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Characteristics and Controlling Factors of Tight Reservoirs in the Shanxi Formation Member 1 of the Lower Permian in the Southwestern Ordos Basin: A Case Study of the Qingtan 3–Long 37 Well Area in the Qingyang Gas Field

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Abstract: *To further clarify the reservoir characteristics and controlling factors of Member 1 of the Lower Permian Shanxi Formation in the Qingtan 3–Long 37 well area of the Qingyang Gas Field, located in the southwestern Ordos Basin, techniques such as grain size analysis, thin section identification, mercury intrusion porosimetry, and physical property testing were employed. The study qualitatively and quantitatively analyzes the petrological and physical properties, pore types, reservoir space types, and pore structure characteristics. It also investigates the primary factors affecting reservoir properties from the perspectives of sedimentation and diagenesis. The results show that: (1) Member 1 of the Shanxi Formation in the study area is characterized by meandering river–delta deposits. The reservoir lithology is dominated by lithic quartz sandstone and feldspathic lithic sandstone, with matrix materials primarily composed of clay and calcareous components. Pore cementation is the main cementation type. (2) The reservoirs are ultra-low porosity and ultra-low permeability, primarily consisting of intergranular primary pores, intergranular dissolution pores, and intragranular pores. The capillary pressure curve types are classified into four categories: Type I (low displacement pressure–coarse throat), Type II (relatively low displacement pressure–medium to coarse throat), Type III (high displacement pressure–fine throat), and Type IV (high displacement pressure–micro throat). (3) Reservoir development is mainly controlled by sedimentation and diagenesis. Reservoir quality positively correlates with grain size, and the most favorable depositional microfacies are found at the bottom of riverbeds. (4) Destructive diagenesis is the primary reason for porosity reduction, whereas constructive diagenesis significantly enhances porosity and permeability in sandstones.*

Keywords: *Ordos Basin, Qingyang Gas Field, Reservoir Characteristics*

1. Introduction

The Qingyang Gas Field is located in the southwestern part of the Ordos Basin, primarily within the Yishan Slope structural unit, and also spans across three major structural units[1]: the Tianhuan Depression, the Weibei Uplift, and the western thrust belt. The region is characterized by weak tectonic deformation, with most stratigraphic contacts being conformable. Structurally, the area exhibits a regionally westward-dipping monocline with a gentle slope, having an inclination of less than 1°[2-3].

The Qingtan 3–Long 37 well area belongs to the Qingtan 1 Block, which is situated in the northeastern part of the Qingyang Gas Field. Tectonically, it lies within the transitional zone between the central-eastern Yishan Slope and the Tianhuan Depression. The primary exploration targets in the Qingyang Gas Field include Member 1 of the Shanxi Formation and Member 8 of the Shihezi Formation in the Upper Paleozoic Permian system.

Previous studies have contributed to understanding the reservoir characteristics in this region. For instance, Duan Zhiqiang et al[4]. conducted a systematic investigation of Member 1 of the Shanxi Formation in the Qingyang Gas Field, integrating sand body distribution patterns, reservoir physical properties, diagenesis, and structural characteristics to establish a reservoir classification standard. Their work identified two Class I reservoir enrichment zones in the southern and central parts of the study area.

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Xia Hui et al[5]., addressing the unclear evolution mechanism of the depositional system in Member 1 of the Shanxi Formation, employed high-resolution sequence stratigraphy. By integrating 3D seismic reflection patterns, core facies sequences, and logging cycle analysis, they subdivided Member 1 into one third-order sequence (SQ1) and three fourth-order sequences (Sq1-1 to Sq1-3), and identified the transgressive–highstand systems tract boundary (T3 interface).

Wang Yongqiang et al[6]., tackling the challenges posed by significant heterogeneity and prediction difficulty of sweet spots in tight sandstone reservoirs of the Qingtan 1 Block, utilized detailed core descriptions, high-pressure mercury intrusion experiments, and 3D seismic inversion data to evaluate the reservoir properties of Member 1 of the Lower Shihezi Formation. By integrating depositional microfacies, diagenetic facies, and fracture development indices, they constructed a ternary classification model of "lithology–physical property–fracture" and divided the reservoirs into four types: I, II, III, and IV.

