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Types and Characteristics of Sedimentary Facies of the Chang 7 Oil Reservoir Group in Heshui Area of the Ordos Basin

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Abstract

The Heshui area is located in the Longdong block in the southern part of the Ordos Basin. It is an important exploration and development zone for the Chang 7 oil reservoir group, which is dominated by low-permeability and tight oil reservoirs and has huge resource potential. The Chang 7 oil reservoir group belongs to the Triassic Yanchang Formation (T3y) and is one of the main source rocks and reservoirs in the Ordos Basin. Based on the identification marks of sedimentary facies, as well as the analysis of core samples, comprehensive mud logging data in the study area and previous research results on regional sedimentary facies, this study shows that the Chang 7 oil reservoir group in the Heshui area is mainly composed of channel-type gravity flow deposits, with the development of subfacies types such as near-source channels, far-source channels, bank deposits, front lobes, and semi-deep lake-deep lake.

Keywords

Heshui Area; Chang 7 Oil Reservoir Group; Sedimentary Facies; Gravity Flow Deposits.

1. Regional Geological Overview

The Ordos Basin refers to the vast desert steppe and Loess Plateau area that lies south of the Yinshan-Daqingshan Mountains, north of the Qinling Mountains, east of the Helan-Liupanshan Mountains, and west of the Lüliang-Zhongtiaoshan Mountains. Spanning five provincial-level administrative regions—Shaanxi Province, Gansu Province, Shanxi Province, Ningxia Hui Autonomous Region, and Inner Mongolia Autonomous Region—the basin covers a total area of 37×10^4km^2. Excluding the peripheral fault-depression basins such as the Hetao, Weihe, Yinchuan, and Liupanshan basins, the central part of the Ordos Basin has an area of approximately 25×10^4 km^2. [1-2]

With sedimentary rock thickness ranging from 5,000 to 10,000 meters, the Ordos Basin is a large-scale multi-cyclic sedimentary basin characterized by overall subsidence, migrated depressions, and simple geological structures. It is also the second-largest Mesozoic-Cenozoic sedimentary basin in China. Its crystalline basement consists of Archean and Proterozoic metamorphic and crystalline rock series, overlaid by Paleozoic, Mesozoic, and Cenozoic caprock deposits. Within the basin, multiple sets of petroleum systems developed during the Early

Paleozoic, Late Paleozoic, and Mesozoic eras, making it a large sedimentary basin with abundant oil and gas prospects.

Surrounded by mountains on all sides, the basin has a complex internal terrain. Bounded by the Great Wall, the northern part is the Ordos Plateau, where deserts and steppes are distributed alternately; the southern part is the Loess Plateau, crisscrossed by gullies and valleys, with an arid climate.

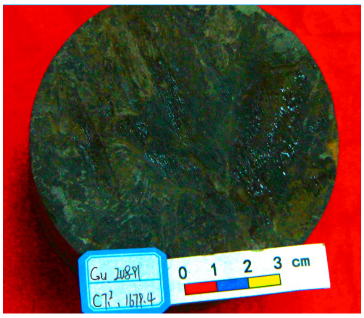
Among its sub-areas, the Heshui Area is located in the Longdong Block in the southern part of the Ordos Basin. As a key exploration and development zone for the Chang-7 oil-bearing formation, it is dominated by low-permeability to tight oil reservoirs and boasts significant resource potential. Belonging to the Triassic Yanchang Formation (T_3y), the Chang-7 oil-bearing formation is one of the major source rocks and reservoir rocks in the Ordos Basin. Formed during the peak development stage of the lake basin, the Heshui Area of the Chang-7 oil-bearing formation is dominated by deep lake to semi-deep lake facies, with local development of gravity flow deposits (turbidite fans and slump bodies).

2. Sedimentary Facies Markers

Sedimentary facies markers are the direct evidence for the correct division of sedimentary facies. Sedimentary facies represent the material manifestation of sedimentary environments and, in fact, reflect the hydrodynamic condition characteristics of different sedimentary environments. Traces of various hydrodynamic conditions are recorded in aspects such as the composition, lithology, texture, sedimentary structures, profile structures, paleontology, and sedimentary geochemistry of sedimentary rocks. Therefore, these characteristics constitute the markers for facies analysis in sedimentology. The main markers for identifying the types and characteristics of sedimentary facies in the Chang-7 oil-bearing formation of the Heshui area include: color and lithology markers, texture markers, sedimentary structure markers, paleontological markers, logging markers, etc.

