EARTH SCIENCES
RESEARCH JOURNAL
Earth Sci. Res. J. Vol. 28, No. 3 (September, 2024): 361 - 366

UNIVERSIDAD NACIONAL DE COLOMBIA

PETROLEUM GEOLOGY

Rolling appraisal and high-efficiency development on a lithologic reservoir of nearshore subaqueous fan in the Tanan oilfield

Quan Wen[1,2]*, Zixuan Sha[2], Guozhi Wang[1]
1. School of Earth Sciences, Chengdu University of Technology, Chengdu 610059, China
2. Exploration and Development Research Institute of Daqing Oilfield Co., Ltd, Daqing, Heilongjiang 163712, China
*Corresponding author: 185209605@ustc.edu.cn

ABSTRACT

The exploration and development process in the Tanan oilfield is guided by geological insights and the aim of economically beneficial exploitation in foreign oilfields. The study primarily focuses on the sequential exploration and development process of "finding fan, finding reservoir, and finding edge" for the lithologic reservoir of Nantun formation, aligning with current oil prices and available geological resources. By analyzing the detailed anatomy of lithologic reservoirs and development characteristics in the Nantun formation, a geological working method of "searching for uplift and fan before root and edge" has gradually emerged. The lithologic reservoir of Nantun formation is a typical nearshore subaqueous fan lithologic-structural reservoir developed under long-term paleo-uplift in the deep fault period of a faulted lacustrine basin. The combination of paleogeomorphologic restoration and seismic sedimentology is crucial in identifying such reservoirs. Reservoir development is influenced by sedimentary subfacies type, with the middle-fan reservoir exhibiting the best physical properties and higher natural productivity, followed by the fan-root reservoir which shows better well productivity after fracturing. The fan-edge reservoir has comparatively poorer physical properties, with less apparent effects of fracturing. This method has proven to be effective in guiding the rolling appraisal and development of such reservoirs, both domestically and internationally, through detailed geological study.

Keywords: Tannan sag; lithologic reservoir; rolling appraisal and development; nearshore subaqueous fan, development strategy

Evaluación y desarrollo de alto impacto en un reservorio litológico de un abánico bajo el agua y cercano a la orilla en el campo petrolífero de Tanan

RESUMEN

Los procesos de exploración y desarrollo del campo petrolífero de Tanan se guían por principios geológicos y el objetivo de una explotación económica aplicable en campos petrolíferos en el extranjero. Este estudio se enfoca en la secuencia de exploración y proceso de desarrollo de "encontrar un abánico, encontrar un reservorio, y encontrar sus límites" para el reservorio litológico de la formación de Nantun, en concordancia con los precios actuales del crudo y con los recursos geológicos disponibles. Al analizar la anatomía detallada del reservorio litológico y las características de desarrollo de la formación Nantun, emergió gradualmente el método de trabajo geológico de "buscar el levantamiento y el abánico antes que la raíz y el borde". El reservorio litológico de la formación de Nantun es un típico abánico bajo el agua de estructura litológica y cercano a la costa que se desarrolló durante el levantamiento del Paleolítico en el período de una falla profunda de una cuenca lacustre fallada. La combinación del restauramiento paleogeomorfológico y la sedimentología sísmica es crucial en la identificación de estos reservorios. El desarrollo del reservorio está influenciado por el tipo de subfacies sedimentarias, donde el abánico intermedio presenta las mejores propiedades físicas y mayor productividad natural, seguido por el abánico de la raíz, que muestra la mejor productividad de pozo tras la fracturación. El abánico del borde del reservorio tiene comparativamente las propiedades físicas más pobres, con menos efectos aparentes en la fracturación. Este método ha demostrado ser efectivo para guiar la evaluación y el desarrollo de dichos yacimientos, tanto a nivel nacional como internacional, mediante un estudio geológico detallado.

Palabras clave: hundimiento en el pozo Tanan; reservorio litológico; evaluación y desarrollo; abánico bajo el agua cercano a la orilla; estrategia de desarrollo

Record
Manuscript received: 11/06/2024
Accepted for publication: 19/10/2024

How to cite item:
Wen, Q., Sha, Z., & Wang, G. (2024). Rolling appraisal and high-efficiency development on a lithologic reservoir of nearshore subaqueous fan in the Tanan oilfield. *Earth Sciences Research Journal,* 28(3), 361-366. https://doi.org/10.15446/esrj.v28n3.115013

