of the single sand body in the plane and section in the study area and the research results of the configuration combination mode of the single sand body, the vertical and lateral superposition modes of the single sand body are anatomized by using the data of single well points and connected well sections, and then, the configuration mode of the single sand body is established [24–26].

3.4.1. Vertical Superposition Model of Multistage Sand Bodies

(1) Isolated Type of One-Stage Sand Body. Only the upper or lower single sand body is deposited, which is separated by an argillaceous interlayer, and there is no connection vertically, i.e., type I (Yan $9_3^{2\text{-}1}$) and type II (Yan $9_3^{2\text{-}2}$), as shown in Figures 12(a) and 12(b). It is mainly caused by the migration and swing of the channel, and the sedimentary center changes.

(2) Vertical Shear Superposition Type of Two-Stage Sand Body. The shear superimposed pattern refers to that when the hydrodynamic force of the river increases, the cutting

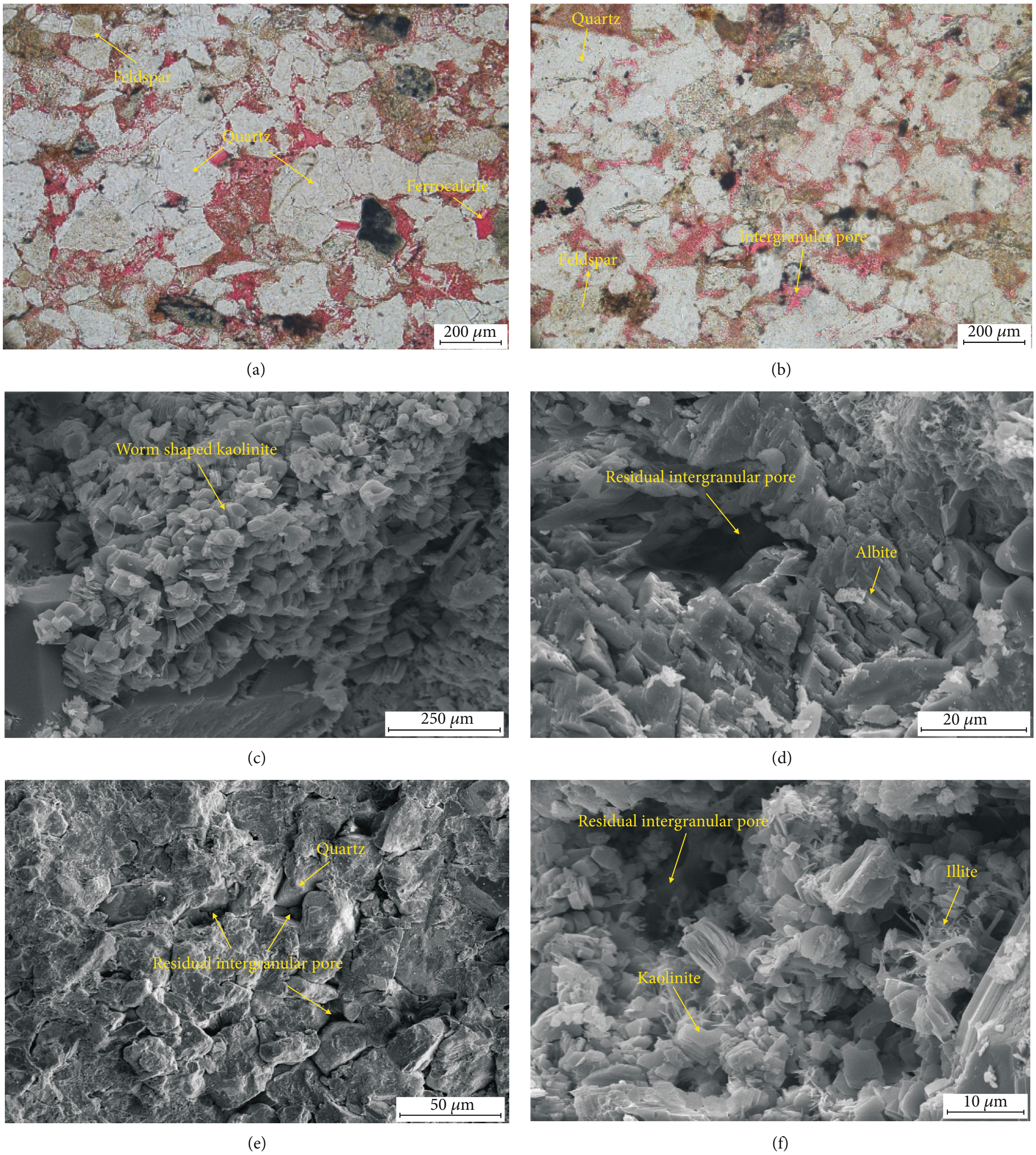


Figure 4: Cast body thin section and SEM image in the sandstone of the Yan 9_3^2 layer. (a) Feldspar, quartz, and iron calcite. (b) Quartz, feldspar, and intergranular pore. (c) Vermicular kaolinite. (d) The remaining intergranular pores and albite. (e) Quartz and residual intergranular pores. (f) Residual intergranular pores, illite, and kaolinite.

capacity of the river channel becomes stronger, showing a part of the incomplete sedimentary rhythm. The formation conditions of this type of superposition style are generally shallow water bodies and strong ponding power. The composite sand body with different thicknesses can be superimposed after the formation of different sedimentary cycles, type I & II, as shown in Figure 12(c).

(3) Vertical Separation Type of Two-Stage Sand Body. Vertical separation type means that the river hydrodynamic force is weak. After the deposition of the single sand body in the earlier time, the sand body in the later time does not cut the formed single sand body, and an obvious argillaceous interlayer was developed between them, and SP and GR logging curves show obvious returns, type I/II, as shown in Figure 12(d).

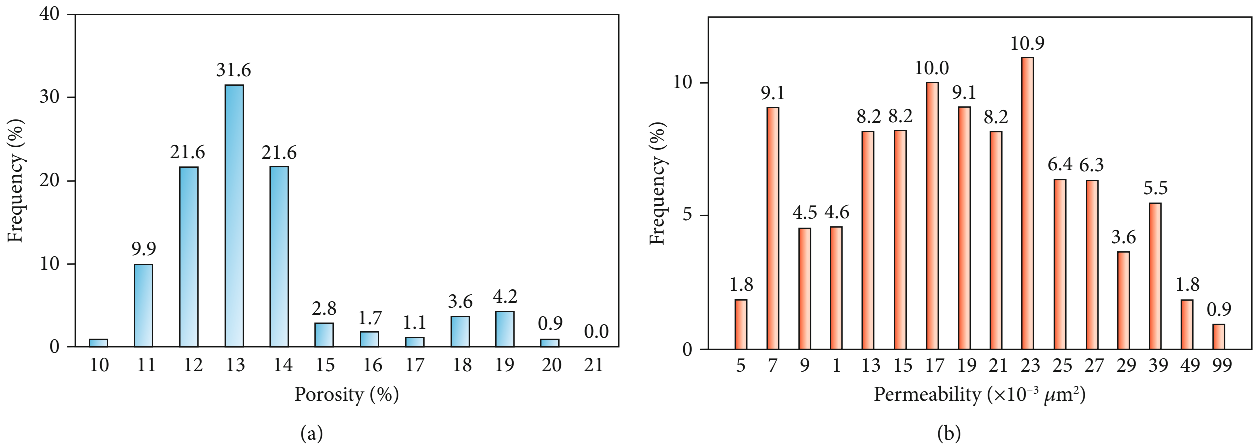


Figure 5: The frequency of (a) porosity and (b) permeability of the Yan 9_3^2 layer.