However, discussions specifically focusing on the characteristics of reservoirs in Member 1 of the Shanxi Formation in the Qingyang Gas Field remain relatively limited. Therefore, a detailed analysis of these characteristics and their controlling factors is both necessary and timely.

This paper is based on core thin section observations and grain size analysis, supplemented by porosity–permeability tests and mercury injection capillary pressure (MICP) data. It investigates the sedimentary characteristics and reservoir performance of the target strata, identifies key reservoir features and influencing factors in the Shanxi Formation sandstones, and provides a geological foundation for reservoir evaluation and classification. Furthermore, leveraging abundant gas testing data in the study area, this research defines the lower limit of effective reservoirs and predicts the spatial distribution of high-quality reservoirs, offering significant theoretical and practical value.

2. Regional Geological Structure and Sedimentary Characteristics

The Ordos Basin, China’s second-largest onshore oil and gas-bearing basin, hosts extensive tight sandstone gas reservoirs and shale gas resources in its southwestern Upper Paleozoic strata. The Qingyang Gas Field is situated in the transitional zone between the Yishan Slope and the Tianhuan Depression on the southwestern margin of the basin. It serves as a key replacement area for the continued growth in natural gas reserves and production in the Changqing Oilfield[7-10].

The Qingtan 1 Block lies in the Longdong region of the southwestern Ordos Basin, specifically within the transition zone between the Yishan Slope and the Tianhuan Depression[11]. Geographically, the block stretches from Huachi in the north to Ning County in the south, from Tali in the west to Qingyang in the east, covering a large exploration area[12]. The Ordos Basin itself is located on the western margin of the North China Craton and is a large, multi-cyclic cratonic basin characterized by structural stability and a vast spatial extent[13].

The Qingtan 3–Long 37 well area is located in the Longdong region of the Ordos Basin and represents a typical study area for investigating the characteristics and controlling factors of tight reservoirs. Structurally, this area belongs to the northern subsiding part of the Zhenyuan Uplift. The region features complex Changchengian structures, with well-developed horst and graben belts, and significant displacements along bounding normal faults[14].

The sedimentary characteristics in the region are largely controlled by its structural framework. From bottom to top, the Upper Paleozoic stratigraphy comprises six formations: the Benxi, Taiyuan, Shanxi, Shihezi, and Shiqianfeng formations. Among these, the Shanxi Formation and the lower part of the Shihezi Formation serve as the primary gas-bearing reservoirs.

During the deposition of the Shanxi Formation, the water body gradually deepened, reflecting a transgressive process accompanied by river system retreat. In the study area, the northern delta system experienced regression, while the southern delta advanced northward, shifting the subsidence center in the same direction.

The target interval, Member 1 of the Shanxi Formation, was deposited in a relatively humid environment, resulting in widespread wetland sedimentation across the region. This member is primarily composed of sedimentary assemblages from meandering river delta plains, delta fronts, and littoral-shallow lake subfacies. These depositional conditions collectively provided a favorable environment for the formation of natural gas reservoirs.

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3. Analysis of Tight Reservoir Characteristics

3.1 Petrological Characteristics

Based on thin section identification, image-based grain size analysis, and laser particle size analysis, the sandstones of the Shanxi Formation in the study area are primarily composed of lithic quartz sandstone and feldspathic lithic sandstone. The detrital components are dominated by quartz, followed by lithic fragments, with feldspar being rare. Quartz content in the detrital fraction ranges from 75% to 95.3%, with an average of 87.8%; lithic content ranges from 4.0% to 23.5%, averaging 11.3%; feldspar is nearly absent. These compositional characteristics plot mainly within the lithic quartz sandstone to feldspathic lithic sandstone fields in the Q－F－R ternary diagram, as shown in Figure 1.

The cementing materials within the Shanxi Formation sandstones are mainly composed of quartz, kaolinite, reticulate clay minerals, and illite. The grain size of sandstone detrital particles varies significantly, and is generally coarse. Medium to coarse grains dominate, followed by very coarse grains, with a small amount of fine grains. Some samples contain gravel-sized particles.