ISSN 1794-6190 e-ISSN 2339-3459
https://doi.org/10.15446/esrj.v28n3.115013

1. Introduction

Tamsag Oilfield is the first project for Daqing Oilfield to enter overseas and realize an independent operation of the "going global" strategy. It includes Tanan Oilfield and Nanbeier Oilfield. After Daqing Oilfield was transferred to it, it gradually overcame a series of unfavorable factors, such as complex geological conditions and cumbersome business operations. It achieved the stage goal of high and stable production of this oilfield. To ensure the continuous stable production of the oilfield and the deepening of exploration and development, Tanan Oilfield has entered the orderly transition and replacement stage from exploration and development of structural reservoirs to lithologic reservoirs. Lithologic reservoir exploration is traced back to the introduction of seismic stratigraphy and sequence stratigraphy in China (Xiaomin, 2001; Houfu et al., 1988). The rise of seismic sedimentology and paleogeomorphology provides new theoretical support for the exploration of lithologic reservoirs (Hongliu, 2011; Lv et al., 2018). Therefore, applying new methods and technologies to find effective means for the exploration and development of lithologic reservoirs has practical guiding significance for achieving "efficient and economic development with fewer wells" in overseas oilfields.

2. Regional geological background

Tanan Oilfield is located in the southernmost section of the oil-rich fault sag belt in the middle of Haita Basin (Fig. 1). The main body of the sag is a complex half-graben-like Semi-Rift fault sag. It is composed of three half grabens and half horsts and is characterized by east-west zonation and north-south zoning (Yaguang, 2018). The whole sag experienced the whole process of the initial fault sag stage, deep fault stage, fault-sag transition stage, sag stage, and structural inversion stage. The developed strata from bottom to top include the Tongbomiao Formation, Nantun Formation, Damoguaihe Formation, Yimin Formation, and Qingyuangang Formation. At present, exploration results show that structural oil reservoirs are mainly developed in the Tongbanmiao Formation at the initial fault sag stage. Lithologic oil reservoirs are mainly developed in the Nantun Formation at the deep fault stage (Fu et al., 2011). Although the geological reserves of lithological reservoirs account for a small share of the total reserves, the current development effect shows that the lithological reservoirs of the Nantun Formation are characterized by thin sandstone thickness and high single-well production. It is called the small but fat reservoirs. Therefore, the exploration and development of lithologic reservoirs in the Nantun Formation are the principal means for Tamsag Oilfield to increase reserves and production with the method of fewer wells and higher efficiency.

3. Rolling appraisal practice

After years of geological exploration, Tanan Sag shows a good full sag oil-bearing scene. However, according to the analysis, the development effect of different types of reservoirs is quite different. This is the primary problem for Haita Oilfield to find oil reservoirs with beneficial reserves. Starting from the geological conditions forming offshore underwater fan lithologic oil and gas reservoirs, this paper discusses the prerequisites for this type's advantageous reservoir formation, which provides a favorable guarantee for rolling appraisal. This paper discusses the role of rolling appraisal in discovering high-quality reserves with the perspective of fine reservoir anatomy combined with dynamic and static data analysis.

Geological conditions of rolling appraisal

The strata of the Nantun Formation are the sedimentary products of the rapidly rising lake level and the rapidly increasing accommodation space during the deep fault stage. The whole Tanan Sag is mainly composed of dark mudstone deposits. According to organic geochemistry and biostratigraphy data, dark mudstone is the main source of rock in the sag. The abundance of organic matter in the source rocks is high, and most of the source rocks enter the threshold of oil generation and enter the peak period of oil generation. At present, sand bodies of lithologic oil reservoirs are distributed in dark mudstone (Sun et al., 2011; Chen et al., 2013). Due to the extensive contact between the source and reservoir, the sand body in the source has the advantage of being close to the source rock and preferentially forming reservoirs (Fig. 2).

