Research on Sedimentary Microfacies of an Oil Layer in a Block of Songliao Basin

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Abstract. This topic uses debris, core log, core description data, combines regional research results, determine that the oil layer in a block of the Songliao Basin is the most developed in the front subfacies and prodelta subfacies of delta underwater sediment. Microfacies include underwater distributary channels, underwater natural levees, distributary bays, estuary dams, distal bars, sheet sand, and prodelta mud. The contiguous distribution of dam sand is the main feature of this area. On the basis of single-well facies research, it is the first time that this topic has studied the features of the plane and profile distribution of the reservoir sedimentary facies belt in the study area, and finally builds the sedimentary facies model, and provides a solid geological basis for fine reservoir description and favorable area prediction.

Keywords: Delta underwater sediment; sedimentary microfacies; contiguous dam sand; sedimentary model.

1. Introduction
The Songliao Basin is a large-scale composite sedimentary basin with faulted dual structure in the Mesozoic and Cenozoic in eastern China[1-4], its area is 2.6×105km2, it is also one of the continental sedimentary basins with the richest oil and gas resources discovered in the world[5]. This oil layer is one of the important gas-bearing layers in the depression structure in the southern Songliao Basin, according to the analysis of the regional sedimentary background, this block is in early Cretaceous Quantou Fm and Qingshankou Fm, its sedimentary environment belongs to delta environment, and its provenance is Baokang provenance in the southwest and Changchun-Huaide provenance in the southeast. These delta front belts which go deep into the center of the lake basin have excellent combination of source, reservoir, and cap, the favorable configuration of structural styles under the delta front sand bodies and regional structural background form large-scale structural-lithological closing belt. Due to different combinations of factors such as structure, faults, facies belts, sand thickness, etc., abundant reservoir types can be formed. The study area is just in the delta front zone and has the conditions for forming large-scale oil reservoirs.

The sedimentary features of the research area are controlled by the paleostructure, palaeogeography and palaeoclimate background of the Songliao Basin. The structural position of the Songliao Basin is the inner zone of the northern profile of the Pacific Rim, it belongs to the continental rift basin, and its
formation and evolution have roughly gone through four stages: hot tension crack, rift, depression, and shrinking fold.

2. Division of Sedimentary Microfacies

This research started with core observation, and carried out detailed observation and description for 11 cored wells in the target oil layer of work area. The comprehensive analysis was conducted in combination with related data such as logging, particle size analysis, rock sheet; determine that the target reservoirs in this area are dominated by delta facies.

The sedimentary features obtained by observing cores, supplemented by logging, logging, particle, sheet and other related information, the main sedimentary system of the target oil layer in this area, the delta front sediment is subdivided into six types of microfacies: underwater distributary channel, estuary dam, distal bar, distributary bay, underwater natural levee, and front sheet sand, among them the estuary dam and front sheet sand are connected to each other, the formed estuary sand dam microfacies is the main oil and gas reservoir facies belt and also the characteristic facies belt of the study area, it is briefly described as follows.

2.1. Identification marks of delta facies

According to the observation and analysis results of core, in the 11 coring well profiles, 9 well profiles present the features of delta underwater sedimentation, namely, they belong to the delta front and the front delta, and no water plain sedimentation are seen. The sedimentary features of delta in this area are obvious, are typical and easy to identify, the fragmental particle size of core shows the "fine-coarse-fine" change trend from bottom to top, namely from reverse cycle to normal cycle, reverse cycle dominated, it constitutes a complete compound cycle, it is the manifestation of the delta transverse phase sequence gradual change in the vertical sequence, the former (transverse) is the "cause" and the latter (vertical) is the "effect". (Fig.1).

![Fig.1 Core facies analysis of study oil layer in W1 well](image-url)
Rock types: they are mainly fine sandstone, siltstone, argillaceous siltstone, silty mudstone, mudstone; they belong to fine debris rocks, often present thin inter-bed or interlayer. A large number of mica fragments are often distributed along the plane.

Sandstone maturity: the most stable component: quartz content only accounts for about one-third of the total terrigenous clastics, and the variation range of content is small, and the content is low; the unstable component: feldspar content is more, which is higher than quartz content, and the variation range is also small, and the content is high; variation range of debris content is wide, from 2% to 40%, and the content varies greatly; the clay matrix is very few, and the content is less than 10%. According to the composition, classification belongs to debris feldspar sandstone and feldspar debris sandstone. The composition maturity is medium to low. According to the statistics of the structure parameters of the sandstone thin slice data, the roundness of the terrigenous fragments of the target oil layer sandstone are all sub-angular, and the rounding degree is relatively low. The target oil layer of sandstone sorting is good-medium, it is in medium to good. After comprehensive judgment, the maturity of the sandstone structure of the target oil layer is medium.

Sedimentary structures are caused by river and lake wake, they are complex and diverse, but they are all products of tractive current. The main bedding types are: groove cross bedding, wavy cross bedding lenticular bedding, wavy bedding, parallel bedding, and horizontal bedding. Bedding structures include: scour surface, scour-fill structure, wave mark and so on. Deformation structures include: convolution structure, slumping structure, and mixing structure.

