Sequence stratigraphic characteristics of fuyu oil layer of the 4th member of Quantou Formation in Sanzhao Sag, Northern Songliao Basin

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Abstract

Fuyu oil layer in Sanzhao Sag is one of the key oil and gas exploration fields in northern Songliao Basin. It is rich in oil and gas resources and has become the key target area for next step of tight oil exploration and development. On the basis of fine core observation and description, well logging, logging and seismic analysis, the identification marks of high resolution sequence boundary of Fuyu oil layer are defined. On this basis, the sequence division scheme of the area is established, and the sequence stratigraphic framework of the study area is established. Then the sedimentary system in high-resolution sequence framework is studied. The study shows that the Fuyu oil layer is a complete long-term base-level cycle structure, the top of which is a lithologic-electrical catastrophic surface with integrated contact with the first member of Qingshan Formation, and the seismic section shows a group of stable reflection homogeneous axes. The interface between the 4th member of Quantou Formation and the first member of Qingshan Formation presents an integrated contact lithologic-electrical abrupt change surface, which is shown in the box-shaped and bell-shaped lower abrupt change on the logging curve. The sequence interface at the bottom of the 4th member of Quantou Formation is a regional unconformity interface. The 4th member of Quantou Formation can be divided into 3 medium-term base level cycles and 7 short-term base level cycles, and the ascending incomplete symmetrical, asymmetrical cycle structures are developed.

Keywords

Sequence stratigraphic; sequence boundary; fuyu oil layer; Sanzhao Sag; Northern Songliao.

1. Introduction

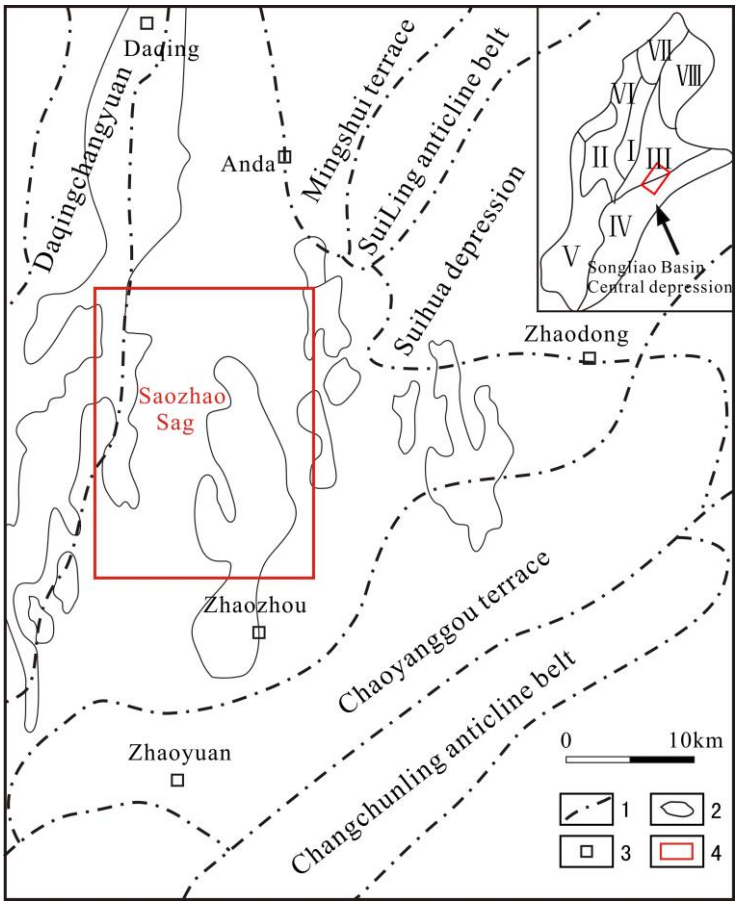
Fuyu oil layer in Sanzhao sag is one of the key oil and gas exploration fields in northern Songliao. Since the discovery of oil source by drilling in 1960s, fine reservoir description, seismic prediction of reservoir sand body and comprehensive petroleum geology research have been carried out successively. Some exploration and development work has also been done in each block of Sanzhao sag. The terrain is very gentle, and the overall strata thickness varies little in the study area. With the successive development of the main blocks favorable for the development of structures and sandstones, the sequence stratigraphy and sedimentary facies of 4th Member of Quantou Formation in Sanzhao Depression, which is a small-scale single-layer sand body with complex spatio-temporal distribution of sedimentary system, are relatively weak, and oil and gas exploration has not made a major

breakthrough, resulting in the enlargement of the development area and blank. It is difficult to work well in the area.