Table 1: Configuration classification of meandering river facies reservoir in the study area.

Stratum level	Interface level	Sand body composition unit	Sedimentary unit
Y 9	Level 4	—	—
Y 9_1, Y 9_2, Y 9_3	Level 3	—	Sedimentary facies
Y 9_3^1, Y 9_3^2	Level 2	Composite sand body of the main channel	The complex of single microphase
Y $9_3^{2\text{-}1}$, Y $9_3^{2\text{-}2}$	Level 1	Single sand body of main channel, river flank, and interchannel bay	Single microfacies

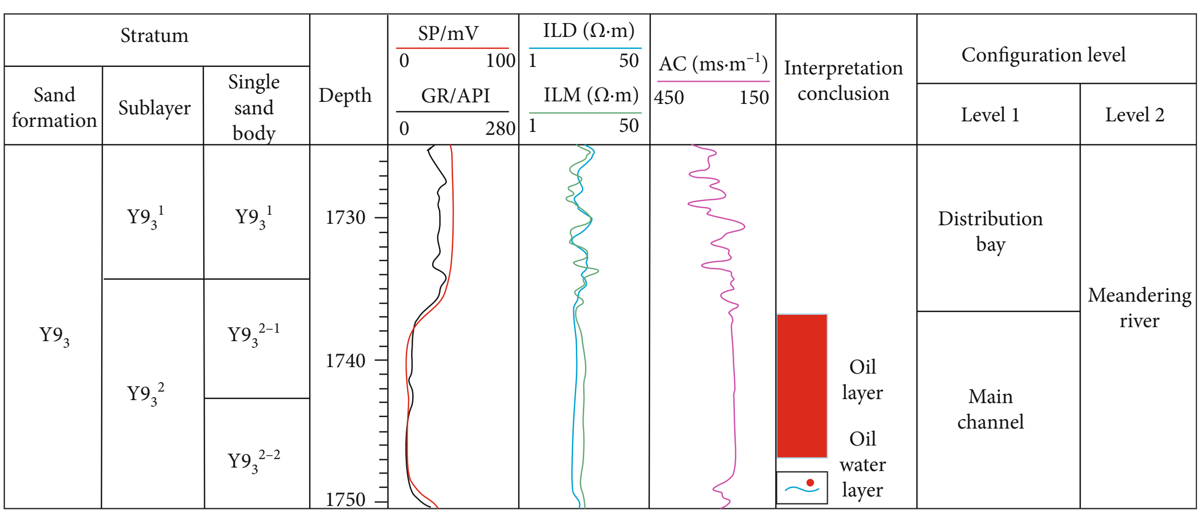


Figure 6: Well logging interpretation modes of reservoir configuration unit in the Yan 9_3^2 layer (D4422).

3.4.2. Lateral Stacking Mode of Multistage Sand Body. The lateral stacking mode of Yan 9_3^2 layers is mainly divided into lateral splicing and lateral separation. Lateral splicing mode means the connection of two-channel sand bodies in the same period. They can be identified according to the height difference and the shape of the logging curve. This kind of composite sand body has good connectivity in general. Lateral separation mode refers to the sand body mode in which the two-channel sand bodies are separated by argillaceous and other impermeable barriers and are not connected with each other.

4. Results and Discussions

4.1. Plane Distribution Characteristics of Sand Body Configuration. Based on the identification of the single sand body sedimentary interface, basic unit division, channel boundary identification, and vertical and lateral superposition

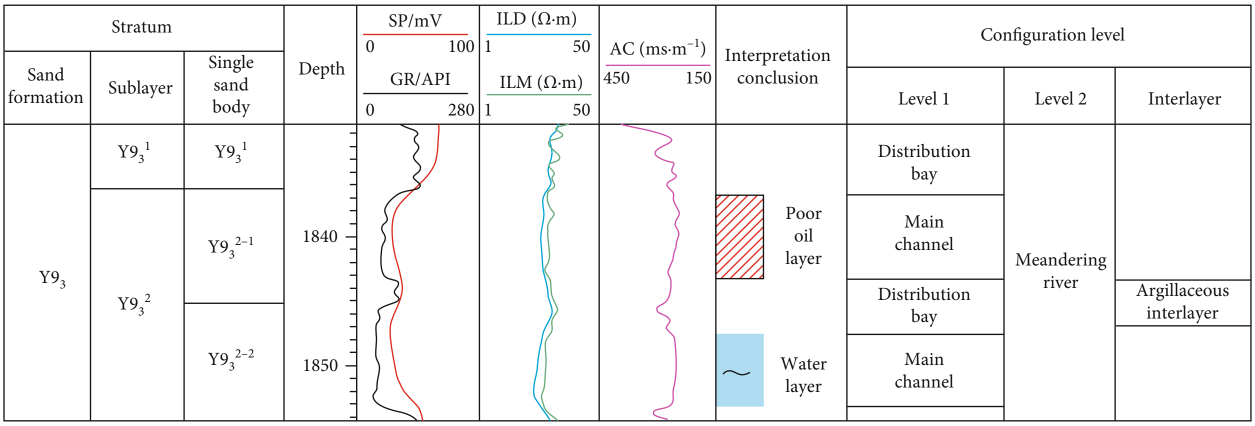


FIGURE 7: Schematic diagram of argillaceous interlayer in the Yan 9_3^2 layer (D4421-2).

TABLE 2: Classification of sedimentary microfacies and its logging response of the Yan 9_3^2 layer.

Sedimentary subfacies	Sedimentary microfacies	Response characteristics of logging curve
Meandering river	Main channel	Medium and high amplitude box shape and a toothed box shape
	River flank	Low amplitude anomaly of microgeneration
	Interchannel bay	Mudstone baseline

