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The Sedimentary Facies Model of the Xing'anling Formation in the X Oilfield of the Hailar Basin

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Abstract: The fault distribution direction in the Sudert structural belt of the Hailar Basin is generally NE and NE-SE, with large fault section widths and rapid changes in fault distances. Small faults are very developed in the area, reflecting the influence of multiple tectonic movements. The faults in the study area show obvious forms such as grabens, domes, fault terraces and "Y"-shaped structures. The top surface of the Xing'anling Formation mainly has fault anticlines, fault noses and fault blocks. The target layer is the Xing'anling Formation of the Nantun Formation, which is the main oil-bearing layer segment of the Xing'anling Formation, with a thickness of approximately 100-130 meters. It is a multi-source and rapid-deposition fan delta sedimentary system. From an overall perspective, the Xing'anling Formation has a gradually decreasing thickness from south to north-west direction and shows a superimposition trend; most of the sand bodies of the first and second oil groups are continuous and are distributed throughout the entire oilfield, with good oil-bearing properties; the reservoirs are mainly composed of gravelly-chert sandstones and chert sandstones, with many tuffs, and the structural maturity and component maturity of the sandstones are both relatively low.

Keywords: X Oilfield; Sedimentary Facies; Fan Delta Sedimentation; Hailar Basin.

1. Overview

The X oilfield is located on the Sudert structural belt between the Beixi and Bezhong depressions in the Beier depression [1]. During the sedimentation period of the Xing'anling Group (the southern section), the ancient topography of the area was complex. Surrounding the study area are secondary structural units such as the Sudert fault uplift belt, the Beibei low uplift, and the Beidong fault uplift belt. Among them, the Sudert fault uplift belt is located in the southwest of the work area and can provide some southwestern direction sources for the X block; the southeast side of the study area is adjacent to the Beidong fault uplift belt over a large area, with intense fault activity, and a series of NNW and N-E trending faults form a co-sedimentary fault step belt. These steep slope fault systems have formed a large-scale sedimentary subsidence center in the central part of the Beier depression, providing continuous space for the development of coarse-grained sedimentary deposits in the fan deltas within the work area, and providing southeast direction sources for the Beibei 28 block and Beibei 14 block, as well as southern direction sources for the Beibei 16 block [2-5]. At the same time, the northeastern part of the Beibei 16 block is close to the Beibei low uplift, resulting in the Beibei 16 block being simultaneously controlled by multiple directions of material supply from the northeast and the south.

2. Depositional Facies Types

Based on the description of core samples from the well sections, and in accordance with the research on the regional sedimentary background of the study area, while considering the characteristics of the facies markers, the various sedimentary microfacies types within the area and their characteristics were refined and determined under the constraints of the facies model. The logging response patterns of each microfacies type were analyzed, and then the facies types of non-core wells were classified based on the facies-electrologically corresponding relationship established by the core-well sections [6]. Through comprehensive analysis, the Xudert Oilfield's Xing'anling I and II oil groups developed a fan delta-lake sedimentary system, which was further divided into four subfacies types: the inner foreland of the fan delta, the outer foreland of the fan delta, the coastal shallow lake, and the semi-deep lake-deep lake. They were further subdivided into eight microfacies types: the main water channel at the foreland, the braided distributary water channel, the terminal distributary water channel, the inter-basin bay of the distributary water channel, the estuary dam, the sheet sand, the shallow lake mud, and the sliding collapse rock. (Table 1) The development characteristics of each sedimentary facies type are described as follows:

Table 1. Classification Table of Sedimentary Types

Facies	Subfacies	Microfacies
Fan deltas facies	fan delta front	Main Channel
		Distributary channel
		interdistributary
	Pro fan deltas	Sheet sand
Lake facies:	Shallow lake	Shallow lake mudstone
	Half-deep Lake - Deep Lake	Turbidite

2.1. Fan Deltas Front

Fan Deltas Front is the main part where the fan delta

deposits sediments close to the source area. It is a concentrated area for coarse-grained sediment deposition. Sediments such as sand and gravel transported from the source area are subjected to the dual effects of gravity flow and traction flow at the inner front edge. In the turbulent high-energy environment, water channel sand bodies migrate, erode, and stack extensively [7], making it the most active area for fan delta front-edge sediment deposition. The sub-basins at the front edge of the fan delta are further divided into three micro-types: the main water channel at the front edge, the braided distributary water channel, and the inter-basin bay between the distributary water channels.