Therefore, according to the principle of high resolution sequence stratigraphy, based on fine core observation, combined with logging and logging data, 4th member of Quantou Formation is divided into fine sequence stratigraphy, summarizes the structural types of base level cycle, establishes high resolution sequence stratigraphic framework, and analyzes the distribution of sedimentary facies in the stratigraphic framework. The characteristics and evolution rules are of great significance for the deployment of oil and gas exploration and the success rate of exploration.

2. Regional geological setting

Songliao Basin is a large-scale Mesozoic-Cenozoic continental composite petroliferous basin with fault-depression dual structure in Northeast China. It is the most abundant non-marine sedimentary basin with oil and gas resources in the world. The total basin area is about $26\times10^4 km^2$. Sanzhao sag is located in the northern part of Songliao basin. It is a secondary structural unit in the central depression of the basin (Fig. 1). The northwest part of Sanzhao depression is located on Daqing placanticline and the southeast part is connected with Chaoyanggou terrace. The Sanzhao depression consists of seven tertiary structural units, namely Shangjia nose structure, Shengping nose structure, Fangtun model nose structure, Shengping West syncline, Xujiaweizi syncline and Yongle syncline, which are generally characterized by four noses and three concaves(Fig. 1).



I. Daqing placanticline; II. Qijia-Gulong sag; III. Sanzhao sag; IV. Chaoyanggou terrace; V. Changling sag; VI. Longhupao-Honggang terrace; VII. Heiyupao sag; VIII. Mingshui terrace; 1. Secondary structural zoning line; 2. oilfield; 3. city; 4. Study area.

Fig.1 The scope of area and geological structure diagram

The 4th member of Quantou Formation was located near the lake in the whole sedimentary period, mainly developed shallow-water delta facies, and partly lake facies appeared in the late 4th member of

Quantou Formation. The main differences between shallow-water delta and normal delta lie in shallow sedimentary water, gentle terrain, weak hydrodynamic conditions, fine grain size of sediments, high shale content and small scale of sedimentary structures. In the study area, delta distributary channels are well developed, and there are no semi-deep lake-deep Lake subfacies and pre-delta subfacies.

3. Sequence stratigraphic division

3.1 Sequence division scheme

Guided by high-resolution sequence stratigraphy, this paper divides The 4th member of Quantou Formation of Sanzhao Sag into three medium-term base-level cycles and seven short-term base-level Cycles by using existing drilling and logging data (Fig. 2).