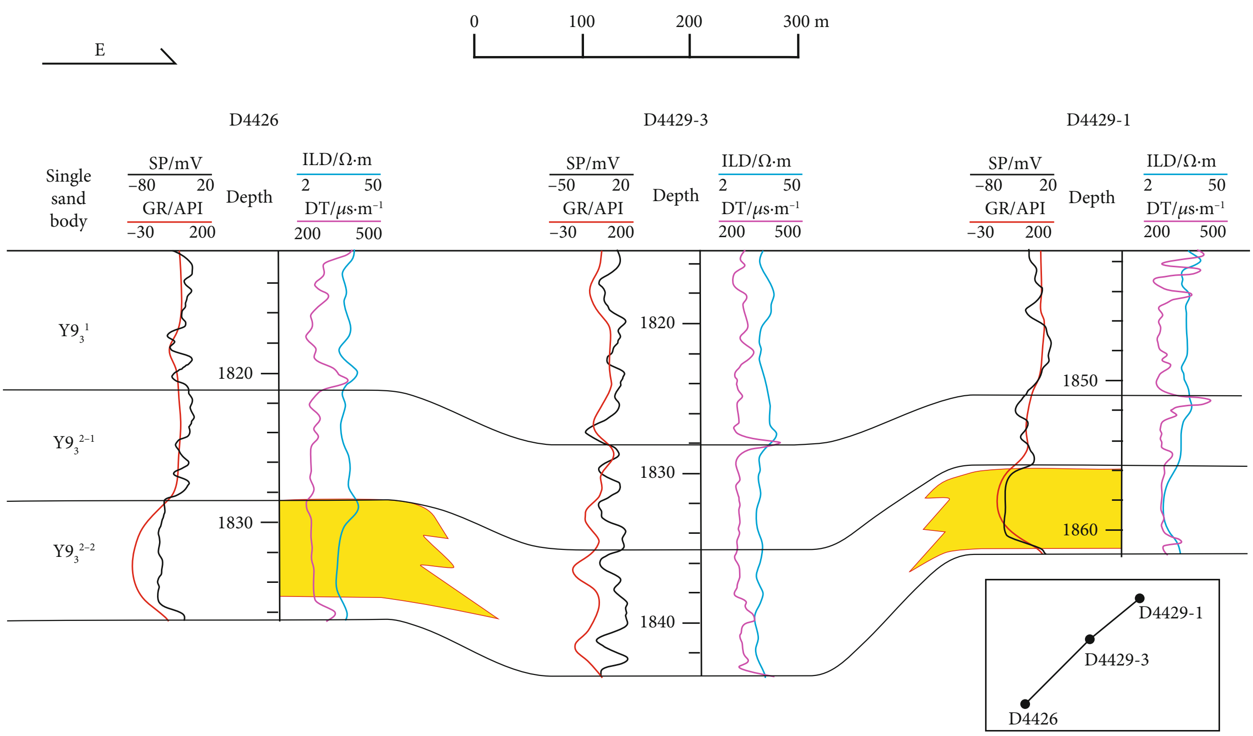


FIGURE 8: Schematic diagram of the argillaceous sedimentation.

pattern identification of configuration, the vertical division and characteristics of the distribution can be analyzed.

According to the previous analysis, there are four types of configurations in the Yan 9_3^2 layer. The distribution features of sand body configuration have obvious regularity (Figure 13). First, the sand body configuration developed in the center of the main river channel is the two-stage sand body vertical shear superposition type (type I & II), which is in the shape of a thick layer superposition, with no return of SP curve and small return of GR curve, which reflects the strong hydrodynamic force and is the main place for oil and gas enrichment.

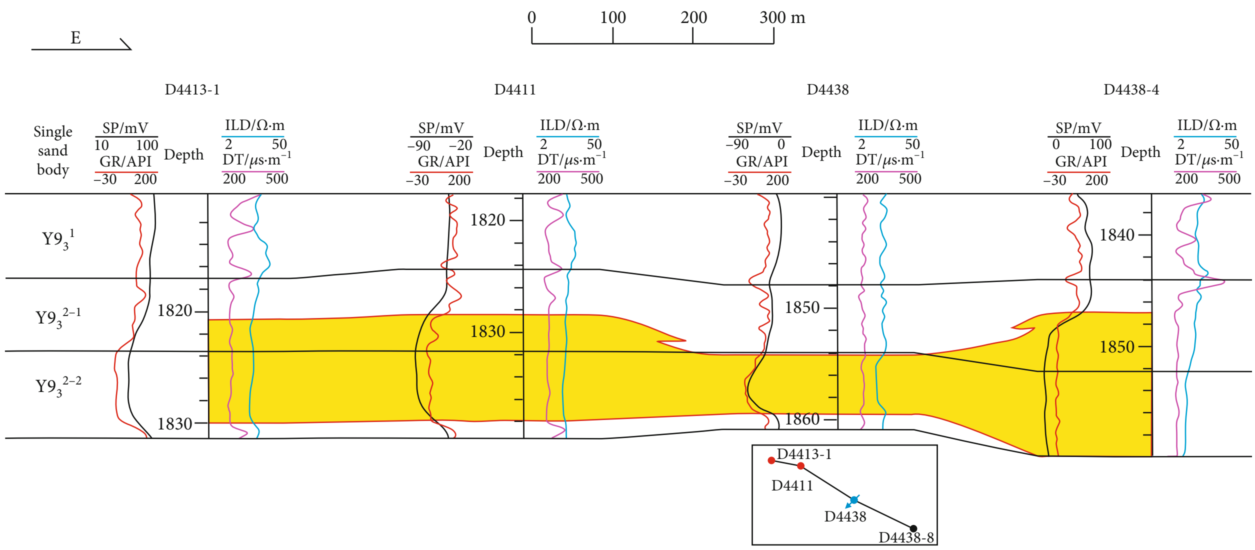


Figure 9: Schematic diagram of the logging curve change.

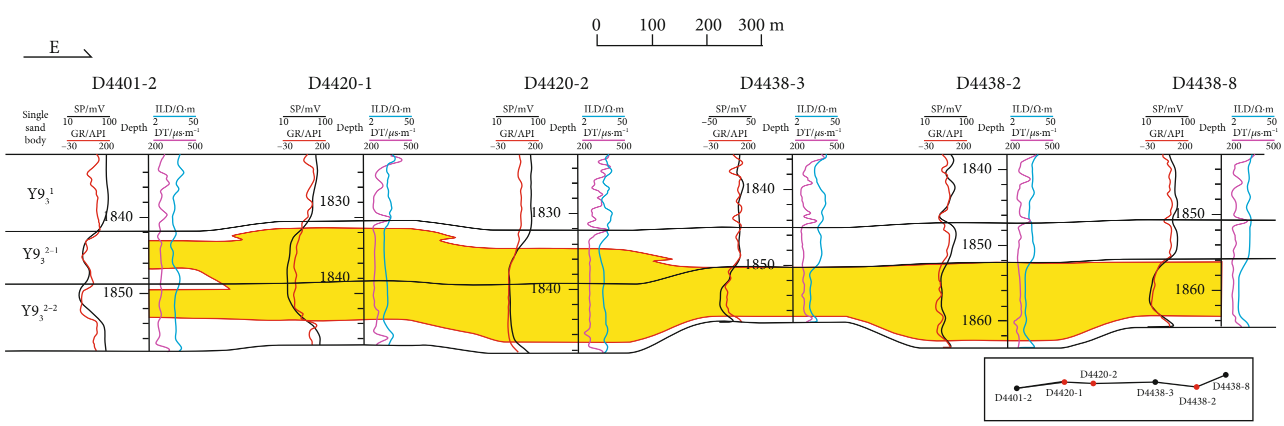


Figure 10: Schematic diagram of sand body thickness change.