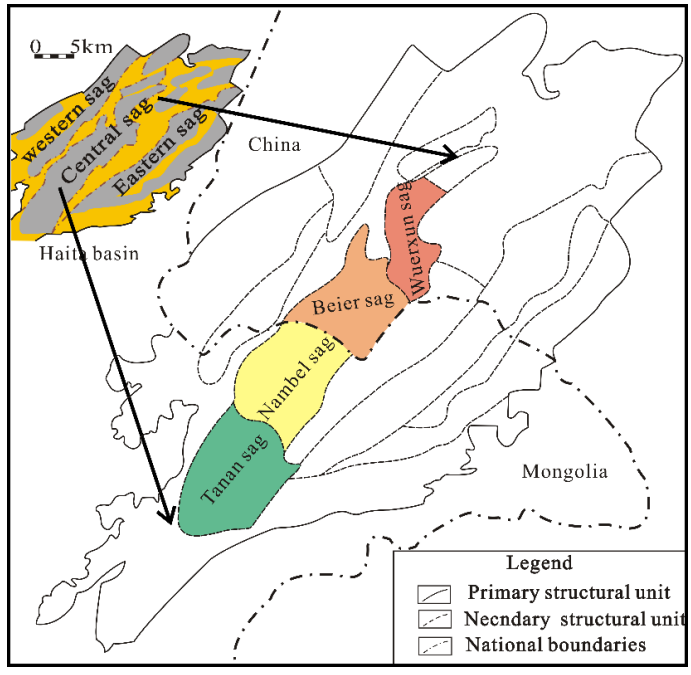

Figure 1. Location of Tanan Sag

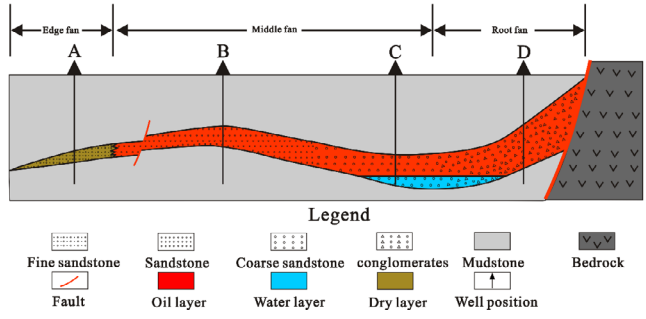

Figure 2. Oil and gas accumulation model of Nantun Formation lithologic reservoir

Significance of rolling appraisal

The basic flow of rolling evaluation is based on geological theory and combined with reservoir dynamic analysis. Taking the reservoir in Figure 2 as an example, the fine reservoir dissection shows that the reservoir is a typical lithologic-structural reservoir jointly controlled by lithology and structure. The good reservoir of the high structure is an oil layer with the logging and production data confirmed. The poor reservoir of the structure is a dry layer, with the logging and production data confirmed. The physical property of the reservoir also controls the lower part of the structure, and the dry layer or water layer is developed. According to the oil production capacity of the reservoir, the oil-bearing reservoir can be further divided into oil and poor oil layers. Conventional exploration and reservoir dissection focus on understanding the reservoir's existence while rolling evaluation and fine reservoir dissection not only consider the reservoir's existence but also focus on the quality of the reservoir. Therefore, it is of practical significance to analyze the main controlling factors of oil production capacity for deploying high-yield wells and discovering high-yield blocks.

Rolling appraisal means

Geological analogy is the main method of rolling appraisal. In this paper, based on the analysis of the formation conditions and genetic mechanism of the

fan body, the geological analogy method is used to effectively identify the fan body in combination with seismic sedimentology and paleogeomorphology.

Feasibility of rolling appraisal

Sufficient provenance, deepwater environment, and abrupt topography are essential for forming nearshore underwater fans. During the sedimentation period of the Nantun Formation, the steep slope belt of the ancient uplift developed in succession for a long time is a favorable location for forming the nearshore underwater fan (Fig. 3). The study of event sedimentology shows that the nearshore subaqueous fan deposits are mostly the products of seismic events. Therefore, under similar geological conditions, the fan body is isochronous, multiple and comparable (Zhang, 2021; Egger et al., 2002; McLeod et al., 2022; Richards & Bowman, 1998; Catuneanu et al., 2016; Stanistreet, 1993; Anselmetti, 2006; Palyvos et al., 2008; Galloway, 1998; Jia et al., 2007; Jiang & Liu, 2010). Therefore, the geological analogy method is an effective means for rolling discovery of such fans.

Identification means of the fan

According to the analysis of fan development conditions, paleogeomorphic restoration combined with seismic sedimentology is used to identify the sedimentary fan effectively. According to the analysis of paleogeomorphic characteristics during the sedimentation period of the Nantun Formation, it is considered that the steep slope zone of the north sag, in the west sub-sag of the Tanan Sag, is a favorable place for the nearshore underwater fan (Ja et al., 2021; Fu et al., 2013; Wu et al., 2018). At present, exploration wells have also confirmed the existence of underwater fans. The seismic sedimentology of underwater fans is evident in 3D seismic data volume. In the flattened seismic profile of the vertical fan strike layer, the fan body is a wedge-shaped seismic reflection embedded in the mud of parallel and sub-parallel seismic reflection. In the flattened seismic profile that crosscuts the fan body layer, the fan is characterized by hillock seismic reflection with a flat bottom and convex top (Fig. 4). In recent years, several fans have been found in the north sag of the western sub sag of Tanan through the methods of paleogeomorphic zoning and seismic sedimentology positioning, realizing the rolling appraisal strategy by means of fine geological research.

