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Analysis of Sedimentary Facies of the Nantun Formation in the Huhehu Depression

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Abstract: The Huhehu Depression has a relatively low level of research at present. In order to clarify the sedimentary type and evolution pattern of the Nantun Formation, comprehensive utilization of core samples, logging data, paleontology and other data, combined with the structural evolution characteristics of the basin, and by adopting paleontology, sedimentology, petrology and combined with structural geology and other technical methods, the sedimentary environment, source characteristics, sedimentary microfacies and sedimentary evolution pattern of the reservoirs in this oilfield were systematically analyzed. The study shows that this oilfield develops a middle-coarse sandstone fan delta sedimentation under a near-source-dominated terrestrial swamp-bay shallow lake environment. The traction flow is the main controlling factor, and the submarine distributary channel sand body at the front is the main oil-bearing reservoir. The sedimentary pattern has the characteristics of high water level period and low water level period sedimentary evolution.

Keywords: Huhehu Depression; Sequence Stratigraphy; Sedimentary System; Coarse-grained Delta.

1. Overview of the Study Area

The Huhehu Depression is located in the eastern part of the Hailar Basin and is a secondary structural unit of the Hailar Basin. It is oriented in a north-east direction and is adjacent to the Xilinbel uplift to the east, connected to the Bayan Mountain uplift to the west, and linked to the Yimin Depression in the north. It extends southward beyond the border and connects with Mongolia. The Huhehu Depression has undergone three stages of tectonic evolution, namely the early extensional depression stage, the mid-stage thermal subsidence depression-dome stage, and the late depression stage. The Cretaceous period was the main sedimentary period of the basin, and it is divided from bottom to top into the Lower Cretaceous Tongbome Formation, Nantun Formation, Damaokanghe Formation, Yimin Formation, and the Upper Cretaceous Qingyuan Gang Formation. The main exploration target layers are mainly distributed in the Tongbome Formation, Nantun Formation, and Damaokanghe Formation.

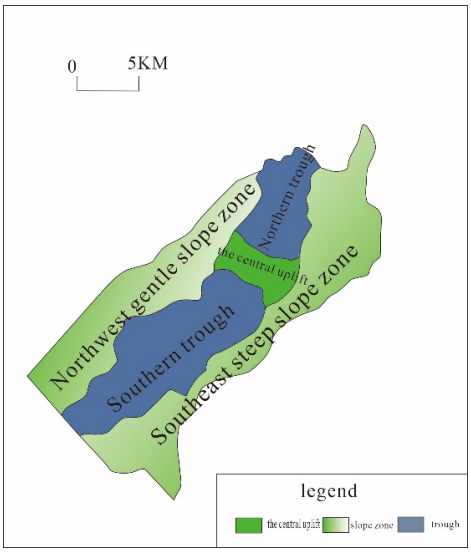


Fig 1. The top surface map of Quantou Formation in the study area

1.1. Stratigraphy Overview

Nantun Formation: The thickness of the Nantun Formation ranges from 450 to 800 meters and can be divided into two sections. The lower part of the Nantun Formation's first member consists of thin-bedded gravel rocks interbedded with thin-bedded dark gray mudstones, with brecciated sandstones visible at the bottom. The upper part is deep-sunken or semi-deep lake sedimentary mudstones interbedded with thin-bedded gravel rocks, with a spore assemblage of double-strand pine spores - original ancient pine spores. The second section of Nantun Formation has a bottom consisting of sandstones from the fan delta front interbedded with dark gray mudstones, with the sandstone thickness decreasing and the number of layers reducing upwards. The upper part is deep-lake or semi-deep lake sedimentary mudstones.

Damaoguqianhe Formation: The thickness is generally 600 to 800 meters and can be divided into two sections. The overall composition is mainly thick-bedded dark gray and dark grayish-brown mudstones, interbedded with thin-bedded sandstones. The second section of Damaoguqianhe Formation has a combination of Bell batophytes - smooth-surfaced pseudobatophytes, while the first section is Kefaloslopus spores - spruce spores - single-strand pine spores.