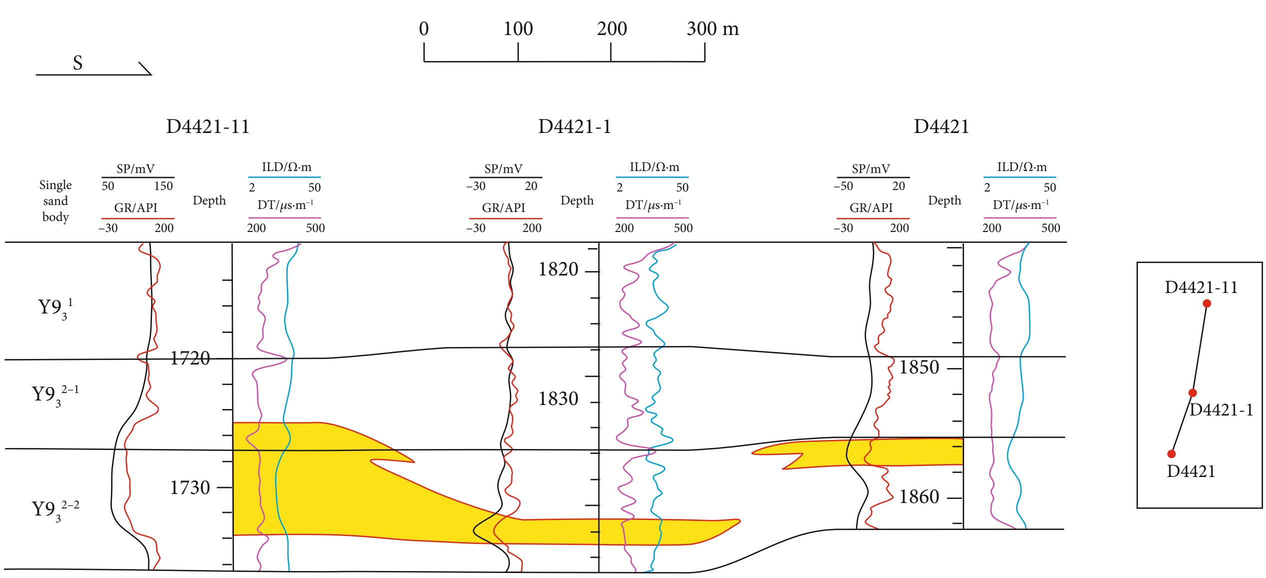


Figure 11: Schematic diagram of the sand body height.

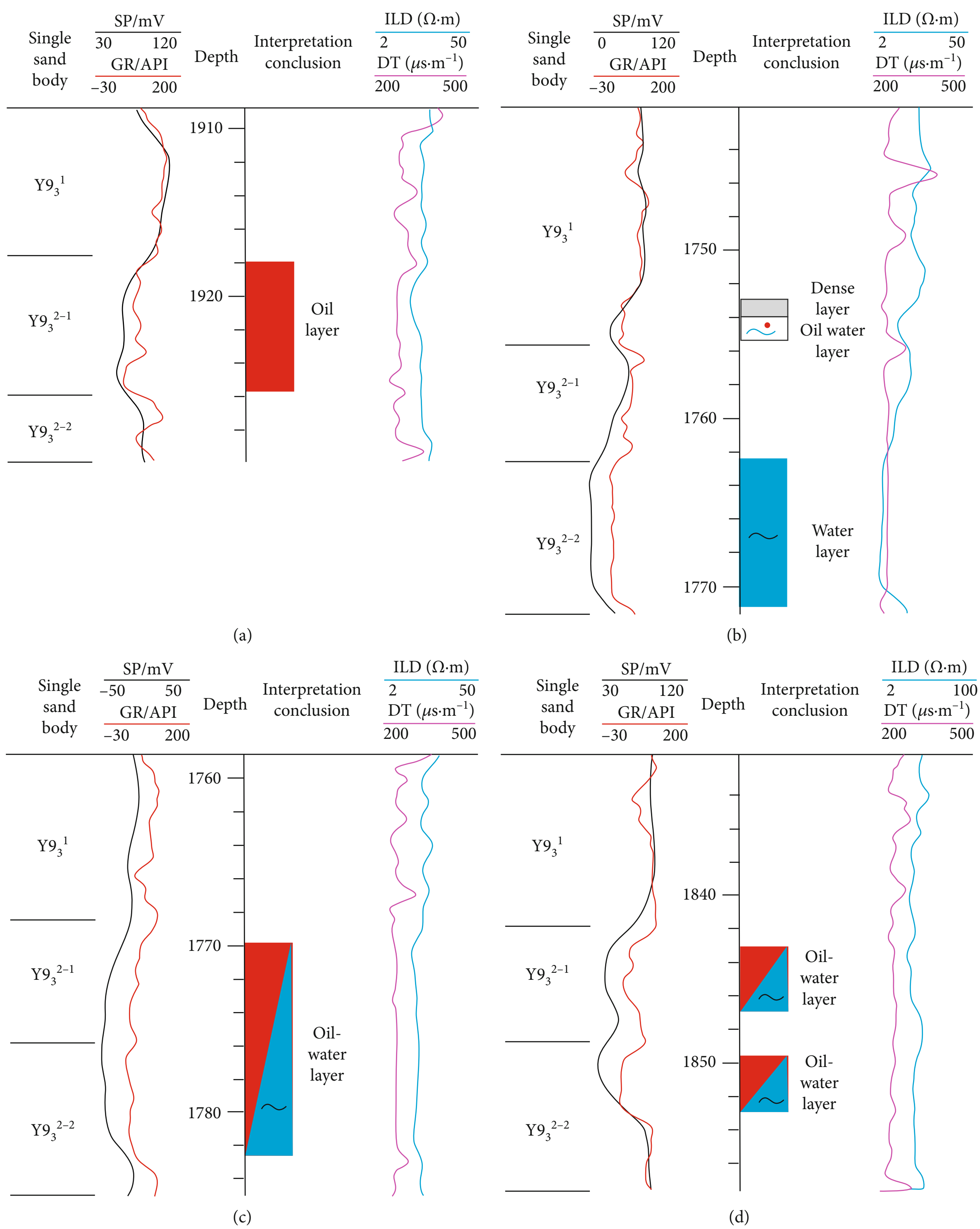


Figure 12: Configuration mode of single sand body superposition in Yan 9_3^2.

Second, the edge of type I & II sand body configuration is a two-stage sand body separation type (type I/II), which belongs to the river flank microfacies and has a small development scale. The main channel has a large thickness and a wide range. The sand body thickness on the side of the channel changes rapidly and pinches out quickly, reflecting the large sedimentary slope angle. The mudstone interlayer developed between the two sets of sand bodies has an obvious return of SP and GR curves. Third, at the edge of the two-stage cutting and stacking type and separation type, only a one-stage single sand body configuration is developed, i.e., type I or type II, and the sandstone thickness is small.