2.1. Color and Lithology Markers

Zhuang 90, 1615.28m, Chang 7_1^2, Grayish-black fine sandstone



Gu 208-91, Chang 7_1^2, 1679.4m, Carbonaceous-bearing black mudstone

Fig 1. Common Rock Types of the Chang 7 Member in the Heshui Area

The color of rocks is the most striking sedimentary marker of sedimentary rocks. It is one of the important bases for identifying rocks, dividing and correlating strata, and analyzing and judging paleogeographic conditions. In particular, the primary color of sedimentary rocks is a direct marker for identifying the quality of source rocks and the oxidation-reduction conditions of the aqueous medium during the deposition of the rock layer. Rocks formed in shallow water or oxidizing environments are light-colored and oxidized, mainly including light gray, grayish yellow, gray, and purple-red. Those formed in deep water or reducing environments are dark-colored, mainly gray, dark gray, grayish green, grayish black, or black. Sand bodies distributed in rivers and deltas are dominated by light gray, grayish yellow, and gray. Mudstones and argillaceous siltstones in interdistributary bays and shallow lakes are grayish black to black. However, when using color to analyze sedimentary environments, attention should be paid to distinguishing authigenic colors from secondary colors. [3-4]

Based on the observation of drilling cores, the Chang-7 oil-bearing formation in the study area is mainly composed of grayish black fine-grained sandstone, black silty mudstone, and mudstone, indicating a deep-water reducing environment (Fig.1).

2.2. Structural Indicators

Thin-section identification and grain size analysis of reservoirs in the Chang 7 oil-bearing interval of the Heshui Area show that sandstone grains in the study area have moderate to good sorting. They are mostly subangular to subrounded with good roundness. The cementation type is porous cementation, dominated by grain support and line contact. Grains in the Chang 7 interval are mainly fine sandstone, followed by siltstone, with an overall relatively fine grain size. [5]

Based on the C-M diagram of the Chang 7 reservoir in the Longdong Area compiled by the Changqing Oilfield Research Institute, the point groups of the collected samples are obviously distributed parallel to the C-M baseline, indicating a dominance of suspended load. The point groups of samples from the Zhuang 230 Block are dominated by graded suspension, reflecting gravity flow deposition (Fig.2).

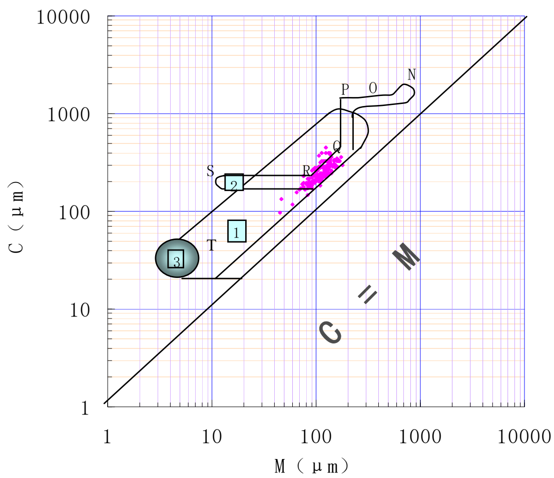


Fig 2. C-M Diagram of the Chang 7 Reservoir in the Longdong Area (Changqing Oilfield Research Institute)

2.3. Sedimentary Structure Indicators

Sedimentary structures are one of the important characteristics of sedimentary rocks. They refer to various structures formed inside or on the surface of sediments due to physical, chemical and biological processes during or after sedimentation, including primary sedimentary structures and secondary sedimentary structures. Among them, primary sedimentary structures can provide information about the nature and energy conditions of the depositional medium during sedimentation. The development of sedimentary structures is directly related to sedimentation rate, water flow mode and medium conditions. Therefore, primary sedimentary structures and their assemblages or sequences have become the most important indicators for judging sedimentary environments and dividing sedimentary facies, subfacies and microfacies (Fig.3).

