Influence of mid-term base level cycle changes on the development characteristics of shallow water delta sand bodies: A case study of the Fuyu oil layer in the Mu 17 block in the southern Songliao Basin

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Abstract: The Fuyu oil layer in the southern Songliao Basin is a shallow-water delta sedimentary system. Frequent changes in the base level lead to obvious differences in the superimposed style, scale and geometry of the sand bodies, which seriously affects the distribution of remaining oil. Taking the Fuyu oil layer in the Mu 17 block in the southern Songliao Basin as an example, using a large number of cores and logging data in the dense well pattern development area, based on the relationship between the accommodated space (A) and the sediment supply (S), it is clear that The Fuyu oil layer develops the superimposed styles of cut-stack, superimposed and isolated sand bodies. In the depositional period of MSC1 and MSC2, the superimposed style of the cut-and-stacked sand body was the main one; in the depositional period of MSC3, the superimposed style of the superimposed sand body was dominant; in the depositional period of MSC4, the sand body was the least developed, and the superimposed style of the isolated sand body was the main one.This study has important guiding significance for clarifying the influence of medium-term base level cycle changes on the superposition law of shallow water delta sand bodies.

Key words: Fuyu oil layer; high-resolution sequence stratigraphy; base level cycle; shallow water delta; sand body stacking style.

1. Introduction

After T.A.Cross proposed the principle of high-resolution sequence stratigraphy[1], scholars at home and abroad carried out a lot of research, and introduced this theory into the study of continental petroliferous basins[2,3]. Practice has proved that this theory can be well applied to continental basins with frequent climate changes, fast changes in accommodating space and sediment supply rate[4]. Although predecessors have carried out a lot of research on the sand body distribution and sedimentary evolution of the Fuyu oil layer in the southern Songliao Basin, there are few studies on the influence of high-frequency base level cyclic changes on the sand body development characteristics under the condition of dense well pattern[5,6], resulting in unclear understanding of the distribution characteristics and controlling factors of sand bodies within the high-resolution sequence stratigraphic framework, which restricts further oil and gas exploration and development. Taking the Fuyu oil layer in the Mu 17 block in the southern Songliao Basin as an example, the development characteristics and controlling factors of sand bodies in the high-resolution sequence stratigraphic framework are analyzed, and the influence of mid-term base level cycle changes on the development characteristics of shallow water delta sand bodies is discussed.

2. Regional geological overview

Block 17 of Mumumu Oilfield is located in the south of Songliao Basin and the northwest of Songyuan City, Jilin Province, and is structurally located in the west of Fuxin uplift belt in the central depression of Songliao Basin[7]. The fuyu oil reservoir is located in the fourth member of Quantou Formation, and the stratum thickness is 80 ~ 120m. It can be divided into 1 long-term (LSC), 4 medium-term (MSC1 ~ MSC4) and 12 short-term base-level cycles (SSC1 ~ SSC12) from bottom to top. Fuyu oil reservoir in the study area is shallow water delta deposition, and the provenance is southwest Baokang water system[8], which can be divided into delta plain and delta front subfacies. The distributary channel sand body spatial development rule is very complex.

3. Evolution law of sand bodies in Fuyu oil layer

In MSC1 period, the provenance supply was sufficient, and the study area was delta plain deposition with high energy, mainly distributary channel microfacies. The widest part of the channel is up to 1km, and the thickness of the channel sand body is between 8 and 12m. The lithology is mainly gray and grayish brown powder-fine sandstone, and the scale of the channel sand body is large. Due to the low accommodation space, multi-stage complex channels are developed, and lateral and vertical overlaps between channels are common (Fig.1a).

During the MSC2 period, the study area was dominated by compound channels, the thickness of the sand body was between 6 and 8 m, and the lithology was mainly gray and brown silt-fine sandstone. The degree of sandbodies is still severe, and the upper part of the channel sandbodies is incompletely preserved (Fig.1b).