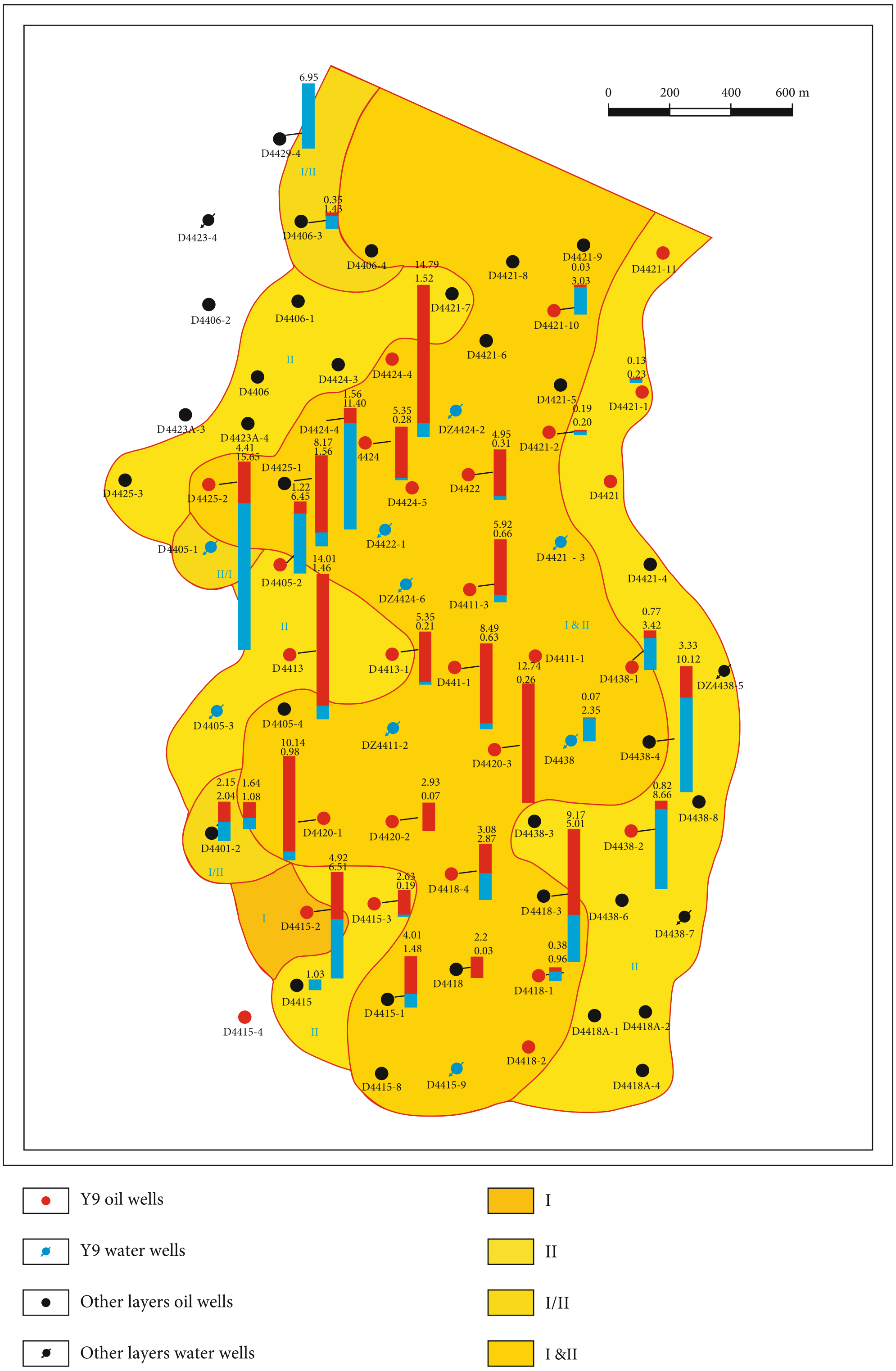


FIGURE 13: Plane distribution of sand body configuration of the Yan 9_3^{2} layer.

4.2. Analysis of Principal Controlling Factors of Oil-Water Distribution. According to the secondary interpretation conclusion of the oil layer and the initial production data, the original oil saturation distribution map of Yan $9_3^{2\text{-}1}$ and Yan $9_3^{2\text{-}2}$ is drawn, and sand body configuration and sandstone thickness, the key factors of oil-water distribution law, are analyzed to provide a basis for the prediction of residual oil distribution law [27–31].

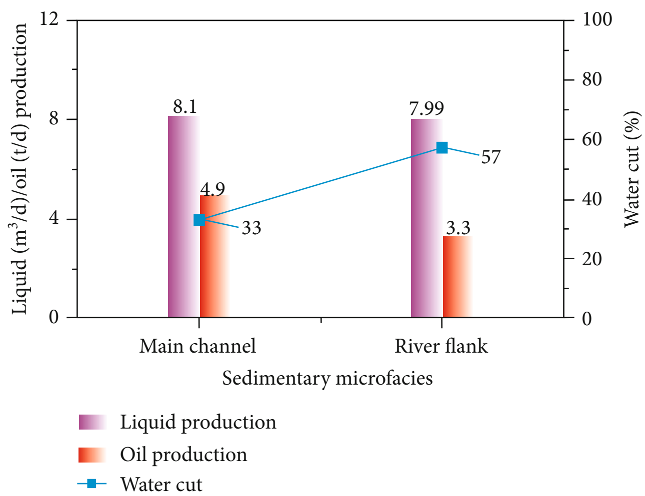


FIGURE 14: Statistics of initial production of different sedimentary microfacies in the Yan 9_3^2 layer.

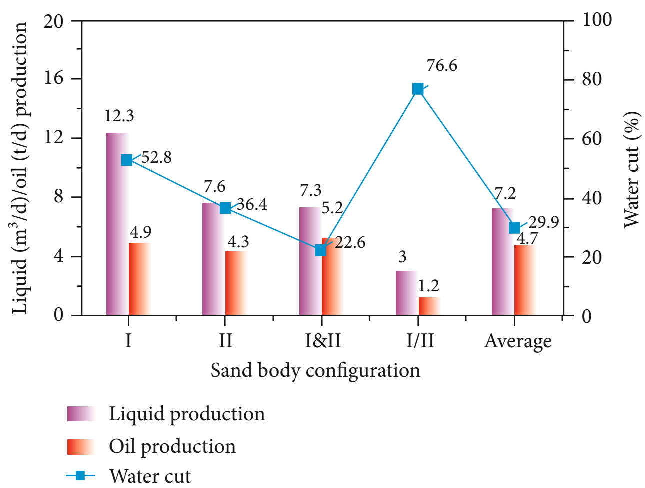


FIGURE 15: Comparison of initial production of different sand body configurations.

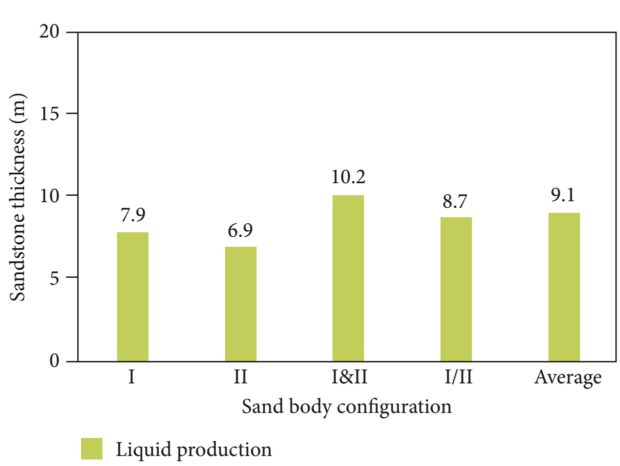


FIGURE 16: Comparison of sand thickness of different sand body configurations.