Curve features of particle size probability: the particle size analysis data of the work area is extremely limited, and the strength analysis data of the target oil layer is not collected. The features of the particle size probability map are very similar, they are composed of two particle size populations (jumping population and suspension population), the jumping population is the main one, its content accounts for about 85%, the size of the debris is mostly 2 to 4.5 Ф, they are fine sand or silt; they are composed of two line segments, and the interprofile point of the two line segments, namely the scouring-return boundary point is about 3Ф. It reflects the interaction of the two hydrodynamic forces of the river and the wave, which is consistent with the formation mechanism of the sand dam.

Logging curve: the total feature is shown in reverse bell shape or funnel shape - bell shape, it presents reverse cycle-positive cycle, namely the composite cycle; the lower reverse cycle is more developed than the positive cycle of upper part.

2.2. Microfacies type and features of delta front subfacies

Delta front subfacies s can be divided into six microplasses: underwater distributary channel, underwater natural levees, distributary bay, estuary dam, distal bar, frontal sheet sand.

2.2.1. Microfacies of underwater distributary channel. Underwater distributary channel is the underwater water extension part where the delta land branch river enters the lake and keeps on moving. The reason for the distributary is the constant formation of the estuary dam. The rock type has gray, brown gray, green gray fine sandstone, green gray siltstone, gray black muddy siltstone, they are mainly sandstone, calcium cement or muddy cement, and the next is siltstone, often constitute positive rhythm.

The bottom of each positive rhythm has brush surface or flush-filling structure, a homogeneous type having a small groove-shaped interleaving layer, a corrugated layer, parallel layer, and a lenticular layer; a deformation structure such as a coil layer can be seen. The logging curve is characterized by a sleek or dental clock shape, a box shape, and a medium. The bedding types include small groove cross bedding, wave shape bedding, parallel bedding and lens bedding; it can be seen that there are deformation structures such as convolution structure. The logging curve is characterized by smooth or toothed bell shape, box shape and medium amplitude.

2.2.2. Microfacies of underwater natural levee. Located on both sides of the underwater distributary channel, it is often located above the underwater distributary channel in the vertical sequence. The rock types are mainly gray-green, green-gray, light gray thin-layered and lamina calcareous siltstone, are
mixed up with brown-grey calcareous fine sandstone layers and clumps, lamellar gray-black argillaceous siltstone and yellow-brown silty mudstone. The sedimentary structure is most developed with wavy bedding, there are cross bedding, lenticular bedding, as well as scouring surfaces and wormholes. The logging curve is characterized by medium-low amplitude and tooth shape.

2.2.3. Microfacies of distributary. The distributary bay is the hollow zone among the underwater distributary channels, and is dominated by clay sediment. The rock types are mainly black-gray mudstone, green-gray calcium-bearing silt and silty mudstone, there are layered, lenticular brown-gray, green-gray siltstone or block mass, and there is locally black carbon-bearing shale. Common carbonized plant debris. The bedding types have horizontal bedding, wavy bedding, and lenticular bedding. Other sedimentary structures can be seen in wormholes. Freshwater conchostraca and ostracod can be seen in biological fossils. The logging curve is characterized by the low-amplitude tooth shape.

2.2.4. Microfacies of estuary sand dam. Estuary sand dam is the most distinctive in the delta, and it is also a type of sand body generally developed in this area. Its main features are as follows:

The rock types are light gray, gray-green, green-grey fine sandstone, siltstone, and medium-fine sandstone, mainly fine sandstone. Contain plant debris, local layer enrichment. Contain a small amount of mud and present round. There are dark gray thin-layered, laminar argillaceous siltstone and silty mudstone. There are medium-layered thickness, and the particle size of the debris from the bottom to the top increases from fine to coarse, present reverse particle order. Brownish-yellow mudstone lamina can be seen at the top of the reverse particle sequence, its thickness is about 4cm. Sandstone has many stable components, few matrixes, good sorting, high component maturity and structural maturity. There are various types of sedimentary structures; the bedding includes wavy cross bedding, small-medium groove cross bedding, parallel bedding, and lenticular bedding. There are also the scour-filling structure and the inflatable structure (Fig.3). The features of the logging curve is characterized by funnel shape, toothed funnel shape, middle-high amplitude lower tooth, and the tooth center line gradually becomes steeper, has feature of outer convergence[6], and it is the combination of foreset amplitude (Fig.2).