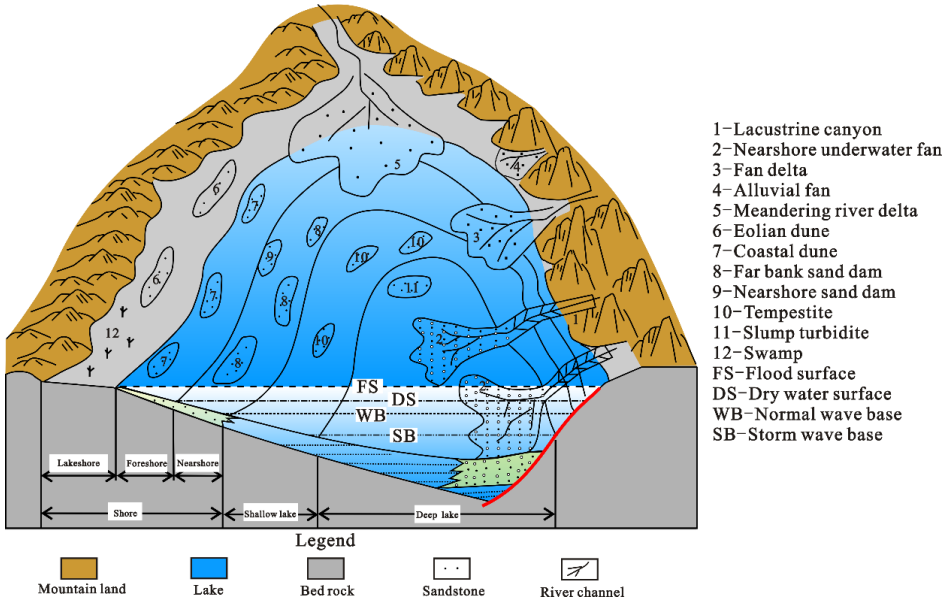

Figure 3. Formation conditions and development pattern of nearshore subaqueous fan

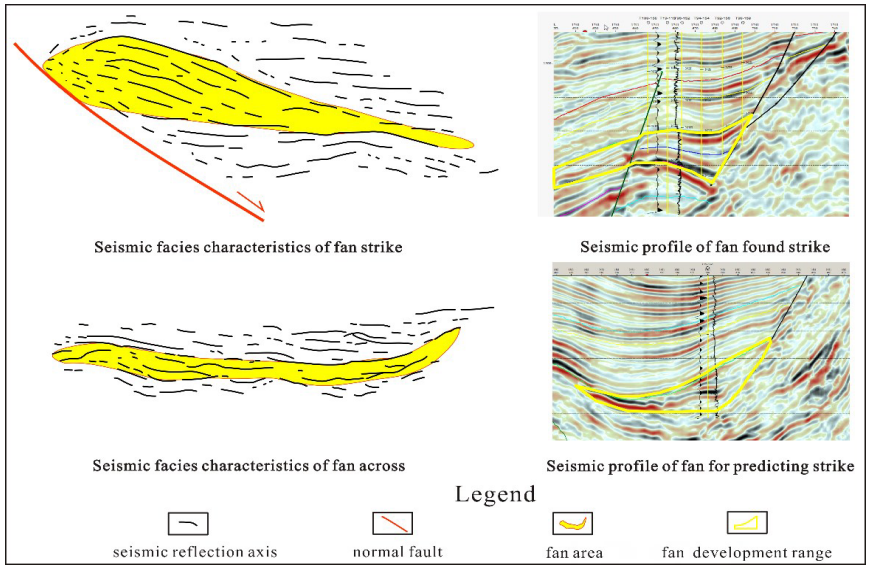

Figure 4. Effective identification method of nearshore underwater fan.

5. Reservoir development characteristics

Analysis of oil production capacity

According to the analysis of initial production intensity of production wells in Well Block A, the reservoir of the whole fan body has strong heterogeneity. The average natural oil recovery intensity of the reservoir in the middle part of the fan is 0.6 t/m • d. The average fracturing production intensity of the reservoir at the root fan is 0.2t/m • d. The average fracturing production intensity of the reservoir at the edge fan is 0.1t/m • d. The reservoir thickness is gradually thinner from the fan root to the fan edge. Controlled by the control of reservoir thickness and oil production intensity, the development effect in the middle and root of the fan is better than that in the edge of the fan (Fig. 5).