4.2.1. Sedimentary Microfacies Control the Oil-Water Distribution. The Yan 9_3^2 belongs to meandering river subfacies, and the sedimentary microfacies are mainly river channels, river flanks, and interchannel bays.

The sand body in the main channel has a large thickness, high initial yield, and low water content; The sand body on the side of the river has a thin thickness, poor physical properties, high shale content, low initial production, high water content, and low oil saturation. Sedimentary microfacies affect the original oil-water distribution (Figure 14).

4.2.2. Sand Body Configuration Affects Oil-Water Distribution. The most developed sand body configuration of Yan 9_3^2 is type I & II (18 wells), followed by type II (8 wells), type I/II (2 wells), and type I (1 well).

The sand body configuration from good to poor in average initial oil production is type I & II, type I, type II, and type I/II. The sand body configurations with initial water

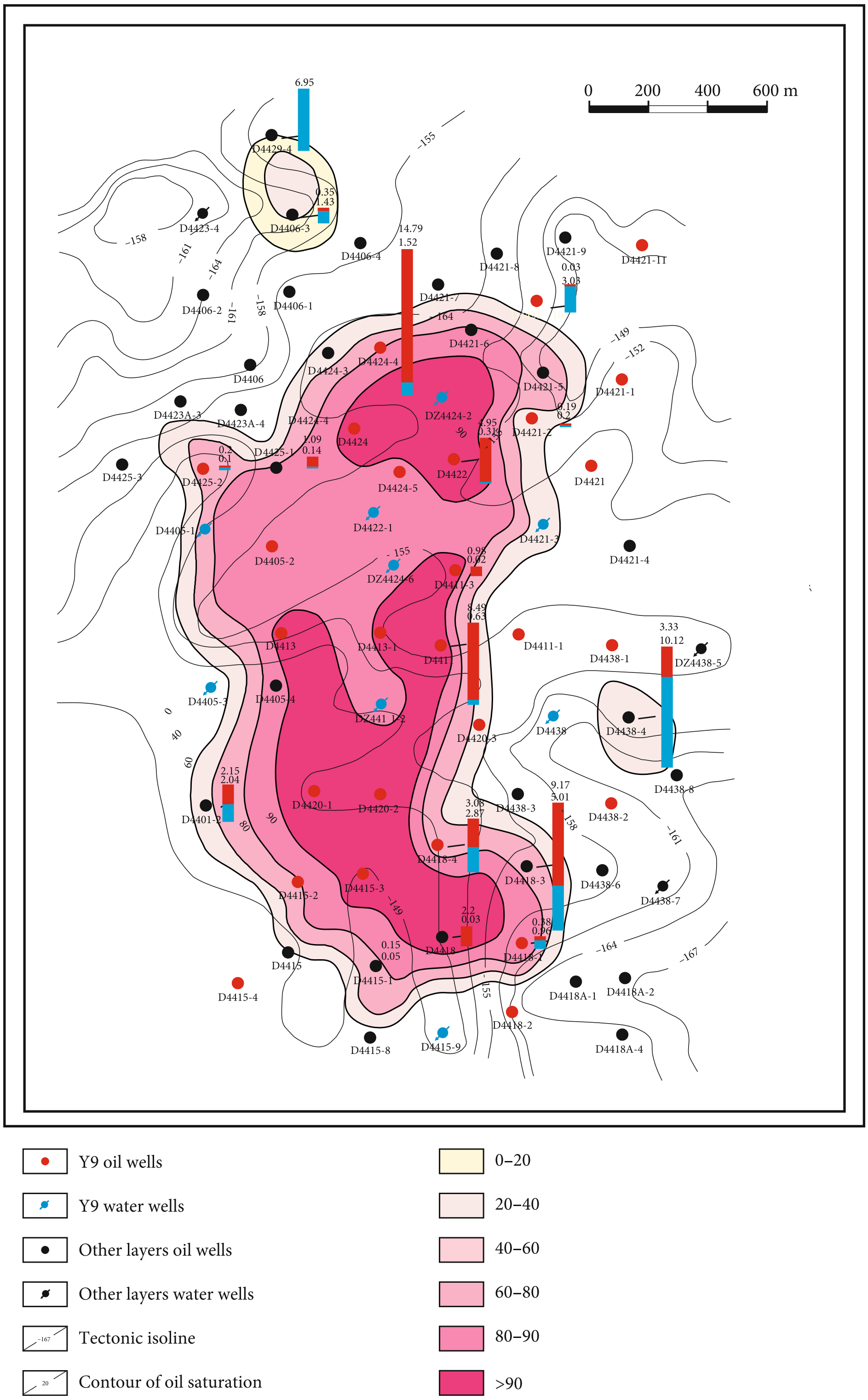


Figure 17: Superposition diagram of oil saturation and structure of Yan $9_3^{2\text{-}1}$.

content from low to high are type I & II, type II, type I, and type I/II (Figure 15).

The original oil-water distribution laws of different types of sand body configurations are obviously different. The production characteristics of type I & II sand body configuration are as follows: firstly, the initial production is relatively higher and the water cut is lower. Most oil wells are basically pure oil layers. Secondly, the production characteristics of