Grain sorting is generally moderate to good; roundness is poor, with most grains being sub-angular. The detrital grains are predominantly supported by point contact. The cementation type is mainly pore-filling cementation.

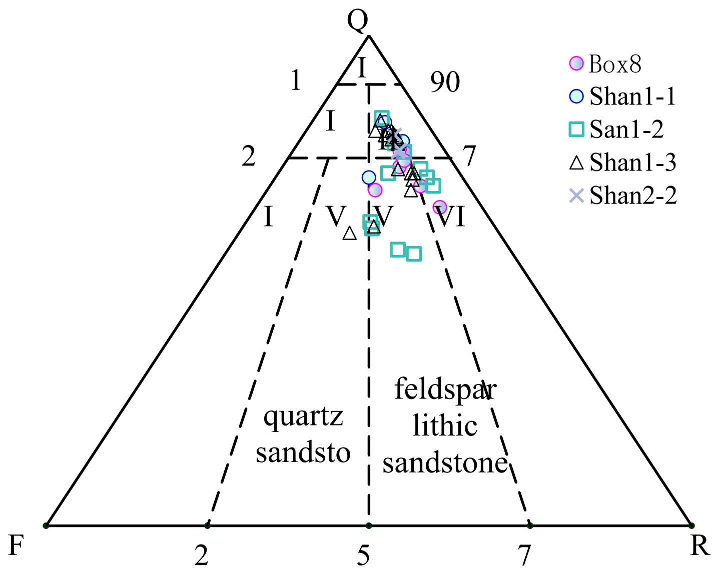

Figure 1 Lithological Classification Ternary Diagram of the Shanxi and Shihezi Formations in the Study Area(I. Quartz sandstone, II. Feldspathic quartz sandstone, III. Lithic quartz sandstone, IV. Feldspathic sandstone, V. Lithic feldspathic sandstone, VI. Feldspathic lithic sandstone, VII. Lithic sandstone)

3.2 Physical Properties

To determine the physical properties of the sandstones in the study area, 39 core plugs were obtained from 11 cored wells for porosity and horizontal permeability testing. The results show that porosity ranges from 0.38% to 10.10%, with the majority falling between 2.88% and 5.84%, and an average porosity of 4.05%. Permeability ranges from 0.013 to 3.795 millidarcies (mD), with most values distributed between 0.073 and 1.000 mD, and an average permeability of 0.352 mD (see Fig*ure* 2).

The analysis indicates that the reservoir types in the study area are primarily pore-type, tight pore-type, and fracture–pore-type composite reservoirs. Member 11 and Member 12 of the Shanxi Formation both exhibit low porosity and low permeability, with average porosity less than 4% and permeability below 0.3 mD. Furthermore, there is a weak correlation between porosity and permeability, suggesting that these intervals are dominated by tight pore-type reservoirs, constrained by cementation or microporous structures, and require hydraulic fracturing to enhance productivity.

In contrast, Member 13 shows a significantly higher average permeability of 0.583 mD compared to its porosity average of 4.03%, and a wider permeability range reaching up to 3.795 mD. This suggests the possible development of fracture–pore-type composite reservoirs in this interval, where local fractures significantly enhance permeability.

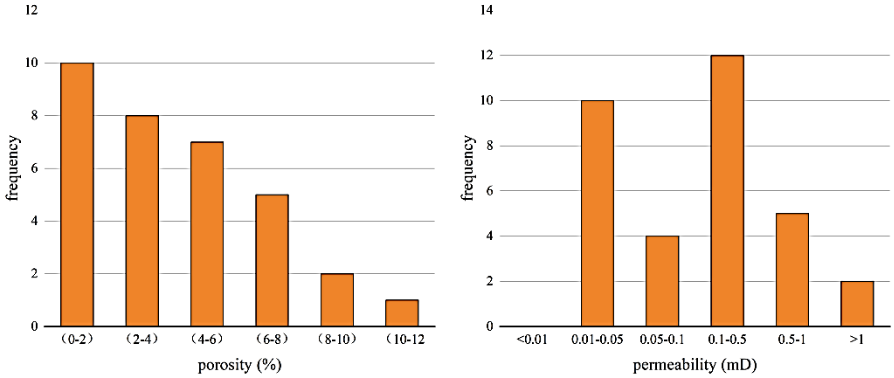

Figure 2 Porosity and Permeability Distribution Characteristics of Sandstone in Member Shan-1