During MSC3 period, the long-term datum level rose rapidly, and the distributary channel energy changed from high energy in SSC6 and SSC7 periods to low energy in SSC8 periods. Compared with MSC2 period, the channel size in this period became smaller, the thickness of sand body in short-term cycle was 5-7m, and the lithology was mostly gray-brown powder-fine sandstone, and the degree of sand body cutting and stacking became weaker (Fig.1c).

During MSC4, the long-term datum level rose to the highest. In SSC9 period, it was a delta plain subfacies, and the thickness of distributary channel sand body was about 5 ~ 6m, and the lithology was mainly gray siltstone, and there was almost no sand body overlapping phenomenon.

During SSC10 ~ SSC12 period, the study area evolved into delta front subfacies, the thickness of underwater distributary channel was between 3 ~ 5m, and the lithology was mainly gray argillaceous siltstone. The energy of the underwater distributary channel gradually disappears and the mouth bar sand body is deposited at its end (Fig.1d).

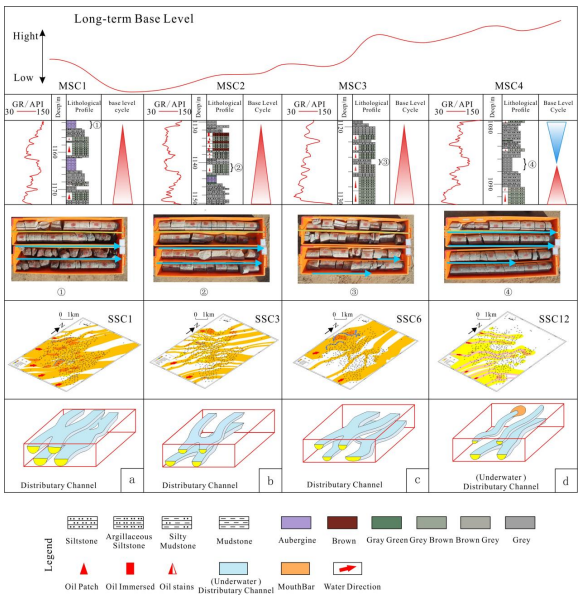

Fig. 1 Development characteristics of sand bodies in high-resolution sequence stratigraphic framework of Fuyu oil layer

4. Influence of mid-term base level cycle changes on sand body development characteristics

4.1 Influence of mid-term base level cycle on sand body stacking style

Sedimentary environment, base level rise and fall and other factors determine the development characteristics of reservoir sand bodies. With the rise and fall of base level, the thickness, width and superposition relationship of channel sand bodies will also change. According to the ratio of A/S, the stacking styles of Fuyu oil layer sand bodies are divided into cut-stacking, stacking and isolated (Fig.2).

1.Intersection type

Intersecting sand bodies were formed in the condition of low base level A/S<<1, and mainly developed in the MSC1 and MSC2 periods. Vertically, the sand bodies are cut and overlapped with each other, and the fine-grained sediments on the top of the channel sand bodies are usually difficult to preserve. The GR curve and the RLLD curve have a high amplitude difference, with slight dentification, and it is difficult to distinguish each stage of sand bodies according to their curve characteristics.

2..Isolated type

The isolated sand bodies were formed under the condition of A/S>1 with a large accommodation space, and were mainly developed in the late MSC3 and MSC4 periods. During this period, the river energy was weak, the transport capacity was weak, and the sediment grain size was fine. The thickness of the distributary channel sand body is obviously thinner, and the connectivity of the sand body on the plane is poor. The mouth bar began to develop in the delta front, which is mainly characterized by a single channel deposition. The channel and the mouth bar appear vertically separated. The GR and RLLD curves show a toothed bell shape or a funnel shape with an inverse rhythm.