Fig.2 Mouth bar microfacies lithologic-electric property feature pattern of study oil layer in W2 well
2.2.5. Microfacies of distal bar. The distal bar is located horizontally in front of the estuary sand dam toward the center of the lake, and vertically below the estuary sand dam, its sediments are finer than that of the estuary sand dam, and often form reverse rhythm with the estuary sand dam. The lithological features are characterized by yellow-green laminar, thin-beded siltstone, fine sandstone and calcareous siltstone, calcareous fine sandstone and black-gray laminar, thin-beded argillaceous siltstone, siltstone forms rhythm layer, the carbon dusts are enriched layer. This kind of structural lamina composed of particle size changes of calcareous and calcium-free fine sandstone, siltstone, and argillaceous siltstone, as well as relatively light-colored fine sandstone, siltstone, and enriched layer carbon dusts are typical features of distal bar sediment in this area. In the vertical direction, the proportion of light-colored fine sandstone and siltstone from bottom to top increases, and the proportion of dark argillaceous siltstone decreases. There are many types of sedimentary structures, including parallel bedding, lenticular bedding, wavy bedding, and horizontal bedding, wave marks can be seen and wormholes are developed in local layers. In addition, there are the drain pipes. Authigenic mineral can be seen from siderite. The logging curve is characterized by funnel-shaped or tooth-funnel-shaped lower part, low-to-medium amplitude, and the curve shape is similar to that of estuary sand dams, but the overall amplitude value is slightly lower than that of estuary sand dams [7].

2.2.6. Front sheet sand microfacies. The delta front sheet sand is the sediment by action of estuary sand dams and distal bar through normal lake waves and storm waves, and then transports the sediments deposited on the flanks of the dam, the sedimentary thickness is small and the area is large. The features
of delta front sheet sandstone in this area are as follows: the rock types are green-gray middle-layered calcareous fine sandstone, medium-fine sandstone, which are well sorted, calcareous cemented, and pure in quality. Parallel bedding is extremely developed. The thickness is mostly 1 to 2 m. The logging curve is characterized by finger shape, bayonet shape, medium-to-high amplitude, and is dominated by reverse cycle.

3. Distribution Features and Sedimentary Facies Model of Sedimentary Facies Belt

According to the requirements, the sedimentary facies belt distribution of the target oil layer in the study area was carried out. Finally, the above-mentioned research results were comprehensively summarized, and the sedimentary facies model of this area was built.

3.1. Provenance direction
Judging from the distribution of heavy minerals and predecessors’ research results, there are two provenance areas during the sedimentary period of the target oil layer in the work area: one in the north-east area outside the area, and the other in the southwest area outside the area. It can be seen from this that the work area during this period is the convergence sedimentary area between the northern water system north of the moon bubble and the Tongyu-Baokang water system.

3.2. Facies analysis of the well-tie profile
In order to confirm the plane distribution of the sedimentary facies belt in the area and explore the evolution features of the sedimentary facies within the layer, three profiles were dissected from west to east, one profile was dissected from northeast to southwest (Fig.4), it can be seen from the facies analysis and comparison diagram of the four well-tie profile that the depth of the lake basin water body present evolution feature from deep to shallow and then to deep during the sedimentary period of the target oil layer. The reservoir development period of the target oil layer is in the middle and late period of this geological historical period, the types of sand bodies include underwater distributary channel, estuary sand dam, distal bar, and front-edge sheet sand.

3.3. Plane distribution features of sedimentary facies belt
On the basis of the above research, plane facies belt division was carried out for the sedimentary facies of the target oil layer (Fig.5).

The sedimentary facies types of the target oil layers in this area are most developed in the front subfacies and prodelta subfacies of delta underwater sedimentation, the scale of the northern delta is the largest scale and there is only a few distribution in the southwest, it can also be seen from the distribution map of the sedimentary facies belt above that, three types of sand bodies: estuary sand dam, distal bar, and front sheet sand are distributed contiguously, the latter is the sedimentary outcome again of the former two after being reformed by lake waves. The lake waves near the estuary have large energy and strong effects, and the formation of sheet sand is undoubtedly; although the effect of the waves on the delta front belt is not strong, the storm can increase its energy sharply, this should be the reason why the formation of delta front sheet sand, and cause the dam sand to be contiguous.

3.4. Sedimentary facies model
Synthesize provenance direction, sedimentary facies types and distribution features of the work area, according to the principle of facies sequence, the sedimentary facies model of the target oil layer is summarized (Fig.6), all the research results of the above-mentioned sedimentary facies are overly generalized, it shows that the work area is located in delta sedimentary environment during this geological period, the main provenance comes from the north and southeast, and the secondary provenance comes from the southwest, the work area is the convergence area of the tripartite water system. The supply of detrital material is sufficient, and delta sediment has developed.
4. Conclusion
1. The sedimentary facies types of the target oil layers in this area are the most developed in the front subfacies of delta underwater sediment and the prodelta subfacies. The main sedimentary microfacies include underwater distributary channels, underwater natural leves, distributary bays, estuary dams, distal bar, and sheet sand.
2. The study area is the largest in the northern delta;
3. The reservoirs in the study area are mainly underwater distributary channels, estuary dams, distal bars and front sheet sand. Because it is located in the delta front belt and the river channel is at the end, although the action of lake waves is not strong, the storm can increase its energy sharply, and makes the three types of sand bodies: estuary sand dam, distal bar, and front sheet sand distributed contiguously;
4. The sedimentary facies model of the study area shows that the main provenance of the geological period come from the north and southeast, the secondary provenance comes from the southwest, and the work area is the convergence area of the tripartite water system. The supply of detrital material is sufficient, and delta sediment has developed.

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