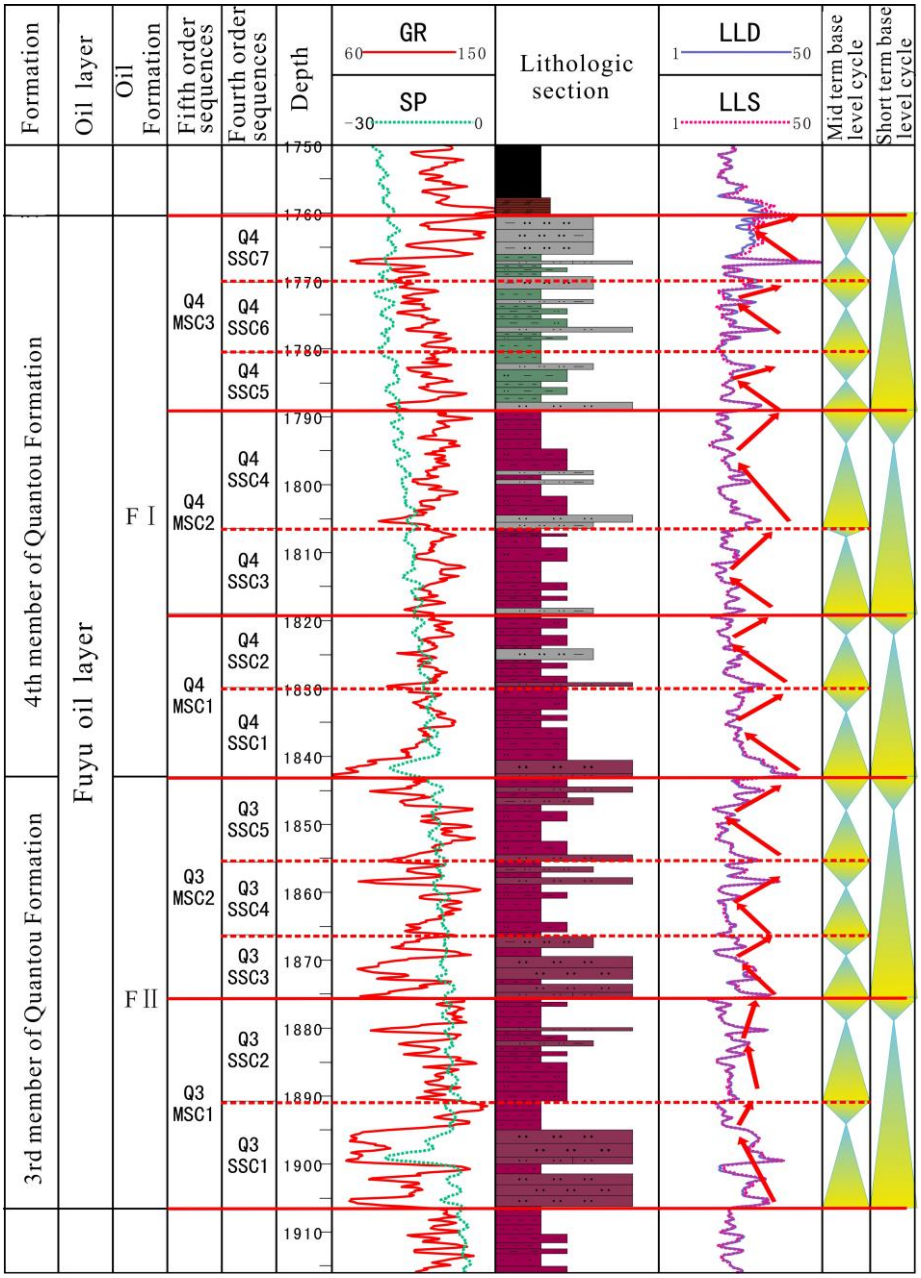


Fig.2 High resolution sequence boundary feature of Fuyu reservoir in Sanzhao sag.

3.2 Sequence boundary identification

The whole section of Sanzhao area is overlying Qingshankou Formation and underlying Quan3 Formation. Previous studies show that the 4th member of Quantou Formation is a long-term ascending

semi-cyclic sequence. There are three sets of oil shale standard beds in Qingshankou Formation overlying the 4th member of Quantou Formation, which have the largest lake flooding deposit. The standard beds are distributed stably in the whole basin. T2 reflector is characterized by moderate to strong amplitude and moderate to strong continuity on seismic section. Logging curves show obvious characteristics of high resistivity, high gamma ray and high time difference, and T2 reflector is formed. The idea of the three order sequence has been widely accepted by scholars. The fifth-order sequence boundary in the study area is generally located at the bottom of the river bed with a certain range of distribution, beneath which there is a paleo-soil layer rich in calcareous nodules, and above which there are erosion and erosion interfaces and muddy gravel sandstone deposits.

On the basis of previous studies, this paper synthesizes core, logging, logging and other data, summarizes the four-level sequence boundary identification marks in Quan4 member, which can be divided into the following two types.

3.2.1 Geological mark

The erosion markers of erosion surface and conglomerate retained in river bed, paleosol, root soil layer and calcareous nodule, which are observed in the core, represent the exposure markers of discontinuous products of sedimentation, and mudstones formed under different environments of purple-red and grey-green.