3.3 Reservoir Space Types

3.1.1 Pore Types

Based on the analysis of rock thin sections and casting thin sections from the study area, three main pore types are identified in the conglomeratic coarse sandstones and medium–coarse sandstones: primary intergranular pores, intergranular dissolution pores, and intragranular pores. Among these, intergranular dissolution pores are the most dominant. The development of reservoir porosity in the study area is jointly controlled by lithologic grain size and diagenesis, showing significant heterogeneity.

Coarse-grained sandstones are mainly characterized by secondary dissolution pores, including intergranular dissolution pores, intragranular dissolution pores, and a small number of oversized dissolution pores. Detrital grains are sub-rounded, and the conglomeratic coarse sandstones exhibit coarse-grained textures with poorly sorted grains; calcareous cement residues and dissolution phenomena are visible , and partial dissolution occurs in the matrix.

Fine to silty sandstones show medium to coarse-grained sandy textures, mainly composed of terrigenous detrital particles and interstitial material. Quartz is the dominant component, with minor amounts of feldspar, mica, and lithic fragments. Grain roundness ranges from sub-angular to sub-rounded. The interstitial material is mainly clay and calcareous components, with significant cementation that leads to underdeveloped pore systems and results in an overall dense rock fabric.

Argillaceous siltstones exhibit a mixed sandy–muddy structure, where silty and clay materials are interwoven in a flaky pattern, containing grains of varying sizes and sub-angular terrigenous detrital particles. The rocks are overall dense and contain banded organic matter.

3.1.2 Pore Structure Characteristics

Based on the distribution characteristics of pore structures in sandstone reservoirs within the study area, a total of 20 representative samples were selected for mercury intrusion porosimetry. According to the mercury injection data, combined with curve morphology and parameter features, the sandstone reservoirs in the study area can be divided into four types of capillary pressure curve patterns.

Type I (low displacement pressure – coarse throat): The capillary pressure curve presents a reverse parabolic shape, with the lowest displacement pressure, generally less than 0.6 MPa. The maximum mercury saturation exceeds 80%, indicating relatively large maximum connected pore-throat radii. Pore-throat radii are mostly greater than 0.75 μm, with a unimodal histogram and excellent sorting. Reservoir properties are characterized by porosity of 5–10%, permeability of (0.21–9.3)×10^{-3} μm², average pore-throat radius of 0.25–15.1 μm, and mercury withdrawal efficiency over 35%. This type of reservoir exhibits the best physical properties, featuring large pore spaces and good connectivity, mainly distributed within fluvial channel sand bodies of the Shanxi Formation and considered the most favorable reservoir type.

Type II (relatively low displacement pressure – medium to coarse throat): The capillary pressure

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curve shows a displacement pressure between 0.8–1.5 MPa, significantly higher than Type I but still within a relatively low range, indicating that although the maximum connected pore-throat radius is somewhat reduced, a certain flow capacity is retained. Maximum mercury saturation ranges from 65% to 85%, reflecting a moderate proportion of effective pore-throat systems. Pore-throat radii are mainly concentrated between 0.07–0.5 μm, with unimodal or bimodal histograms, medium overall sorting, and increased heterogeneity compared to Type I. Reservoir physical properties include porosity of 3%–6%, permeability of (0.06–0.96)×10^{-3} μm², and average pore-throat radius of 0.03–0.55 μm, indicating a reduction in pore volume and decreased flow capacity compared to Type I. This type of reservoir typically develops along channel margins or in depositional environments with limited local sediment supply, representing medium-quality reservoirs.