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Zhuang230, Chang7_1^2 ,1695.85m, Parallel bedding

Gu Ping41-65, Chang7_1^3, 2374.58m, mud gravel

Zhuang230, Chang7_2^2, 1732.25m, Bouma Sequence ACD intervals

Fig 3. Core Photos of Sedimentary Structures in the Chang 7 Oil-Bearing Interval of the Heshui Area

2.4. Paleontological and Authigenic Mineral Indicators

Organisms cannot survive without the environment and are strictly restricted by various environmental factors. Organisms preserved in strata are called paleontological fossils, which can be roughly divided into two categories: body fossils and trace fossils. Core observations show that paleontological indicators in the study area mainly include plant fossil fragments and fish fossils. The plant fossil fragments are small in size, indicating complete reworking by lake waves and a relatively deep water environment. The occurrence of a large amount of pyrite and fish fossils indicates that the water body was relatively deep (Fig.4).

Zhuang50, Chang7_3, 1944.07m, Fish bone fossils

Zhuang233, Chang 7_3, 1815.1m, pyrite-bearing deformation structures

Zhuang 233, Chang7_3, 1825.1m, plant fossil fragment-bearing

Fig 4. Animal and Plant Fossils as well as Authigenic Minerals in the Chang 7 Member of the Heshui Area

2.5. Logging Facies Indicators

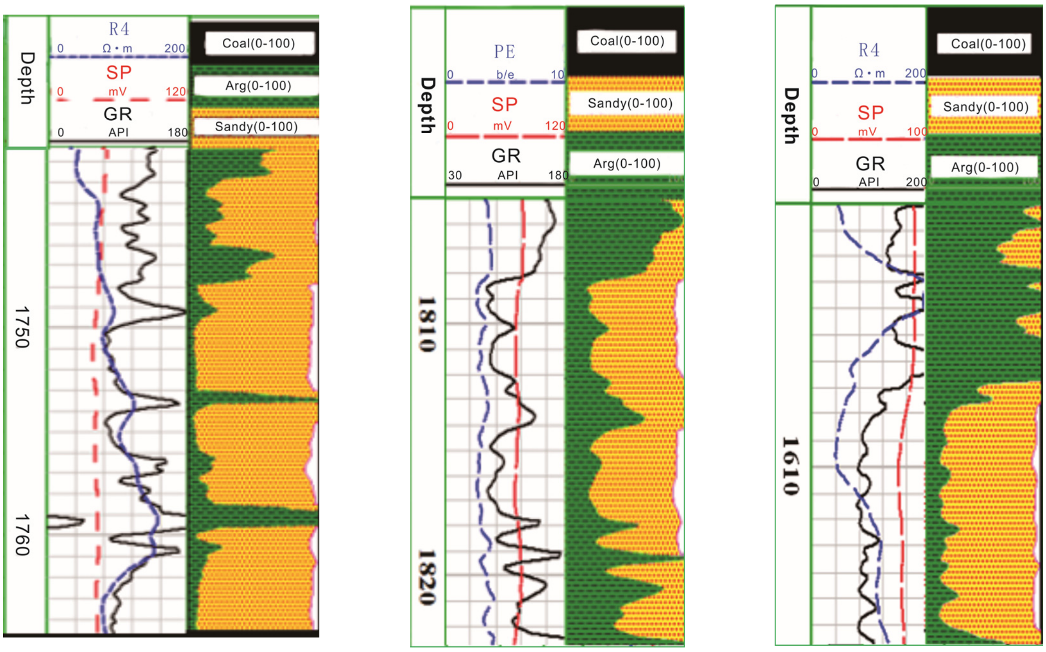
The shape of logging curves can qualitatively reflect changes in formation lithology, grain size and shale content, thereby reflecting changes in the vertical combination sequence of strata and sedimentary environments. Logging facies analysis is an indispensable method, especially for wells with little coring, low coring rate or no coring, where sedimentary facies analysis mainly relies on logging facies analysis. The results of litho-electrical conversion model analysis of logging facies from numerous wells have confirmed that natural gamma (GR) can well reflect the sedimentary sequence and evolutionary characteristics of shale content and clastic grain size changes. Combined with the comprehensive analysis of resistivity, spontaneous potential (SP) and density, it is verified that the logging facies litho-electrical conversion model dominated by natural gamma curves and supplemented by apparent resistivity and spontaneous potential has a high coincidence rate in interpreting lithology and sedimentary facies of logging curves in non-cored intervals, which can fully meet the needs of production and scientific research. Common logging facies types represented by natural gamma curves are as follows (Fig.5): [6-7]