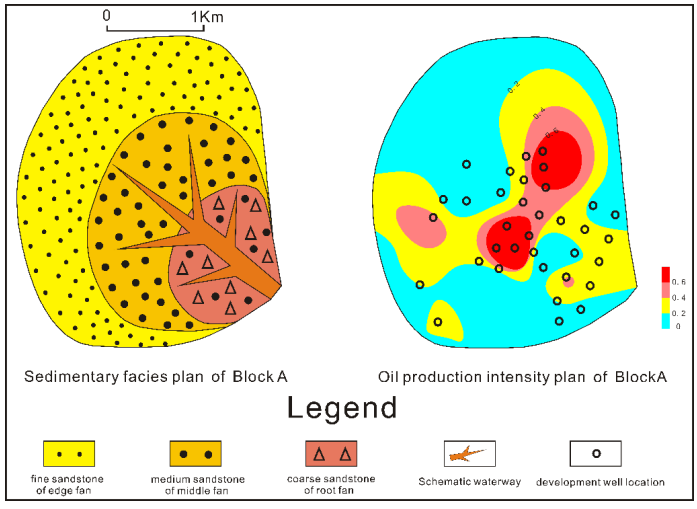

Figure 5. Distribution of initial oil production intensity of oil wells in each subfacies.

Production mode optimization

According to the analysis of current development characteristics, different development methods can be formulated for the location of different subfacies of the fan. The natural productivity of the oil wells in the middle part of the fan is relatively high, so the development mode of natural energy exploitation first and then water injection in the later stage of well pattern conversion can be adopted. The natural productivity of the oil wells at the root fan is low, so synchronous fracturing and water injection can be used. The sandstone at the edge fan is thin and the reservoir physical property is poor, but the sand body distribution continuity is good, so large-scale horizontal well fracturing can be used.

6. Rolling development ideas

The sedimentary subfacies of the nearshore subaqueous fan control the development characteristics of the reservoir, and thus the productivity of the oil wells. It also provides favorable geological support for the rolling development design concept.

Genetic analysis of high yield reservoir

The nearshore subaqueous fan is a typical gravity flow deposit, and its sedimentary mechanism and structure are very different from those of traction flow deposits. At present, domestic and foreign scholars have basically the same subfacies division of offshore underwater fan, which can be divided into three sedimentary subfacies: root fan (inner fan), middle fan (in the middle of fan), and edge fan (fan end, outer fan). Controlled by paleotopographic slope and sedimentary mechanism, the three sedimentary subfacies are very different in sedimentary scope, sedimentary thickness, bedding structure, rock grain size combination and vertical superposition style. The root fan subfacies are mainly developed in small restricted valleys near the provenance area. The lateral distribution range of sand body is limited, and the vertical superposed thickness of single stage sand body or multi stage sand body is relatively large. The cores and field outcrops show conglomerate, sandstone and mudstone mixed accumulation, and the Bauma sequence is clearly visible. The micro casting thin section shows the mixed accumulation of unequal grain sandy gravel, the gravel directivity is not obvious, the particles are in line contact with each other, the content of matrix is high, the pores are moderately developed, and the connectivity is poor. The pore characteristics of this kind of reservoir are the main reason for the low natural productivity of the reservoir. The subfacies of the middle fan are the sedimentary parts of the gravity flow sediments that are washed out of the valley and spread rapidly. Under the action of gravity, the sediments spread out in a "waterfall" shape with the rapid release of energy and the sudden increase of accommodation space. Compared with the root fan, the sedimentary area on the plane is obviously enlarged. The sedimentary thickness of single stage sand body is thinner than that of fan root. The core and field outcrop show that sandstone is mainly deposited. The sandstones of various grain sizes are vertically orderly distributed with grain sequence bedding characteristics, and incomplete Bauma sequence can be seen. Micro casting thin section shows that sandstone has obvious sorting and roundness. The particles are in a point line basis relationship, with less impurity content, better development of primary pores and better connectivity. Good reservoir characteristics are the main reason for high natural productivity of reservoirs. The fan margin subfacies are the extreme end of the fan. It is the product of turbidite sedimentation of fine-grained sandstone with weakened capacity. The lithology is mainly fine sandstone and mudstone. On the plane, they are distributed in the outer edge of the fan. Because of the fine grain size of the sediment, the porosity and connectivity are poor. The core shows that oil bearing phenomenon is not obvious. Poor physical property and oil-bearing property of the reservoir are the main factors that have no obvious effect of increasing production after fracturing (Zhao & Zhu, 2001; Wang et al., 2015)(Fig. 6).