Type III (high displacement pressure – fine throat): The capillary pressure curve exhibits clear fine-throat characteristics, with displacement pressure generally greater than 6.0 MPa—an order of magnitude higher than Type I (<0.6 MPa) and Type II (0.8–1.5 MPa), indicating extremely reduced maximum connected pore-throat radii, with an average less than 0.05 μm. Maximum mercury saturation is the lowest at less than 30%, far below Type I (>80%) and Type II (65–85%), indicating a severely underdeveloped effective pore-throat network. The pore-throat radii are highly concentrated within the ultra-fine throat range (<0.05 μm), and the histogram presents a flat and broad unimodal pattern with very poor sorting. Pore heterogeneity reaches the highest level within the study area. Reservoir properties are characterized by porosity less than 3% and permeability less than 0.03×10^{-3} μm²—1 to 2 orders of magnitude lower than Type II. The average pore-throat radius is less than 0.05 μm, indicating that capillary forces dominate within the pore system. This type of reservoir mainly develops in fine-grained overbank deposits or strongly diagenetically altered zones of the Shanxi Formation and represents the poorest quality reservoir.

Type IV (high displacement pressure – micro-pore and micro-throat): This type exhibits extreme microporous and micro-throat characteristics, with the highest displacement pressures in the study area ranging from 0.26 to 14 MPa, significantly higher than Type III (>6.0 MPa), indicating that the maximum connected pore-throat radius is reduced to the nanometer scale, with an average of only 0.80 μm and a minimum of 0.05 μm. Maximum mercury saturation is the lowest among all rock samples, typically below 25%, much lower than Type III (<30%), indicating a severely deficient effective pore-throat network dominated by isolated micro-pores and semi-enclosed pores. The pore-throat radii are highly concentrated in the micro-throat range (<0.1 μm), with a sharp unimodal histogram and extremely poor sorting. Pore heterogeneity reaches its maximum level in the study area. Reservoir properties show porosity less than 4% and permeability less than 0.1×10^{-3} μm². Although porosity is slightly higher than in Type III (<3%), the extremely small pore-throat radius (mostly <0.1 μm) results in poor connectivity, low pore-throat coordination numbers (<1.5), and further degraded flow capacity, with capillary forces completely dominating. This type of reservoir mainly develops in zones of intense compaction and cementation or in distal overbank deposits with extremely high clay content in the Shanxi Formation, representing the worst reservoir quality and lowest development potential in the study area.

4. Factors Controlling Reservoir Physical Properties

4.1 Sedimentary Processes

Member 1 of the Shanxi Formation in the Qingtan 3–Long 37 well area is part of a meandering river–delta depositional system, with subfacies dominated by meandering river delta front to littoral-shallow lake environments. Depositional elements include river channels, crevasse splays, natural levees, floodplain lakes, and overbank plains. Among these, the riverbed base within the channel represents the most favorable depositional microfacies, characterized by the development of gravel-bearing medium–coarse sandstones, which exhibit an average porosity of 4.94% and average permeability of 0.333 mD. Natural levees, floodplains, and crevasse splays are mainly composed of fine to silty sandstones. Silty mudstones, typical products of floodplain lake sedimentation, were deposited in stagnant or low-energy water environments and are widely distributed in overbank plains or inter-distributary bays, with relatively poor physical properties. Statistical analysis shows a significant positive correlation between reservoir physical properties and grain size. Gravel-bearing medium–coarse sandstones and fine–silty sandstones exhibit relatively good physical properties, whereas silty mudstones display the poorest.

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4.2 Diagenesis

Diagenesis in clastic rocks refers to the physical, chemical, and biological changes that occur after sedimentation and before metamorphism, which affect reservoir characteristics such as pore types, pore structures, and fluid flow capacity[15]. Diagenesis can be divided into two types: destructive diagenesis and constructive diagenesis.