2. Classification of Sedimentary Facies

A fan delta is a sedimentary system formed when an alluvial fan directly advances into a lake basin. It often occurs in areas with a steep short-axis slope of the depression. It is a coarse-grained sedimentary system that is widely developed under the growth fault context. Its sedimentation process has a dual mechanism of gravity flow and traction flow [1-2]. The sediment grain size is coarse, consisting of sandstone, conglomerate, and mudstone or mudstone interbedded with coal seams. On seismic profiles, the seismic reflection symmetrical axis converges in a wedge shape towards the lake basin direction, while the reflections towards the landward direction and the fault root are more chaotic. The subfacies mainly consist of fan delta plain, fan delta front, and

pre-fan delta. The fan delta is mainly distributed in the northwest gentle slope zone and the southeast steep slope zone of the southern section.

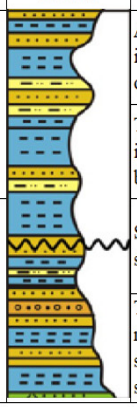
Stratum		Thickness	Lithological section	Lithological description	Fossil assemblage of ancient organisms	Sedimentary evolution
Damoguanhe formation	second member	300-1000		A large section of black mudstone interspersed with a small amount of sandstone	The combination of Pterophyllum Bell and Pterophyllum photophilum	Fluvial phase
	first member			Thick-bedded black mudstone intercalates and medium and thin-bedded sandstone	Kefenla Suo powder - Spruce powder - Single bundle pine powder	Lake mud
Nantun formation	second member	450-800		Sand and mud interbedded coal seams	Clauso powder - Spruce powder - single bundle pine powder	Fan delta
	first member			The bottom of relatively pure mudstone and interbedded sandstone shows tuxaceous sandstone	Double-bundle pine powder - Original ancient pine powder	Braided river delta Lake

Fig 2. Comprehensive stratigraphic column of the Huhehu Depression

Table 1. Table of sedimentary facies classification

Facies	Subfacies	Microfacies
Fan Deltas	Deltas plain	Main distributary channel
		distributary edge
		natural levee
		interdistributary bay
	Deltas front	Main distributary channel
		sand sheet
		distal bar
		mouth bar
		interdistributary bay
	Pro-fan deltas	lake mud, turbidite

2.1. Facies Marker

(1) Delta plain subfacies

The fan delta plain is the terrestrial part of the fan delta, mainly featuring two microfacies: distributary channels and distributary inter-bays. The lithology of the distributary channels is mainly composed of grayish-white conglomerate, conglomerate with gravel, coarse sandstone, and fine sandstone[3-6]. There are no bedding planes within them, and the component maturity is low, with poor sorting and rounding. The grain size probability curve is mainly composed of two segments with a lower slope. The overall rolling content is approximately 75%, and the overall jumping content is approximately 25%. Their intersection point is in the range of 0 to 1 Φ, and the grain size range is wide, reflecting the water dynamic characteristics of high energy rolling overall after transportation and deposition, with fine-grained jumping components filling the spaces between the rolling components, indicating that the sediment carried by the gravity flow into the lake is affected by the water flow, resulting in a decrease in energy, water turbulence, and the transformation of the gravity flow into a traction flow. Vertically, it presents a positive cyclic trend of grain size increasing upwards, and the resistivity curve and gamma logging curve mainly show two forms: toothed box-shaped and toothed hourglass-shaped.

(2) Delta front subfacies

The grain size at the front edge of the fan delta in this area is slightly finer than that of the plain sub-basin, and the colors are mainly gray and dark gray. The content of silty material has significantly increased, and the sorting is better than that of the plain. The layering types and inclusions are abundant, and the bottom is significantly eroded. Within this area, three microfacies, namely underwater distributary channels, underwater distributary inter-bays, and sheet-like sands, are mainly developed. The estuary dam is not developed, which may be related to the greater energy of the underwater distributary channels and their frequent diversion.

Underwater distributary channels are the underwater extensions of the terrestrial meandering channels and are the most important microfacial type. The sediments are mainly composed of conglomerate and sandstone, and the sorting is better than that on land. The layering types and organic matter content are abundant, and the bottom is significantly eroded. The grain size probability curve is mainly two-stage, and the overall intersection point of jumps and suspensions is in the range of 1.8 to 2.5 Φ. The overall suspension is approximately 30% to 40%, reflecting poor sorting, and both traction flow and gravity flow mechanisms coexist. The positive rhythmic underwater distributary channel sedimentary characteristics are obvious, and the resistivity curve is mainly tooth-shaped box-shaped and bell-shaped, with box-shaped being the

dominant type.

