Sedimentary characteristics and geological significance of sublacustrine fan in the Houdomoer tectonic belt

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Abstract
At present, the sedimentary characteristics of the sublacustrine fans in the Houdomoer tectonic belt have not been clearly understood, which restricts further oil and gas exploration. In this research, the sedimentary characteristics of the sublacustrine fans and their oil and gas geological significance are studied based on the data of core, well logging, logging and earthquake. It is found that the sublacustrine fans in the study area can be divided into three types. The sublacustrine fan of the Houdomoer tectonic belt is located in the stratum next to the best source rock in Nantun Formation. Oil and gas are injected into the sublacustrine fan sand body from the bottom and side. Generally, oil and gas accumulation is mainly controlled by the physical characteristics of the reservoir. Experimental analysis shows that the reservoir capacity of different sedimentary microfacies is quite different. The braided channel microfacies of the middle fan is the most favorable type of reservoir facies belt, and the main channel microfacies of the inner fan is the second most favorable reservoir. The practice of oil and gas exploration also proves that the high-yield wells are mostly located in the braided channel microfacies of the middle fan. Therefore, this microfacies type has a broad exploration prospect.

1. Introduction
Since the concept of the sublacustrine fan was put forward, scholars at home and abroad have carried out a lot of scientific research on the genesis and sedimentary characteristics of different regions and types of sublacustrine fans [1-5], in the continental faulted basin of China, the sedimentary system of the lake bottom fan is also widely developed. Many domestic scholars have studied and discussed the lake bottom fan in the Bohai Bay Basin, Songliao Basin and Erlian Basin [6-9]. Houdomoer tectonic belt is an area with high oil and gas production and enrichment in Beier depression of Hailar basin. In this study, the data of core, logging, well logging and seismic are comprehensively applied. Combined with the characteristics of regional structural evolution, the sedimentary characteristics of lake bottom fan in Houdomoer tectonic belt are expounded from the aspects of rock facies type and facies marker identification, and further combined with experimental analysis data and test Oil data are used to analyze the law of oil and gas enrichment, so as to provide a reference for the next exploration work.

2. Geological background
Houdomoer tectonic belt is located in the northwest of Beier depression, the largest oil-gas rich depression in Hailar Basin. It is a concave uplift belt formed by multi-stage structural transformation
(Fig.1). It is connected with Beixi slope belt in the north, Suderte structural belt in the south, Beixi sub sag in the west, Bayantala structural belt in the East. There are Jurassic volcanic basement, lower Cretaceous Tongbomiao Formation, lower Cretaceous Nantun Formation, lower Cretaceous Damoguaihe Formation, lower Cretaceous Yimin Formation, Upper Cretaceous Qingyuangang Formation and Quaternary strata in the Houdomoer tectonic belt from bottom to top. Nantun Formation is the main target stratum for exploration. The sedimentary system of sublacustrine fan developed in the sedimentary period of Nantun Formation. Many wells have seen good oil and gas shows, and well h3-3 has obtained 382 t/d high-yield industrial oil flow, so the exploration prospect is very broad.

![Figure 1. Regional geographic location of the Houdomoer tectonic belt](image)