2.1.1. Main Channel at the Fan Deltas Front

The main water channel is the main supply channel for transporting terrestrial clastic sediments from the source area to the fan delta. The layers of the main water channel are stacked and eroded strongly in different periods, making it the main trunk of the water channel sedimentary system of the fan delta front edge. It has a certain influence on the extension direction and development scale of the fan bodies within the lake basin. The lithology is mainly composed of conglomerate, sand conglomerate, and coarse sandstone with gravel. The sedimentary section of the main water channel has a sudden contact with the overlying and underlying strata in terms of lithology, and the water channel is often characterized by blocky or composite bedding. Commonly, there are concave and convex undulating erosion surfaces. The single-layer thickness of the main water channel sand body is mostly greater than 6 meters. The well logging response characteristics are low GR and high resistance, and the curve shows a high-amplitude box-type or bell-shaped-box-type combination (Figure 1).

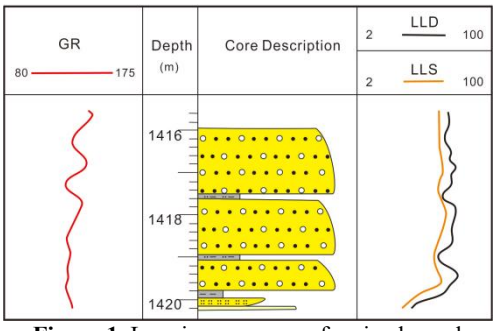


Figure 1. Logging response of main channel

2.1.2. Braided Stream Channel

This is a secondary channel formed by the bifurcation of the main channel at the front. The water energy is relatively weakened, and with the decline in transportation capacity, sometimes fine-grained sediments can remain at the top of the braided channel, showing a positive cyclic sedimentary sequence that is gradually coarser from bottom to top. The bottom sediments of the channels in this area are mostly sand-gravel rocks and coarse-grained sandy rocks, transitioning upward to medium-fine sandstones; the layering types are diverse, including parallel bedding and slot-like, wedge-like, and plate-like interbedded bedding, and mudstone cleavage fragments can be seen. The bottom erosion and scouring effects are obvious; the single-layer thickness of the sand bodies in the channels is mostly greater than 4 meters, and the well logging response characteristics are medium-low GR and medium resistance; the curves show medium-high amplitude box-shaped or funnel-shaped. [8-10]

2.1.3. Channel Diversion Bay

This is located on both sides and in the middle of the underwater stream channels. Affected by the weak water flow environment with low energy, it is dominated by fine-grained suspended sediments, with a high content of mud. The rock types are mainly gray, gray-green mudstones, silty mudstones, mud-siltstones or a small amount of siltstones. Plant charcoal fragments can be seen. The electrical response characteristics are high GR and low resistance; the curves are close to the mudstone baseline and show low-amplitude tooth-like or low-amplitude funnel-shaped.