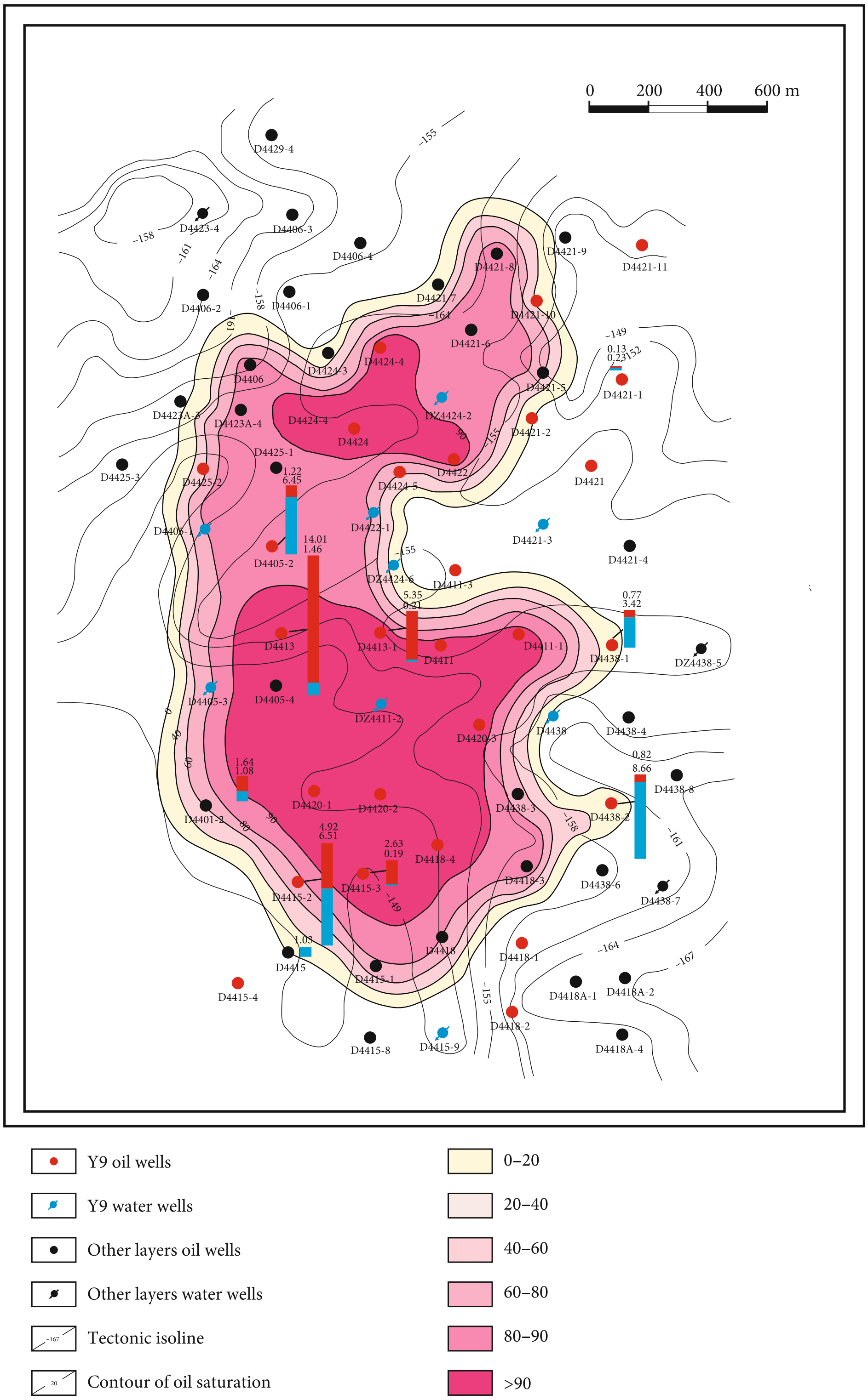


FIGURE 18: Superposition diagram of oil saturation and structure of Yan $9_3^{2\text{-}2}$.

type II sand body configuration are that the water saturation increases obviously, the initial liquid production is high, and the oil production is low.

In conclusion, sandstone thickness and sand body configuration are one of the key control factors affecting oil-water distribution (Figure 16).

4.2.3. Structure Affects Oil-Water Distribution. The Yan 9_3^2 oil layer has relatively good physical properties. Affected by the structure, the oil-water differentiation is obvious. In particular, pure oil layers are developed in areas with a good matching between sandstone thickness and high structure, and the initial water cut is less than 10% (Figures 17 and 18).

It can be seen from the plane distribution of sand body shape and oil saturation distribution that the sand body thickness at the overlapping position of the two phases of sand bodies is large, and the initial production is pure oil. For the oil layer with only one-stage single sand body developed, and because the structural position of the Yan $9_3^{2\text{-}1}$ layer is relatively higher than that of the Yan $9_3^{2\text{-}2}$ layer, the initial water content of the Yan $9_3^{2\text{-}2}$ layer is higher than that of the Yan $9_3^{2\text{-}1}$ layer.

5. Conclusions

(1) The Yan 9_3^2 layer of Y oil area in Dingbian is a meandering river deposit, which is a structural lithologic oil reservoir. The lithology is lithic arkose and arkose, and the interstitial materials are mainly kaolinite, illite, and carbonate

(2) The level 2 sedimentary interface of the Yan 9_3^2 oil layer is mainly an argillaceous interlayer, and the level 1 sedimentary interface is an argillaceous interlayer. The configuration units of the single sand body are Yan $9_3^{2\text{-}1}$ (phase I) and Yan $9_3^{2\text{-}2}$ (phase II). The vertical configuration modes include the isolated type of one-stage sand body, vertical separation type of two-stage sand body, and vertical shear superposition type of two-stage sand body

(3) The distribution of the Yan 9_3^2 reservoir configuration on the plane has obvious regularity. The principal factors of oil-water distribution include sedimentary microfacies, sand body thickness, sandstone configuration, and structural characteristics

Data Availability

The experimental data used to support the findings of this study are included in the manuscript.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

Acknowledgments

The authors would like to acknowledge the financial support from the Shaanxi Natural Science Basic Research Program, China (2022JQ-290).

References

[1] Z. Qingguo, B. Zhidong, S. Xinmin, and S. Jixu, "Hierarchical division and origin of single sand bodies in Fuyu oil layer, Fuyu Oilfield," *Petroleum Exploration and Development*, vol. 35, no. 2, pp. 157–163, 2008.

[2] L. Jun, S. Xinmin, X. Peihua, Z. Hailong, and S. Jingmin, "Hierarchical subdivision and origin of single sand body in the reservoirs of meandering river facies in the Yang da cheng zi formation of Fu yu Oilfield," *Oil and Gas Geology*, vol. 31, no. 1, pp. 119–125, 2010.

[3] L. Weiwei, D. Hailong, X. Bo, Z. Liang, and C. Pengxing, "Establishment of reservoir configuration model of lacustrine delta based on single sand body: taking S area in Ordos Basin as an example," *Journal of Xi'an University of Petroleum*, vol. 35, no. 2, pp. 26–34, 2020.

[4] W. Yong, Z. Tao, Z. Jie, X. Li Weizhen, and Z. Y. Zhaolin, "Study on the distribution relationship of single sand body configuration elements of Chang 6 formation in block h of Ansai Oilfield," *Chemical Management*, vol. 553, no. 10, pp. 219-220, 2020.

[5] N. Bo, F. Zhao Jiahong, L. J. Ping et al., "Trend judgment of abandoned channels and fine architecture characterization in meandering river reservoirs: a case study of Neogene Minhuazhen Formation NmIII2 layer in Shijiutuo bulge, Chengnning uplift, Bohai Bay Basin, East China," *Petroleum Exploration and Development*, vol. 46, no. 5, pp. 891–901, 2019.

[6] X. Bo, L. Baofang, F. Han, W. Yingbiao, J. Shengli, and Q. Yuwei, "Superimposition relationships of the individual sandbody in the shallow-water-delta underwater distributary channel of Member Ed1 in Block Nanpu 1-1," *Petroleum Geology and Oilfield Development in Daqing*, vol. 38, no. 1, pp. 51–59, 2019.

[7] W. Langbo, G. Xiangrui, D. Bo et al., "Study on single sand body in ultra-low permeability reservoir and adjustment to injection- production: an example from Wangyao area of Ansai Oilfield," *Journal of Petrochemical Universities*, vol. 31, no. 2, pp. 82–88, 2018.