Sheet-like sands are distributed at the end of the underwater distributary channel entering the lake. It is a thin-layer sand body formed by the modification of lake waves. The lithology is gray siltstone, mud-siltstone, and mudstone, with an inverted rhythm [7-10]. The natural potential curve response is funnel-shaped or finger-shaped, indicating the characteristics of sand-mud interbedded deposition.

(3) Pro-fan deltas

The pro-fan delta deposits developed at the farthest end of the fan delta offshore. The source supply was difficult to reach this area directly. It was mainly composed of suspended still water sediments. The lithology was mainly gray, dark gray, gray-black mudstone and silty mudstone. Horizontal bedding and blocky bedding could be observed, and lens-shaped bedding was occasionally seen. The well logging curve presented a low-amplitude tooth-like pattern.

2.2. Sedimentary Facies Evolution

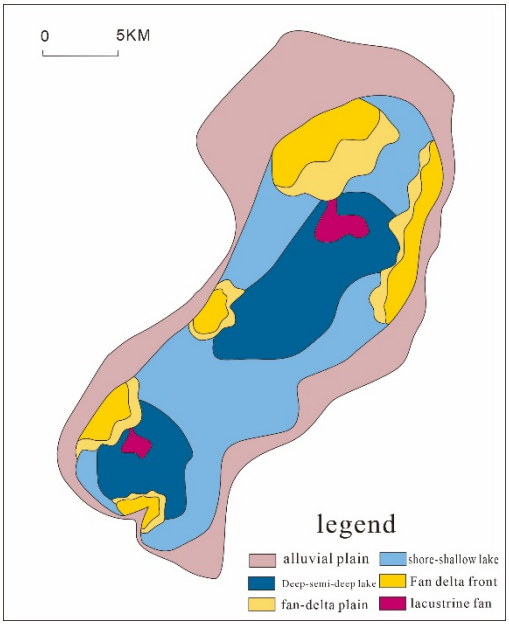


Fig 3. Sedimentary microfacies map of Nantun Formation

During the sedimentary period of the Nantun Formation, it was in a period of intense subsidence, controlled by the northeast-dominant faults and the nearly north-south faults. The crust underwent subsidence, accompanied by more intense stretching, causing the first regional-scale large-scale water influx within this depression. As a result, the lake area expanded and the water depth also increased. Under the joint control of the main controlling faults and the secondary faults induced by them, the main sedimentary systems developed were fan deltas, braided river deltas, and lake-bottom fans. A set of lacustrine deposits dominated by black mudstones was deposited, becoming high-quality source rocks for Huhehu Depression. The fan delta sedimentary system mainly developed in the southern part of Huhehu Depression, while in the northern slope zone and the northern part of the southeastern steep slope zone, large fan bodies developed in the braided river delta sedimentary system controlled by the material source. The deep lake - semi-deep lake sub-environment was mainly developed in the central part of the depression sag, and a small amount of beach-bar sand bodies developed in the local shallow lake sub-environment. At the front edge of the fan delta and the front edge - deep lake of the braided river delta, due to the gravitational flow effect, the lake bottom fans were relatively developed.

3. Conclusion

Under the isochronous stratigraphic framework, the main sedimentary systems in the study area were identified as alluvial fans, fan deltas, braided river deltas, lake floor fans and lake deposits. The sedimentary facies and distribution patterns of different system domains in the Lower Cretaceous strata were systematically studied, and the sedimentary evolution models of different strata in Huhehu Depression were established. The evolution of sedimentary systems corresponds to the tectonic evolution and shows obvious stages. The sedimentary systems underwent a change pattern of coarse - fine - coarse. The bottom strata of the Nantun Formation developed alluvial fans and fan deltas; the southern part of the middle strata developed fan delta sedimentary systems, while the northern part developed braided river delta systems; the upper strata mainly developed braided river delta systems and lake floor fan sedimentary systems.

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