The erosion surface at the bottom of the river and the sediments trapped at the bottom represent the depositional background of the area where the datum level falls below or coincides with the surface, and the accommodation space is zero or even negative, which is the position of datum conversion. Plant root and soil layers and other exposure indicators are the product of sedimentary discontinuity, which shows the particularity of no obvious sedimentation, and no strong denudation, which is mainly applicable to the coastal zone, that is, most of the time in the underwater environment, there is a certain time for the water environment. Gray-green and gray-black represent the reduction environment of mudstone formed in the delta front underwater, and purple-red and yellow-orange represent the oxidation environment of mudstone formed in the delta plain continental.

3.2.2 Logging mark

Among all kinds of electrical curves, natural gamma curve and apparent resistivity curve are more reliable, followed by natural potential curve. The response values of natural gamma-ray and apparent resistivity logging curves are mainly affected by the shale content, sorting and grain size variation of sediments. Therefore, the variation of log amplitude and curve shape can provide hydrodynamic conditions of sedimentary environment, source supply conditions, sedimentation mode, section structure and sedimentary facies evolution sequence, etc. Many aspects of information.

The logging section is located at the top of the quasi-sequence formation or at the abrupt change of lithology, and the logging curve is located at the top of the funnel curve or at the place where the amplitude of the logging curve changes obviously.

3.3 Base level cycle structure types

The base level cycle is determined mainly by the change of phase or phase sequence. It can record the complete cycle of the dividing line between two time units. It is controlled by the boundary of different causes. The interface of the base level cycle is composed of two half cycles of rising and falling on the base level. The cyclicity of strata is the response of sedimentation, erosion, non-sedimentation caused by sediment passing through, starvation caused by non-compensation and even non-sedimentation to the spatial migration of time. The stratigraphic cycle of different strata in stratigraphic records records the corresponding base level cycles.

By comparing and analyzing the rock-electricity relationship of coring wells, the sequence in the study area has a complete half-cycle sedimentary record of ascending and descending on the base level, and usually has a rhythmic cycle of coarsening and then coarsening. The ascending half-cycle is usually composed of siltstone and argillaceous siltstone of river course or crevasse fan, and the descending

half-cycle is usually composed of river course or argillaceous siltstone of crevasse fan. The silt and mudstone interbedded in the embankment or natural dyke. According to the thickness variation of ascending and descending semicycles in sequence, three types of base-level cycles can be classified: (1) incomplete symmetry with ascending as the main type; (2) near complete symmetry with ascending and descending semicycles nearly equal; (3) incomplete symmetry with descending as the main type.

3.3.1 Medium-term base level cycle

The 4th member of Quanzhou Formation is divided into three medium-term base-level cycles from bottom to top. Each medium-term cycle is generally superimposed by two to three short-term cycles, and the whole cycle is asymmetrical cycles dominated by ascent. The mid-term base-level cycle is composed of a series of short-term base-level cycles. The type of the mid-term cycle is controlled by the structure type and structure style of the short-term cycle. The superimposed pattern of C is generally retrograde, while that of progradational or accretionary strata is above it. The lake water across the interface changes from overall upward to overall upward shallow, and the interface is a relatively largest lake flooding surface in one stage.

3.3.2 Short-term base level cycle

The sequence structure of short-term cycles is mainly determined by the change of facies or facies sequence. It can be a complete cycle with a dividing line of two time units, or an incomplete cycle representing the rising or falling period of development.

The short-term base-level cycles of SSC1 and SSC2 are mainly delta plain sediments, and the short-term base-level cycles are incompletely symmetrical cycles with upward ascension. The channel sand bodies favorable for reservoir development are mainly concentrated in the early half-cycle of SSC3 and SSC4. The short-term base-level of the plain develops complete symmetric cycles and up-rising incomplete symmetric cycles. The channel sand bodies favorable for reservoir development are distributed in the Early-Middle period of the ascending semi-cycle. SSC7-SSCS3 short-term cycles developed a shallow lake-delta front subfacies, and the short-term base-level of the front developed an incomplete symmetric cycle with near-complete-complete symmetric cycle and upward-dominant asymmetric cycle, while the short-term base-level of the shallow lake developed an incomplete symmetric cycle with downward-dominant asymmetric cycle.