[8] L. Junfei, "Characterization of single sand body and remaining oil distribution in braided river reservoir," *Complex Reservoir*, vol. 14, no. 4, pp. 65–68, 2021.

[9] Z. Rui, L. Zongbin, T. Bo, Z. Xuefang, and L. Chao, "Identification and quantitative evaluation of inter-well single sand body connectivity of SZ oilfield in Bohai Sea [J]," *Geological Science and Technology Information*, vol. 37, no. 5, pp. 78–83, 2018.

[10] Z. Ye, S. Yongmin, L. Xinju, W. Lin, and F. Bo, "Precise identification and classification of composite single sandbodies in the Ansai shallow water delta front," *Special Oil and Gas Reservoir*, vol. 25, no. 23, pp. 56–60, 2018.

[11] W. Qin Guosheng, S. X. Shenghe, Z. Cunyou, Z. Lianyong, and C. Cheng, "Sedimentary characteristics of distal fine-grain braided delta and architecture analysis of single sand body," *Journal of China University of Petroleum (Natural Science Edition)*, vol. 41, no. 6, pp. 9–19, 2017.

[12] F. Congjun, B. Zhidong, Z. Jihui, and Z. Zhaoqian, "Dividing of base-level cycle and its controlling on single sand body in the Fourth Member of Quantou Formation in Fuyu Oilfield," *Journal of Jilin University (Earth Science Edition)*, vol. 42, Supplement 2, pp. 62–69, 2012.

[13] L. Yuming, L. Yuanyuan, Z. You, S. Aiqin, C. Shize, and Z. Houyuan, "Identification of single sand body in thick sand layer of braided river with dense well pattern in Lamadian Oilfield," *Fault Block Oil and Gas Field*, vol. 18, no. 5, pp. 556–559, 2011.

[14] F. Congjun, B. Zhidong, S. Qitong, Y. Sun Mengsi, and D. H. Shiyan, "Single sand body identification in compound distributary channel of delta plain: a case study from the fourth member of Quantou Formation in the southern part of central Fuyu oilfield," *Oil and Gas Geology*, vol. 33, no. 1, pp. 77–83, 2012.

[15] R. Shuangpo, Y. Guangqing, and M. Wenjing, "Genetic types and superimposition patterns of subaqueous distributary channel thin sandbodies in delta front: a case study from the

IV-VI reservoir groups of H3 in Biqian 10 area of Gucheng oilfield," *Acta Sedimentologica Sinica*, vol. 34, no. 3, pp. 582–593, 2016.

[16] W. Yibo, M. Shizhong, W. Xingyan, and L. Haifeng, "Sedimentary microfacies to mono-sandstone body in high water cut stage - taking PII oil-bearing formation of Lamadian Oilfield as an example," *Journal of Daqing Petroleum Institute*, vol. 32, no. 1, p. 12, 2008.

[17] Q. Gang, X. J. Qun, P. Yubin, and S. Meng, "Genetic analysis and depiction on single sand body in channel: taking Fuyu oil group in Middle 38 Area of Fuyu Oilfield as an example," *Fault Block Oil and Gas Field*, vol. 21, no. 3, pp. 309–313, 2014.

[18] Y. Hailong, Z. Xinchun, Y. Xingli, and C. Yubao, "Control factors and distribution patterns of residual oil in Chang-6 reservoir of Tang 114 field," *Unconventional Oil and Gas*, vol. 6, pp. 49–56, 2020.

[19] D. Pengfei, Z. Gang, A. Shan, and W. Yongfei, "Characteristics of reservoir and accumulation model of 9th member of Yan'an formation in Fanxue area, Dingbian oilfield," *Unconventional Oil and Gas*, vol. 4, pp. 16–22, 2020.

[20] L. Cheng, W. Dong, L. Xueqing et al., "Study on distribution characteristics of residual oil in eastern X6 block of Daqing Oilfield based on nuclear magnetic resonance," *Unconventional Oil and Gas*, vol. 9, no. 3, pp. 96–102, 2022.

[21] L. Lei, Z. Jilong, W. Fang, F. Yue, and H. Rong, "Study on vector adjustment strategy based on classification and evaluation of remaining oil," *Unconventional Oil and Gas*, vol. 3, pp. 80–89, 2021.

[22] A. D. Miall, "Architectural-element analysis: a new method of facies analysis applied to fluvial deposits," *Earth Science Review*, vol. 22, no. 4, pp. 261–308, 1985.

[23] F. Congjun, B. Zhidong, Y. Ling, X. Si Xiong, and H. X. Guibin, "Reservoir architecture and remaining oil distribution of deltaic front underwater distributary channel," *Petroleum Exploration and Development*, vol. 41, no. 3, pp. 323–329, 2014.

[24] L. Junfei, Y. Xiaoming, S. Baobing, D. Shengguo, and Y. Bin, "Division of single sand body in mouth bar of delta front and remaining oil distribution," *Special Oil and Gas Reservoir*, vol. 26, no. 2, pp. 59–64, 2019.

[25] F. Congjun, B. Zhidong, D. Chunming, and Z. Zhaoqian, "Superposition patterns of underwater distributary channel sands in delta front and its control on oil distribution: a case study from K_1q^4 in J19 block, Fuyu Oilfield," *Oil and Gas Geology*, vol. 36, no. 1, pp. 128–135, 2015.

[26] L. Xinju, G. Yuegang, Z. Hongjun, X. Lina, and W. Xuesheng, "Distribution mechanism and potential tapping to remaining oil in overlap single sandbody of Ansai reservoir with extralow permeability," *Complex Oil and Gas Reservoir*, vol. 8, no. 4, pp. 45–48, 2015.

[27] L. Chengyan, S. Tingbin, D. Chunmei, L. Zhipeng, T. Min, and L. Shijiang, "Fine characterization of remaining oil based on a single sand body in the high water cut period," *Journal of Petroleum*, vol. 34, no. 6, pp. 1131–1136, 2013.

[28] X. Hui, L. Chengyan, L. Guanglun, G. Bao, and F. Caixing, "Remaining oil distribution law and potential tapping measures of subaqueous distributary channel single sandbody," *Journal of China University of Petroleum (Natural Science Edition)*, vol. 37, no. 2, pp. 14–20, 2013.

[29] L. Zhipeng, L. Chengyan, P. Xuehong, B. Lixia, and W. Yue, "Control effect of single sand body interlayer of Minghuazhen Formation on remaining oil in high shallow south area," *Journal of Petroleum and Natural Gas*, vol. 33, no. 9, pp. 23–27, 2011.

[30] H. Jie, W. Jingyao, L. Jun, J. Youwei, Z. Changlong, and W. Fenggang, "Research of architecture of monosandbody in meandering reservoir and control factors of remaining oil on Fuyu formation, Fuyu Oilfield," *Geoscience*, vol. 25, no. 2, pp. 308–314, 2011.

[31] Z. Xinmao, G. X. Yongle, Z. Zheng, C. Jianyang, and W. Jiqiang, "Application of fine description of single sand body in meandering river to old oilfield redevelopment," *Xinjiang Petroleum Geology*, vol. 31, no. 3, pp. 284–287, 2010.