4.2.1 Destructive Diagenesis

Compaction occurs during burial, as the continued deposition of overlying strata and lateral stress compress sediment grains, causing grain breakage, displacement, and deformation, which leads to pore water expulsion and a reduction in pore space. In the Qingtan 3–Long 37 well area, the Shanxi Formation Member 1 reservoir is generally buried at depths of 2800–3500 m. Thin section observation under the microscope reveals that particle contacts in the Member 1 sandstones are of the linear and sutured-linear types. Cementation is another major factor contributing to the reduction in reservoir porosity. The composition of cement in the Shanxi Formation Member 1 sandstones of this area is complex, mainly characterized by pore-filling cementation. The major cementing minerals are calcite, illite, kaolinite, and chlorite-type clay minerals. The cement content exerts direct control over reservoir properties; when the cement content exceeds 5.0%, both porosity and permeability are significantly reduced[16].

4.2.2 Constructive Diagenesis

Constructive diagenesis plays a key role in improving the porosity and permeability of sandstone reservoirs. In the Qingtan 3–Long 37 well area, the main constructive processes include dissolution and fracturing. Dissolution is a chemical process that enhances porosity and permeability by dissolving mineral grains. Fracturing, on the other hand, improves these properties through mechanical breakage, with especially strong effects on permeability. Cast thin section analysis shows that the dominant pore types in Member 1 sandstones of the Shanxi Formation are primary intergranular pores, intergranular dissolution pores, and intragranular pores. According to measured surface porosity statistics, the average surface porosity of intergranular and intragranular dissolution pores reaches 9.7%, indicating well-developed dissolution. Under the influence of orogenic activity at the basin margin, intense compression leads to the formation of fractures, which also represent a form of constructive diagenesis. Although fractures do not increase pore volume, they significantly enhance permeability.

5. Conclusions

Member 1 of the Shanxi Formation in the Qingtan 3–Long 37 well area was deposited in a meandering river–delta environment. The reservoir lithologies are primarily lithic quartz sandstone and feldspathic lithic sandstone. The detrital components are dominated by quartz and lithic fragments, with feldspar being nearly absent. The interstitial material mainly consists of clay and calcareous components, and the cementation is primarily of the pore-filling type. The sandstone detrital grains exhibit relatively good sorting, sub-angular roundness, and moderate textural maturity.

The reservoirs in the study area are characterized by ultra-low porosity and ultra-low permeability, dominated by intergranular pores, intergranular dissolution pores, and intragranular pores. When intergranular and secondary dissolution pores co-develop, reservoir connectivity is relatively good. Based on pore structure, the sandstone reservoirs can be classified into four types according to capillary pressure curve characteristics: Type I (low displacement pressure – coarse throat), Type II (relatively low displacement pressure – medium to coarse throat), Type III (high displacement pressure – fine throat), and Type IV (high displacement pressure – micro-pore and micro-throat).

The development of reservoirs in the study area is mainly controlled by sedimentation and diagenesis. The depositional microfacies of Member 1 of the Shanxi Formation include channel, crevasse splay, natural levee, floodplain lake, and overbank plain. The main lithologies include gravel-bearing medium–coarse sandstone, fine–silty sandstone, and silty mudstone. There is a positive correlation between grain size and reservoir physical properties. Destructive diagenesis is the main factor leading to porosity reduction. Compaction reduces the original intergranular porosity, and when the cement content exceeds 5.0%, both porosity and permeability are significantly reduced. Constructive diagenesis can significantly enhance porosity and permeability. Dissolution increases porosity, and the presence of fractures further improves reservoir permeability.

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References

[1] Wang Yongqiang, Wang Yue, Li Chuanhao, Zhang Haoran, Sun Liyong, Liu Pengfei. Sedimentary Characteristics and Sandbody Distribution of Qingyang Gas Field [J]. Petrochemical Industry Technology, 2023, 30(10):144-145, 226.

[2] Liu Pengfei, Gao Wei, Sun Liyong, Zhang Xinyuan. Analysis of Production Construction Area in Block X of Qingyang Gas Field [J]. Petrochemical Industry Application, 2024, 43(2):74-75, 117.

[3] Wang Yongqiang, Li Chuanhao, Ji Yecheng, et al. Structure and Stratigraphic Characteristics of Qingyang Gas Field[J]. China Petroleum and Chemical Standards and Quality,2022, 42(22): 100-101+104.

[4] Duan Zhiqiang, Xia Hui, Wang Long, et al. Reservoir Characteristics and Controlling Factors of Shan 1 Member in Qingyang Gas Field, Ordos Basin[J]. Petroleum Geology,2022, 43(03): 285-293.