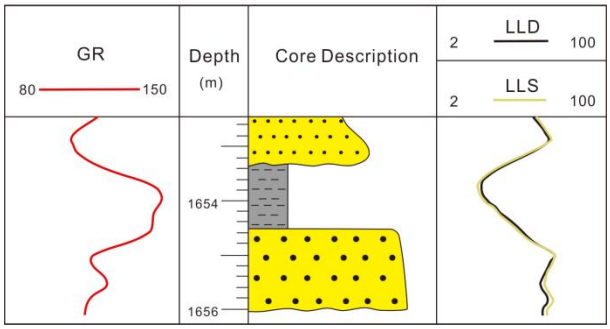


Figure 2. Logging response of interdistributary

3. Distribution of Depositional Facies

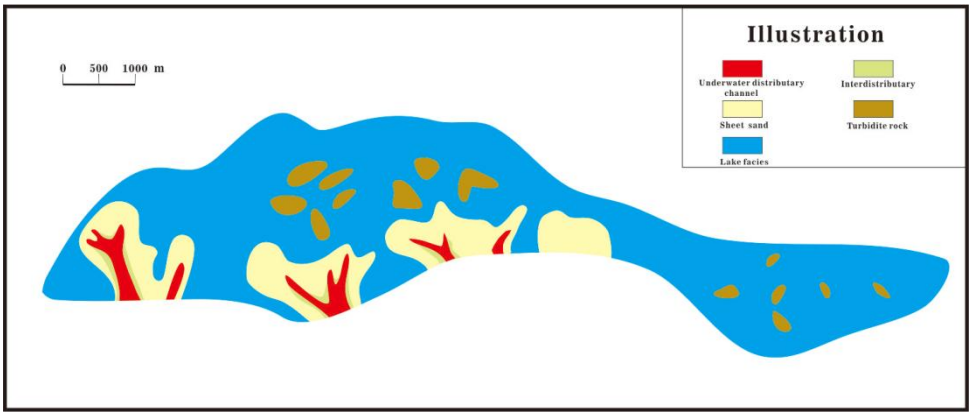


Figure 3. Deposition microfacies map

Taking the 25 small layers of the II oil group as an example, during this period, large-scale lake sedimentation was the main form. Only in the southern parts of Be 28 and 14 blocks could we observe four small-scale fan-triangle front-edge sediments. The sheet-like sand spread area was limited, isolated terminal channels were scattered, the channel extension was short, and the estuary dams were not developed. In the northern part of the block, there were multiple gravity-

formed lens-shaped turbidite sand bodies distributed in front of the fan edge. In the Be 16 block, only scattered lacustrine turbidite rocks could be observed, and no fan body was developed. [10-12]

During the sedimentation period of the 21-23 layers of the Xing'anling II oil formation, a short-term base-level rise half-cycle was developed. During this period, the lake level slightly dropped, but the water body remained very deep. Compared with the previous cycle, the fan bodies showed a small accumulation feature, and the number of fan bodies increased, with a larger scale.

Taking the 23 layer of the II oil formation as an example, the lake facies deposition range was reduced. In the Be28 and 14 blocks, multiple small-scale fan bodies developed from south to north and accumulated in a small area towards the central part of the lake basin. The fan bodies were distributed independently and not connected to each other. Only in the area from Be14-X60-60 to Be14-X62-62 wells in Be14 block, the source supply was relatively strong, and the deposited fan bodies were larger in scale. Overall, the fan-shaped isolated terminal channels were developed. The lateral width of the water channels was generally narrow, and some water channels had river mouth dam deposits at the end of their extension. Fan front edges showed small areas of turbidite rock development on the outside. The Be16 block was influenced by multiple directions of source supply from the south, and the small-scale fan bodies were distributed in the same direction.

The southeastern part of the block was close to the Be Dong fault uplift zone. The coarse-grained clastic materials provided by the single-directional source supply were transported over a short distance to the steeply inclined depositional baseform, forming fan bodies arranged in a skirt-like pattern. The lateral part was partially superimposed to form a continuous fan group advancing towards the lake basin. Near the source area, the double force mechanism of gravity flow and traction flow acted, with the front edge of the fan delta dominated by blocky gravel, sand-gravel, and gravelly coarse sandstone deposits. The transition to the outer front edge was dominated by medium-coarse sand, fine-sandstone, and fine-sandstone. The well logging curves mostly presented medium-high amplitude box-shaped, bell-shaped, and their combinations. The particle sorting of the rocks was poor, and the structural maturity was low. The grain size probability diagram was mainly arc-shaped, one-stage, and low-slope two-stage. The suspended total content was high. Under different A/S ratios, the deposition types of the front water channels were diverse, including thick-layered continuous front main water channels, wide-band interwoven distributed meander-shaped distributary water channels, and narrow-strip isolated distributed terminal distributary water channels. River mouth dams were less developed. Due to the large depositional slope, some sediment outside the fan edge was subjected to gravitational sliding and collapse under the induced force, forming lens-shaped turbidite sand bodies. The fan angle of the steep-slope fan was small, the length-width ratio was not large, and the fan was controlled by gravitational factors and extended for a short distance, but often formed continuous fan groups distributed in a large-scale manner. The continuity of the sand body was affected by multiple factors such as the type of facies belt and the rise and fall of the base level.

4. Conclusion

Based on the distribution characteristics and scale of different types of fan bodies, the sedimentary slope of the fan delta in the X area is relatively steep. Due to the influence of gravity, the fan bodies accumulate relatively far inland, having a lower aspect ratio. There are many small fan bodies, which are adjacent laterally and in a fan-like distribution pattern, and are accompanied by turbidite rocks in the front of the fan body. The fan delta in the Bezhong area formed during the middle and late stages of the rift. The sedimentary landform is relatively gentle. The fan delta has a certain extension distance underwater. The fan bodies are relatively large in length and width, and the traction flow sedimentary components are dominant. The front of the fan body is accompanied by beach-bank sedimentary sand bodies. The meandering river fan delta in the Wudong area formed at the transition zone between the gentle slope front and the depression, far from the source area. The slope area is wide in the horizontal direction, providing space for the development of large-scale meandering plains. After the meandering plain enters the lake, the fan body of the meandering river fan delta is relatively large, and the fan body is distributed in a mat-like pattern.

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