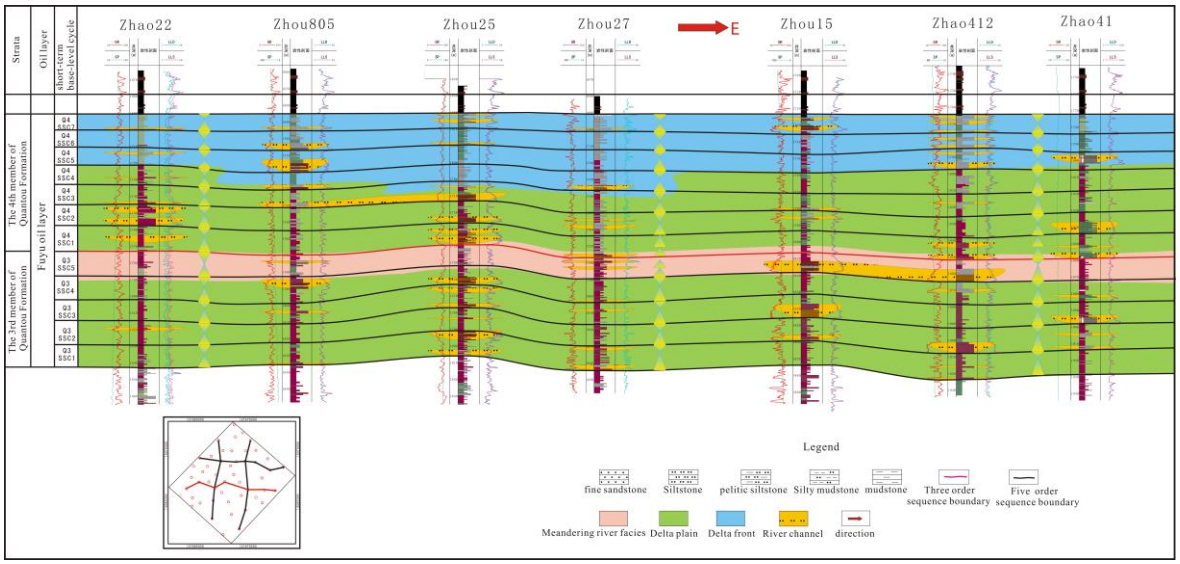


Fig.2 High frequency sequence stratigraphic framework and depositional system distribution in Sanzhao area

4. Establishment of sequence stratigraphic framework

According to the cyclic isochronal correlation rule of high-resolution sequence stratigraphy, on the basis of single-well sequence stratigraphy division, the well-connected section in the study area is

divided and correlated, and the high-resolution sequence stratigraphic correlation framework of the 4th member of Quantou Formation is established. The one-dimensional single-well stratigraphy and lithologic information are transformed into two-dimensional sequence information.

According to the analysis of sequence profile of EW-trending continuous wells, the 4th member of Quantou Formation is divided into three medium-term base level cycles and seven short-term base level cycles. The top and bottom interfaces of the connecting well section are relatively obvious, the medium-short term base-level cycles are well developed, and the lithology and electrical properties of each interface have a good corresponding relationship. Thickness of Zhao 22 well from well to the eastern part of the well has little change in general. It is about 80-89.11 m in the range of vertical SSC5, SSC2, SSC1 single-layer sandstone thickness is relatively large, the maximum can reach 10.5 m.

5. Conclusion

There is a lithologic-electrical catastrophic surface of integrated contact between the 4th member of Quantou Formation and the first member of Qingshan Formation, and a regional unconformity sequence boundary marker is developed at the bottom of the 4th member of Quantou Formation. The fifth-order sequence boundary in the study area is generally located at the bottom of the river bed with a certain range of distribution, beneath which there is a paleo-soil layer rich in calcareous nodules, and above which there are erosion and erosion interfaces and muddy gravel sandstone deposits.

The 4th member of Quantou Formation is a long-term ascending semi-cycle, Q4 bottom and Q3 top boundary are the bottom boundaries of the sequence, T2 reflector is the top boundaries of Q4 sequence, sequence internal bottom-up can be divided into three medium-term base-level cycles (MSC1-MSC3), seven short-term base-level cycles (SSC1-SSC7).

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