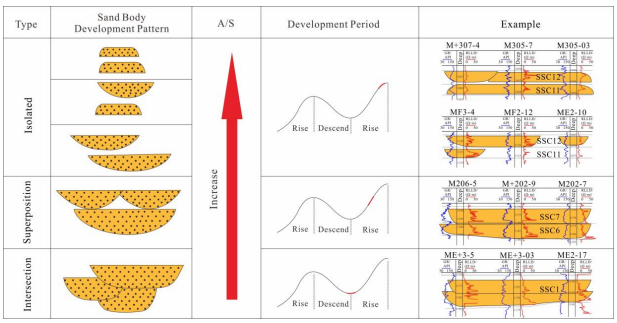

Fig.2 The relationship between the superposition style of the channel sand bodies in the Fuyu oil layer and the change of the base level

4.2 Influence of mid-term base level cycle changes on sand body development characteristics

Base level changes can cause relative changes in A/S values, and mid-term base level cycle changes have more prominent control over the development characteristics of reservoir sand bodies. Affected by the change of the mid-term base level, the Fuyu oil layer develops slicing-stacking-superimposing-isolated sand bodies from bottom to top.

During the depositional period of MSC1 and MSC2, the mid-term base level cycle was located at the lower position of the long-term base level, and the sand bodies were mainly of the cut-stack type. The sand body drilling rate is high, the sand bodies are mostly developed in continuous sheets on the plane, and the sand-to-ground ratio is generally greater than 50%. The sand thickness and sand-to-ground ratio in each short-term cycle are significantly higher than those of other short-term cycles. During the deposition of MSC3, the width and thickness of the sand bodies in the study area were significantly reduced, and the sand bodies developed from sheets to strips on the plane. During the deposition of MSC4, the mid-term base level cyclically rose to the highest level of the long-term base level, the shale content greatly increased, and the drilling rate of sand bodies was extremely low, mainly isolated sand bodies, and the sand bodies were intermittently distributed on the plane. The ratio is generally less than 40%, the width of the sand body is small laterally, and the connectivity is poor (Fig.3).

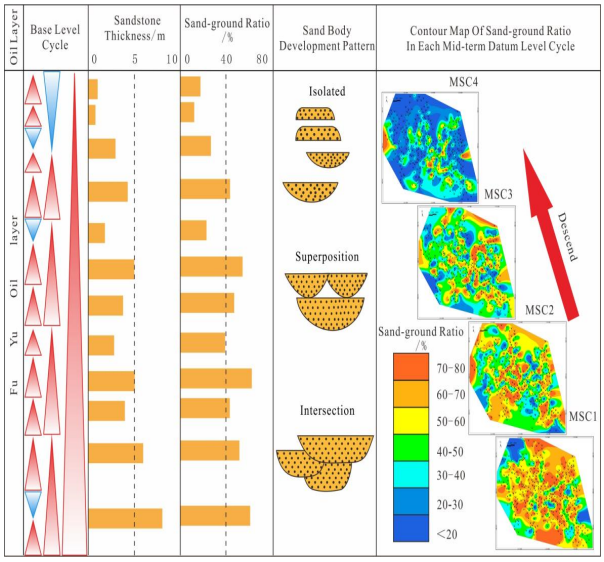

Fig.3 Distribution characteristics of mid-term base level cyclic sand bodies in Fuyu oil layer

When the short-term cycles are in different evolution stages of the mid-term base level cycle, the scale of sand bodies in each short-term cycle will also be different. In the early stage of the mid-term base level rise, the sand layer thickness and the ratio of sand to ground in the short-term cycle are significantly higher; in the late stage of the mid-term base level rise and near the rise-fall transition position, the accommodating space is relatively high, and the thickness of the sand layer in the short-term cycle, the ratio of sand to ground are significantly lower.

5. Conclusion

(1)During the depositional period of MSC1 to MSC4, the study area evolved from a delta plain subfacies to a delta front subfacies. The scale of the channels in each mid-term base level cycle decreased, and the lateral and vertical overlap between channels were weakened.

(2)In the study area,three types of sand body stacking styles were identified: intersection type, superposition type and isolated type. When the long-term base level changes from low to high, the sand body stacking style of the mid-term base level cycle shows the characteristics of transition from cutting-stacking-stacking-isolating type, and the sand thickness and sand-to-ground ratio in the short-term base level cycle generally show the same pattern. decreasing trend.

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