[5] Xia Hui, Wang Long, Zhang Daofeng, et al. Sequence architecture, sedimentary evolution and controlling factors of the Permian Shanxi Formation Member 1 in the Qingyang Gas Field, Ordos Basin[J]. Oil & Gas Geology,2022,43(06):1397-1412+1488.

[6] Wang Yongqiang, Liu Yamin, Lu Zhen, et al. Reservoir Evaluation and Prediction of Block Qingtan 1 in Qingyang Gas Field[J]. Petrochemical Industry Technology,2022,29(09):147-149.

[7] Jiang Fujie, Jia Chengzao, Pang Xiongqi, Jiang Lin, Zhang Chunlin, Ma Xingzhi, Qi Zhenguo, Chen Junqing, Pang Hong, Hu Tao, Chen Dongxia. Accumulation characteristics and geological model of natural gas enrichment in the Upper Paleozoic total petroleum system of the Ordos Basin[J]. Petroleum Exploration and Development,2023,50(2):250-261

[8] Yang Hua, Liu Xinshe, Yan Xiaoxiong. Tectonic-sedimentary evolution and tight sandstone gas accumulation in the Ordos Basin since the Late Paleozoic[J]. Earth Science Frontiers,2015,22(3): 174-183

[9] Li Jinbu, Wang Jiping, Wang Long, et al. Paleogeomorphology restoration and its controlling effect on delta-front sedimentary sand bodies: A case study of the 1-3 sub-members of the Permian Shanxi Formation in the Qingyang Gas Field, Ordos Basin[J]. Oil & Gas Geology,2021,42(05): 1136-1145+1158.

[10] Jinhua Fu, Xinshan Wei, Shunshe Luo, Zhifeng Zuo, Hu Zhou, Baoxian Liu, Qing fenKong, Sha Zhan, Junxiang Nan. Discovery and geological understanding of the Qingyang deep coal-derived gas field[J]. Petroleum Exploration and Development,2019,46(6):1047-1061

[11] Sheng Chen, Xinyu Li, Bo Yang, Xuan Li, Yaojun Wang, Yadi Yang, Wenhui Du, Yonggen Li, Xiujiao Wang, Lianqun Zhang,Detailed analysis of seismic reflection characteristics of tight sandstone reservoirs in the upper paleozoic of the ordos basin: A casestudy of block X[J], Unconventional Resources,Volume 4,2024,100085, ISSN 2666-5190,

[12] Citation: Xiao, L.; Yang, L.; Zhang, X.;Guan, X.; Wei, Q. Densification Mechanisms and Pore Evolution Analysis of a Tight Reservoir: A Case Studyof Shan-1 Member ofUpper Paleozoic Shanxi Formation in SWOrdos Basin, China[J]. Minerals 2023,13,960. https://doi.org/10.3390/min13070960

[13] Wang, H.; Zhang, J.; Yong, Z.; Qu, X. The Differential Enrichment Law of Tight Sandstone Gas in the Eighth Member of Shihezi Formation in the North and South of Ordos Basin[J]. Energies 2024,17, 5978.

[14] He Dengfa, Bao Hongping, Sun Fangyuan, Zhang Caili, Kai Baize, Xu Yanhua, Cheng Xiang, Zhai Yonghe. Geological Structure and Genetic Mechanism of the Central Paleo-Uplift in the Ordos Basin[J]. Chinese Journal of Geology.,2020,55(3):627-656

[15] Li Xiwei, Jiang Shu, Shi Yuanpeng, et al. Characteristics and Controlling Factors of Deep Clastic Rock Reservoirs: A Case Study of Yangwuzhai Area in Raoyang Sag [J/OL]. Earth Science, 1-22[2025-05-25].

[16] Qiu Longwei, Mu Xiangji, Li Hao, et al. Influence of diagenesis on pore developmentin tight sandstone reservoirs of the Lower Shihezi Formation in the Hangjinqi area [J]. Petroleum Geology and Recovery Efficiency,2019,26(2): 42-50