### 3. Characteristics of sublacustrine fan

Through the detailed observation and description of the core data of more than 10 cored wells in the Houdomoer tectonic belt and the sampling and the whole rock X-ray diffraction experiment analysis, it is found that the sedimentary rock type of the lake bottom fan in the Houdomoer tectonic belt is mainly clastic rock, which is relatively developed from mudstone to glutenite, in which the shale accounts for 14%, siltstone accounts for 16%, sandstone accounts for 45%, conglomerate accounts for 25%. The sandstone is mainly lithic. The main characteristics (quartz component accounts for 4-31%, cuttings component accounts for 65-95%, feldspar for 5-35%). The component maturity is relatively low, which reflects the sedimentary characteristics of the lake bottom fan in Houdomoer tectonic belt caused by collapse and rapid accumulation near the source (Fig.2).
In the process of core observation and description, various types of deformation structures (Fig.3) have been identified, including convolution structure, slump deformation structure, mudstone tearing debris, pillow structure, liquefaction structure, heavy load model structure and flame structure. These sedimentary structures are important evidence for judging fan deposition. The main feature of the wrapping structure is the wrinkling phenomenon in a single layer, which does not involve adjacent layers. Although the lamination is complex, it is continuous without fault. Generally, the twisted lamination is cut by the upper layer at the top of the single layer, and gradually returns to normal at the bottom. The convoluted bedding may be formed when liquefaction occurs in the sedimentary layer, the transverse flow occurs in the later liquefaction layer, or the sediment discharges the pore water again (Fig.3a); the slump deformation structure is the various deformation structures and irregular distortions formed by the incomplete consolidation of the sediment on the slope due to the sliding, which is generally associated with the rapid accumulation of gravity flow, and the lithology is mixed. Obvious signs (Fig.3b); the debris of mudstone tearing is mainly the debris with flexibility or plasticity and quasi syngenetic sediment (argillaceous) in the lake basin, which can be further divided into two types: irregular and long strip. The former is mainly distributed in the sandy debris flow, while the latter is distributed in the silty or muddy debris flow (Fig.3c); The pillow structure refers to the sandy sphere surrounded by mudstone. Most scholars think that the pillow structure is mainly caused by the formation vibration, which causes the sand layer to break and fall into the underlying mudstone (Fig.3d); the liquefaction structure is the product of the rapid accumulation of silt, fine sand and other products under the influence of gravity, load pressure or formation vibration. With the action of external force, the pressure borne by the original particle support is transferred to the pore fluid so that the pore pressure increases greatly, the friction between particles decreases and liquefy, and flow occurs under the action of a small tangential force. Although the flow is local, it can still strongly transform the sedimentary structure (Fig.3e); the heavy load structure and flame structure generally appear at the same time, which is caused by the fact that the underlying soft mud with strong plasticity rich in pore water is trapped in the underlying mudstone layer due to the uneven load pressure when bearing the overlying sand layer, thus forming the heavy load structure. When the mudstone layer is flame shaped or tongue shaped, it penetrates the overlying sandstone layer, forming a flame structure (Fig.3f).
4. Sedimentary facies types and plane distribution characteristics of the sublacustrine fan

In this study, the sublacustrine fan's sedimentary facies types and plane distribution characteristics are comprehensively applied with the data of core, seismic, logging and well logging. Based on the research of single well core facies, logging facies and well logging facies at the well point, in the area without well, the combination of "well earthquake" is used as the bridge source, the seismic attribute is the main one (Fig. 4a), the sand ground ratio, paleogeomorphology and heavy minerals are combined to carve precisely. The spatial distribution of the sublacustrine fan deposits in the Houdomoer tectonic belt is illustrated (Fig. 4b).

The subfacies of the inner fan in the sublacustrine fan are mainly developed in the eastern part of Houdomoer tectonic belt near the fault slope break zone, which can further identify the microfacies of the main channel of the inner fan and the microfacies between the channels of the inner fan. Among them, the main channel microfacies of the inner fan is the framework sand body that forms the subfacies of the inner fan, which is usually composed of thick sand conglomerate supported by particles. The composition of gravel is relatively complex and poor in sorting and rounding, mainly in massive structure without obvious bedding. The microfacies between the inner fan channels are fine-grained sedimentary bodies composed of mudstones and siltstones overflowing outside the main channel of the inner fan, which are mostly developed with horizontal, deformed, wavy and other weak hydrodynamic bedding. The distribution of the middle fan subfacies in the sublacustrine fan is extensive, and the development of many large-scale and well formed braided channels is a typical feature of the middle fan subfacies. In the middle fan subfacies, the middle fan braided channel
microfacies and the middle fan braided channel microfacies can be further identified. The middle fan braided channel microfacies are mainly composed of thick sandstone, glutenite, conglomerate and thin dark mudstone, and massive bedding can be seen large scale cross bedding, deformation bedding and other sedimentary structures. The microfacies between the braided channels of the middle fan are mainly composed of fine-grained rocks, mostly interbedded with siltstone and dark mudstone, which can identify small cross bedding, wavy bedding, deformation bedding and other sedimentary structures. The subfacies of the outer fan of the sublacustrine fan are not easy to identify in this area. The microfacies of the turbidite sand of the outer fan are only identified in well H12 and other well areas. The lithology is composed of thick dark mudstone mixed with thin sandstone, and sedimentary structures such as deformation bedding, horizontal bedding, wavy bedding and heavy load model can be seen.