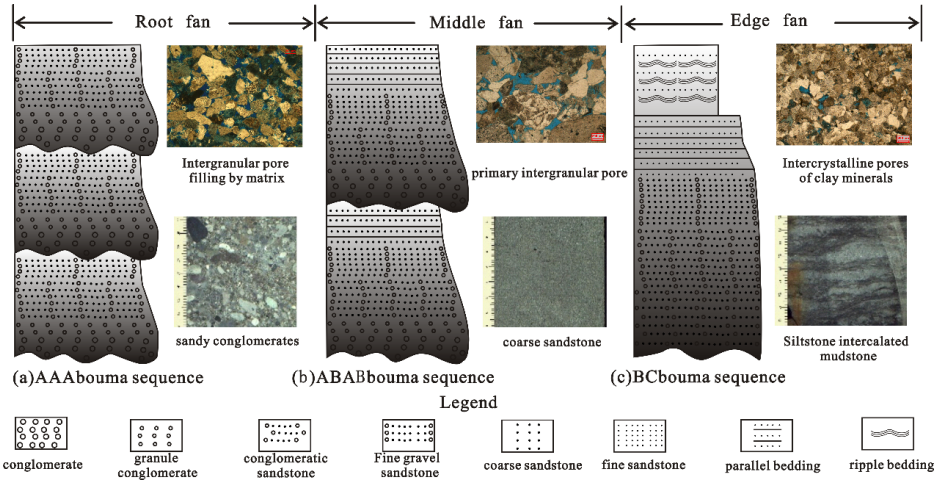

Figure 6. Lithology and microscopic characteristics of fan subfacies reservoir.

Rolling development design concept

Compared with marine reservoirs, continental reservoirs have strong heterogeneity. In the process of developing continental reservoirs, a complete set of reservoir evaluation theory of first excellent then poor and rolling outward expansion has been gradually formed. At present, experts at home and abroad have established a relatively complete evaluation system of reservoir quantitative characterization and reservoir classification evaluation. However, the reservoir evaluation methods based on the geological characteristics of reservoirs of different types are not perfect. Influenced by the current oil price, the concept of rolling development is becoming more and more important. The concept change from geological reservoir to economic reservoir is the main concept to realize economic and effective development. Based on the analysis of the sedimentary characteristics and reservoir characteristics of offshore underwater fan lithologic oil and gas reservoirs and focusing on the dynamic development effect of the reservoir, this paper establishes a complete rolling development concept for such reservoirs.

The economic boundary of the reservoir is gradually explored by means of fine geological research. Based on the principle of overall understanding and step-by-step implementation and best before poor and benefit first, the root fan of nearshore underwater fan type reservoir is the priority production area. The sandstone at the root of the fan is thick, and the conventional fracturing effect is obvious. It is the most favorable sweet spot under the current oil price. Although the oil reservoir of middle fan subfacies has the characteristics of natural productivity and wide distribution of sand bodies, the sandstone thickness is relatively thin as a whole, and the single well controlled reserves and single well production are small, which can be a favorable replacement area at the root of the fan. The characteristics of fan margin subfacies, such as poor reservoir property, unobvious oil bearing characteristics, thin thickness and wide plane distribution, restrict the development of such reservoirs to large-scale fracturing by horizontal wells. At present, the technology of this kind of production method is very mature, but under the control of oil price and operating cost, we are gradually looking for the economic boundary of the reservoir, which requires us to develop such reservoirs under the guidance of fine geological research and follow the principle of rolling development (Ding et al., 2013; Zhao & Li, 2022). In a word, the geological research is the foundation, the rolling exploration and development is the principle, and the economic benefit is the purpose of developing strongly heterogeneous reservoir reservoirs, especially the development of such reservoirs abroad. The integrated geological development process is an effective method to build an international first-class oil exploration and development company.

7. Results

The main idea of rolling evaluation is to search for new fan bodies in similar structural positions and layers based on geological analogy. According to this method, we have discovered a new fan body on the southwest side of Well A area, with a fan body size comparable to that of Well A area. The predicted fan body is relatively reliable. The predicted mountain body and the discovered fan body are located on the same fault control plane and have the same source of material. Vertically, through seismic profile analysis, two fan bodies are located on the same layer, so the two fan bodies should be products of sedimentation from the same event. At the same time, based on the seismic reflection characteristics of different parts of the fan body in Well A area, we accurately predicted the development positions of each subfacies of the fan body on the plane and profile, laying a solid geological foundation for rolling development. Based on the development experience of well A's fan body, a three-dimensional development plan for the new fan body has been developed. In predicting the root and middle parts of the fan body, a vertical well development model is adopted, and rolling drilling is carried out in the order of starting from the middle of the fan and then the root of the fan. At the same time, the oil wells at the root of the fan are developed using fracturing methods. Due to the thin and poor physical properties of the reservoir at the fan edge, large-scale horizontal well fracturing is used for mining.