(1) Bell-shaped Curve

The curve shows negative or low values, with medium to high amplitude in the lower part, low amplitude in the upper part, and a large width. Its values increase from bottom to top. It represents medium-low hydrodynamic energy conditions, with unevenly distributed sediments that are coarse at the bottom and fine at the top, reflecting a transition from sandstone to mudstone as shale content in the sandstone increases upward. This curve indicates a gradual decrease in water flow energy or a reduction in material supply from bottom to top, often representing lateral migration of channels. When multiple erosion surfaces, superimposed channel sand bodies, and thin argillaceous interlayers are combined, the rhythmic changes in grain size and shale content of each superimposed sand body can lead to multiple superpositions of bell-shaped curves, forming a macro Christmas tree shape.

(2) Box-shaped Curve

The box-shaped curve indicates strong hydrodynamic energy, uniform sediment distribution, relatively coarse grain size, sufficient provenance supply, and high sedimentation rate. The bottom and top show abrupt contacts or slight normal rhythmic changes, transitioning to a serrated box-shaped curve. It reflects the sedimentary characteristics of distributary channels and sandy debris flows with multi-rhythmic superposition, composed of sandstones and siltstones of different particle sizes. The internal structure is uneven, and multiple mudstone or siltstone interlayers may develop.



Box-shaped (Ban4, Chang7) Funnel-shaped & Bell shaped (Ban39, Chang7) Finger-shaped (Zhuang90, Chang7)

Fig 5. Log Facies Characteristics of the Chang 7 Member in the Heshui Area

(3) Superimposed Funnel-shaped Curve

The curve shows negative or low values that gradually decrease from bottom to top. The amplitude is relatively low in the lower part and medium to high in the upper part, with a large width. It represents a medium-low energy sedimentary environment, with sediments that are coarse at the top and fine at the bottom, and gradually enhanced provenance supply. Most superimposed funnel-shaped curves, with amplitudes decreasing downward (gradual bottom contact and abrupt top contact), correspond to lithological associations of interbedded thin-

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bedded sandstone, siltstone, and mudstone that coarsen upward, with sandstone mainly developed in the upper part. [8]

(4) Flat Curve

A flat to relatively flat curve with high gamma values reflects the deposition of a continuous thick mudstone interval. When the content of carbonaceous debris and organic matter is high, its apparent resistivity is significantly higher than that of ordinary mudstone.

(5) Serrated Curve

The curve shows relatively negative or low values, with medium-low amplitude and small width, belonging to a medium-low energy sedimentary environment with fine-grained sediments.

3. Conclusion

Based on the aforementioned identification indicators of sedimentary facies, as well as the analysis of core data, comprehensive logging data in the study area and previous research results on regional sedimentary facies, the Chang 7 oil-bearing interval in the Heshui Area is dominated by channel-type gravity flow deposition. It develops subfacies types such as proximal channel, distal channel, levee deposit, front lobe, and semi-deep lake—deep lake (Table 1).

Table 1. Sedimentary Facies Classification for the Chang 7 Oil-Bearing Interval in the Heshui Area

Sedimentary Facies	Subfacies-Microfacies	Sedimentary Units	Producing Horizon
Channel-type Gravity Flow Deposition - Lake	Proximal Channel	Sandy Debris Flow Deposition & Slump Deposition	Chang 7
	Distal Channel	Sandy Debris Flow Deposition & Turbidite Deposition	
	Levee Deposit	Turbidite Deposition	
	Front Lobe	Turbidite Deposition & Deep-Water Autochthonous Deposition	
	Semi-deep Lake - Deep Lake	Deep-Water Autochthonous Deposition	

(1) Proximal Channel

This subfacies is mainly developed on the slope break zone, close to the provenance area. It is dominated by sandy debris flow lithofacies and slump deposits, with relatively coarse grain size (mainly fine sandstone) and well-developed massive bedding. The maximum thickness can reach 2 meters, with erosion surfaces visible at the bottom and local crumpling deformation. It contains a small amount of plant debris from shallow water, and occurs interbedded with levee deposits or deep-water autochthonous deposits vertically, forming a combined rhythm of alternating sandy debris flow deposits and deep-water autochthonous deposits.