5. Geologic significance of sedimentary oil and gas in sublacustrine fan
The sublacustrine fan deposits are usually close to the deep lacustrine mudstones. Therefore, the physical characteristics of the reservoir are the main factors that restrict the sedimentary accumulation of the sublacustrine fan. The sublacustrine fan deposits in the Houdomoer tectonic belt have similar characteristics. The sublacustrine fan bodies in the study area are mainly next to the best source rock section in the Nantun Formation. According to the types of organic matter, the types of dark mudstone organic matter in the source rock section adjacent to the lake bottom fan are mainly type I and type II 1, with TOC average of 2.3% and maximum of 7.21%, S1+S2 average of 11.96 mg/g and maximum of 46.64 mg/g, showing good oil-bearing characteristics. And RO is between 0.75-1.2, which is a mature source rock and is in a large amount of hydrocarbon expulsion period. The oil and gas generated by the source rock is injected into the bottom fan sand body from the bottom and side. Generally, fault lithologic oil and gas reservoir is formed by fault shielding or directly blocked by surrounding mudstone to form lithologic oil and gas reservoir in the form of lens.

According to the physical property data measured by 139 core samples of different microfacies from more than 10 cored wells in the Houdomoer tectonic belt (Fig.5), the storage capacity of different sedimentary microfacies in the lake bottom fan sedimentary system is quite different. The porosity of braided channel microfacies in the middle fan of the lake bottom fan is more than 15% and the permeability is more than 1 md. The high-quality reservoirs with medium high porosity and medium high permeability are mainly developed, which are obviously better than other types of microfacies and are the most favorable type of reservoir facies belt. The main channel microfacies in the inner fan of the lake bottom fan is the second, and the porosity is mostly between 8-12%, which is the more favorable reservoir. The turbidite sand microfacies in the outer fan of the lake bottom fan have poor reservoir capacity, with pores Porosity is between 4-10% and permeability is less than 1md; porosity of main channel microfacies and braided channel microfacies is less than 8% and permeability is less

Figure 4a. Seismic multi-attribute fusion maps of Houdomoer tectonic belt.
Figure 4b. Planar distribution of sublacustrine fan in the Houdomoer tectonic belt.
than 0.1 md, most of them are invalid reservoirs. The oil and gas exploration practice also proves that the high-yield wells are mostly located in the braided channel microfacies of the middle fan of the lake bottom fan, which has a broad exploration prospect.

![Physical characteristics of different types of microfacies in sublacustrine fan sediments](image)

**Figure 5.** Physical characteristics of different types of microfacies in sublacustrine fan sediments

6. Conclusion
Based on the data of core, logging, well logging and earthquake, it is considered a typical sedimentary system of sublacustrine fan in the Houdomoer tectonic belt, and three subfacies of inner fan, middle fan and outer fan are identified. The bottom fan of Houdomoer tectonic belt is next to the best source rock section of Nantun Formation. Oil and gas are injected into the sand body of the bottom fan from the bottom and side. The accumulation of oil and gas is mainly controlled by the physical characteristics of the reservoir. The reservoir capacity of different sedimentary microfacies in the sublacustrine fan sedimentary system is quite different. The braided channel microfacies of the middle fan is the most favorable type of reservoir facies belt, and the main channel microfacies of the inner fan is the second most favorable reservoir. The oil and gas exploration practice also proves that the high-yield wells are mostly located in the braided channel microfacies of the middle fan, and the exploration prospect is broad.

7. References
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