8. Discussion

New fan body found

The discovery of the nearshore underwater fan of the new fan body is the product of event deposition, and finding similar geological features is the key to the discovery of the new fan body. We search for a new fan body based on the reasonable matching of the known development horizon of the fan body, the development scale of the fan controlling fault and the supply direction of the provenance.

Subfacies division

Sub-facies division Because the geological characteristics of each subfacies of the fan body are obviously different, different development methods should be adopted according to the existing development experience. Therefore, it is particularly important to accurately predict the plane position of each subfacies after the discovery of a new fan body. The current method is to accurately calibrate the position of each subfacies on the plane by applying the sedimentary facies model and seismic reflection characteristics after the discovery of the fan body. At the same time, the layer seismic attributes of the corresponding layers can be extracted for auxiliary division of subfacies.

8Selection of development mode

Due to the fact that fan deltas belong to rapid accumulation near the source, there is a significant difference in sedimentary characteristics and physical properties between different sedimentary subfacies. Based on the current development results, the sedimentary thickness of the reservoir at the end and middle of the fan is relatively large, and vertical wells can be used for development. However, at the end of the fan, the reservoir is not only thin in thickness but also has poor physical properties, so using a horizontal well development model is better.

9. Conclusion

1. Starting from the geological conditions, this paper discusses the characteristics of nearshore underwater fan lithologic reservoirs with near source advantages, which provides a rich material basis for rolling evaluation and searching for sweet spo reservoirs. Starting from the connotation of geological analogy method, the feasible means and methods for finding fans by rolling evaluation are established.
2. The dynamic development characteristics of such reservoirs are carefully dissected, and the organic combination of geological characteristics and development effects is realized. The concept of geological development integration is established, which is guided by the geological laws and selected the best development means. Multi-disciplinary, multi means and multi-scale three-dimensional reservoir precise development is realized.
3. By means of fine geological research and reservoir performance analysis method, the control effect of reservoir heterogeneity on oil production capacity of oil wells is analyzed in detail. A rolling development process based on geological characteristics has been established. It points out the direction for the economic and effective development of the oilfield.

Acknowledgements

This work was financially supported by Scientific research project of Daqing Oilfield Co., Ltd: Fine characterization of main sand body and remaining oil in complex fault block oilfield(No. 2020DQYK013)

References

Anselmetti, F., Ariztegui, D., Hodell, D., Hillesheim, M., Brenner, M., Gilli, A., McKenzie, J., & Mueller, A. (2006). Late Quaternary climate-induced lake level variations in Lake Petén Itzá, Guatemala, inferred from seismic stratigraphic analysis. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 230(1-2), 52-69. https://doi.org/10.1016/j.palaeo.2005.06.037

Catuneanu, O., Hancox, P., Cairncross, B., & Rubidge, B. (2002). Foredeep submarine fans and forebulge deltas: Orogenic off-loading in the underfilled Karoo Basin. *Journal of African Earth Sciences,* 35(4), 489-502. https://doi.org/10.1016/S0899-5362(02)00154-9

Chen, W., Qi, J., & Jiang, H. (2013). Characteristics of fault structure in Tanan Sag, Haita Basin in Dornod Aymag, Mongolia and its hydrocarbon significance. *Journal of Palaeogeography,* 15(4), 539-550.

Ding, S., Jiang, H., & Chen, M. (2013). Development Models of Overseas Deepwater Oilfields. *Petroleum Geology and Oilfield Development in Daqing,* 32(5), 41-47.

Egger, H., Homayoun, M., & Schnabel, W. (2002). Tectonic and climatic control of Paleogene sedimentation in the Rhenodanubian Flysch basin (Eastern Alps, Austria). *Sedimentary Geology,* 152(3-4), 247-262. https://doi.org/10.1016/S0037-0738(02)00072-6

Fu, X., Wang, Y., Qu, Y. & Shamel, W. (2011). The law of oil and gas distribution and mainly controlling factors of the passive rift basin: The Tanan depression of Tamuchage Basin. *Scientia Geologica Sinica*, 46(4), 1119-1131.

Fu, X., Deng, J., & Wang, G. (2013). Sedimentary-Tectonic Evolution During Early Triassic In Luoji Area, Zhongdian, Yunnan. *Mineralogical Journal,* S2, 1013-1014.