(2) Distal Channel

This subfacies is mainly developed between the slope break zone and the deep-water basin, far from the provenance area. It is dominated by sandy debris flow deposits and turbidite deposits, with relatively fine grain size, mostly fine-grained siltstone with Bouma sequences, massive fine sandstone, and massive mudstone. Local traces of mudstone erosion are visible. Vertically, it often shows superposition of sandy debris flow and turbidite, overlain by levee deposits.

(3) Levee

This subfacies is mainly developed between channels, dominated by turbidite deposits with relatively fine grain size. It mostly consists of siltstone with Bouma sequences and massive mudstone. Vertically, it is often deposited on the upper part of channels, with limited lateral extension, and frequently occurs interbedded with autochthonous deposits, forming a rhythm of alternating turbidite deposits and deep-water autochthonous deposits.

(4) Front Lobe

This subfacies is mainly developed at the farthest position of gravity flow deposition, near the edge of the deep-water basin and far from the provenance. It is dominated by turbidite deposits, mostly siltstone with Bouma sequences and massive mudstone lithofacies. It often occurs interbedded with deep-water autochthonous deposits, showing interbedding of siltstone with Bouma sequences, massive mudstone lithofacies, horizontal bedding mudstone lithofacies, and horizontal bedding shale lithofacies. It develops a combined rhythm of alternating turbidite deposits and deep-water autochthonous deposits, with stable occurrence and long extension.

(5) Semi-deep Lake—Deep Lake Mud

It is mainly composed of gray and grayish-black mudstone deposits, developed in each sublayer of the Chang 7 oil-bearing interval. The natural gamma (GR) and spontaneous potential (SP) curves are flat and close to the baseline, showing micro-serrated shapes, mostly corresponding to semi-deep lake—deep lake mudstone or the mudstone E segment of turbidites.

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References

[1] Pan Jie, Liu Zhongqun, Pu Renhai, et al. Analysis of paleocurrent and sedimentary facies of Chang 7-Chang 8 in Jinghe Oilfield on the southwestern margin of the Ordos Basin [J]. Acta Sedimentologica Sinica, 2017,35(01):124-138.

[2] Liu X ,Yang S ,Gou S , et al.Sedimentary Facies Characteristics of Chang 6 and Chang 7 Members of Yanchang Formation in Heshui Area, China[J].Journal of Geoscience and Environment Protection, 2024, 12(09):182-197.

[3] Xiao Ling, Chen Xi, Lei Ning, et al. Characteristics and main controlling factors of Triassic Chang 7 Member shale oil reservoirs in Heshui area, Ordos Basin [J]. Lithologic Reservoirs, 2023, 35(2): 80-93.

[4] Wei Qinlian, Zhang Huifang, Han Yonglin, et al. Microscopic Pore Structure Characteristics and Fluid Mobility in Tight Reservoirs: A Case Study of the Chang 7 Member in the Western Xin'anbian Area of the Ordos Basin, China. Minerals,2023, 13,1063.

[5] Xiao Ling, Yang Leilei, Zhang Xuwen, et al. Densification Mechanisms and Pore Evolution Analysis of a Tight Reservoir: A Case Study of Shan-1 Member of Upper Paleozoic Shanxi Formation in SW Ordos Basin, China. Minerals,2023,13,960.

[6] Bai Ying, Ma Zhanrong, Huang Zhengliang, et al. Lithofacies types and sedimentary model of mixed sedimentary rocks of the Ordovician Wulalike Formation on the western margin of the Ordos Basin [J/OL]. Acta Sedimentologica Sinica, 1-21 [2025-07-13].

[7] Jiang Wenqi, Feng Youliang, Zou Caineng, et al. Sedimentary characteristics and main influencing factors of fine-grained gravity flow in the 73 sub-member of Yanchang Formation, Longdong area, Ordos Basin[J]. Earth Science, 2025, 50(06): 2209-2226.

[8] Chang Liangjie, Pang Jungang, Wang Xinyue. Analysis of sedimentary characteristics of gravity flow in the 7th member of Triassic Yanchang Formation in Heshui area[J]. Journal of Chongqing University of Science and Technology (Natural Science Edition), 2022, 24(02): 23-30.