Galloway, W. E. (1998). Siliciclastic Slope and Base-of-Slope Depositional Systems: Component Facies, Stratigraphic Architecture, and Classification. *AAPG Bulletin*, 82(4), 569-595. https://doi.org/10.1306/1D9BC-5BB-172D-11D7-8645000102C1865D

Hongliu, Z. (2011). *Seismic Sedimentology.* Beijing: Petroleum Industry Press.

Houfu, Z., Hongliu, Z., & Wanxuan, Z. (1988). Regional seismic stratigraphic method for fault-depressed basins in land. Oil & Gas Geology, 9(3): 231-241. DOI: 10.11743/ogg19880304

Ja, H., Tian, J., & Liu, Z. (2021). Quaternary Seismic Facies and Sedimentary System in the Sanhu Area Qaidam Basin. *Acta Geologica Sichuan,* 38(3), 359-362.

Jia, D. H., Xu, C. G., & Yang, B. (2007). Paleogene palaeogeomorphology its control on sedimentary Liaodong Zone, reconstruction and evolution and systems in central-southern Liaodongwan Bay (in Chinese). *Journal of Palaeogeography,* 9(2), 155-166.

Jiang, Z. & Liu, H. (2010). Lacustrine palaeoshoreline and its controls on sandbodies and hydrocarbon. *Journal of Palaeogeography,* 12(5), 591-598.

Lv, Z. Y., Zhang, X. T., Bian, L. E., Wang, J., & Wang, T. (2018). Exploration discoveries of elusive reservoirs using detailed paleogeomorphology reconstructions. *Journal of Southwest Petroleum University (Science & Technology Edition),* 40(6), 12-22.

McLeod, A, E., Underhill, J. R., Davies, S. J., & Dawers, N. H. (2002). The influence of fault array evolution on synrift sedimentation patterns: Controls on deposition in the Strathspey-Brent-Statfjord half graben, northern North Sea. AAPG Bulletin, 86(6), 1061-1094.

Palyvos, N., Lemeille, F., Sorel, D., Pantosti, D., & Pavlopoulos, K. (2008). Geomorphic and biological indicators of paleoseismicity and Holocene uplift rate at a coastal normal fault footwall (western Corinth Gulf, Greece). *Geomorphology,* 96(1-2), 16-38. DOI: 10.1016/j.geomorph.2007.07.010

Richards, M., & Bowman, M. (1998). Submarine fans and related depositional systems II: variability in reservoir architecture and wireline log character. *Marine and Petroleum Geology,* 15(8), 821–839. DOI:10.1016/S0264-8172(98)00042-7.

Stanistreet, I., & McCarthy, T. (1993). The Okavango Fan and the classification of subaerial fan systems. *Sedimentary Geology,* 85(1-4), 115-133. https://doi.org/10.1016/0037-0738(93)90078-J

Sun, Y., Sui, L., Fu, X., Shen, J., Kang, L., & Sun, Q. (2011). Response of troughs structure and hydrocarbon source rock at middle fault depression belt in Hailer-Tamtsag Basin. *Chinese Journal of Geology,* 46(04), 919-28.

Wang, Z., Jiang, H., & Guan, L. (2015). Formation Mechanism of Favorable Reservoir of Complex Fault Block Reservoir in Hailaer Basin. *Lithologic Reservoirs,* 27(1), 26-31.

Wu, H., Song, S., Yang, S., & Song, W. (2018). Characteristics and Distribution Regularity of Near-shore Subaqueous Fans Gravity Flow Sandstone: A Case Study of the 3 Oilbearing Horizon of Wutonggou Formation in East Area of Lukeqin Oilfield. *Henan Science,* 36(10), 1600-1606.

Xiaomin, Z. (2001). *Principle and Application of Sequence Stratigraphy*. Beijing: Petroleum Industry Press.

Yaguang, L. (2018). Dissolution Characteristics And Its Influencing Factors Of Tongbomiao Formation Reservoir In Tanan Sag Of Tamutsag Basin. *Petroleum Geology and Oilfield Development in Daqing,* 37(3), 22-28.

Zhang, X. (2021). Sedimentary Characteristics and Sedimentary Model of Offshore Subaqueous Fan in Continental Faulted Lacustrine Basin: A Case Study of Tanan Sag in Haita Basin. *West-China Exploration Engineering,* 12, 61-64.

Zhao, C., & Zhu, X. (2001). *Sedimentary petrology*. Beijing: Petroleum Industry Press.

Zhao, J. & Li, Y. (2022). A Brief Analysis of Efficient Development of Overseas Oilfields. *Standards and Quality of Petroleum and Chemical Industry in China,* 15, 149-150.