Research on the Evolution Law of Sedimentary Characteristics of Quansan and Quansi Members in the Da-anbei Area

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Abstract. Based on the analysis of core and well logging data, this paper analyzes the Quansan and Quansi sections in the Da-anbei area, the south of Songliao basin, to confirm sedimentary environment and establish corresponding logging facies model. After identifying each single well facies, the sedimentary microfacies distribution map of Da-anbei oil field was drawn, and the sedimentary evolution law of the area was established. The research indicates that, in the Da-anbei, the Quansan and Quansi sections successively developed the (high-energy) far-shore delta distributary plain, (low-energy) far-shore delta plain, nearshore delta plain, lake and shore interactive sedimentary area and the delta front sedimentary area.

1.Introduction

The strata in the area is well developed. From the bottom to top, the drilling strata is Quantou formation of three section(YangDachengzi oil layer) and four section (Fuyu formation) in the lower cretaceous , Qingshankou, Yaojia, Nengjiang, Sifangtai, Mingshui formation in the upper cretaceous system, the tertiary and quaternary system. Among them, deposition of the Quan san to Nenjiang formation is continuous and the stratum thickens eastward. The lithology of Quansan is brown and gray siltstone, fine sandstone and interbedded with fuchsia and gray mudstone. The thickness of Quansi formation is 100-200m. The lithological association is variable thickness alternating layers which are composed by siltstone, fine sandstone and mudstone. The middle and lower lithology is mainly fuchsia mudstone and fine sandstone, and the upper is dark mudstone and siltstone.

According to sedimentary cycle, marker layer, thickness, and high-resolution sequence stratigraphy, based on the division and comparison of small layers of skeleton profile, the division of single-well cycle is adjusted to achieve the unification of the stratified boundary within the whole region, and to complete the division and comparison of small layers of 181 Wells in Quansan and Quansi in Da-an bei area. There are 3 sand groups in the Quansan memeber, 9 small layers (the number of small layers is 13-21). There are 4 sand groups in the Quansi, 12 small layers (no. 1-12) and 19 single layers.

2. Sedimentary facies characteristics

2.1. source analysis

According to the analysis of 874 heavy mineral data from 29 Wells in the Da 'anbei, the heavy mineral types in this area include zircon, tourmaline, garnet, white titanium, anatase, cassiterite, epidotite and magnetite, accounting for 81.6% to 100% of the total amount of heavy mineral in sandstone. Among them, the main heavy minerals are zircon (17.2% ~ 100%), tourmaline (0% ~ 15.6%), garnet (0% ~ 55.2%) and white titanium (0% ~ 71.9%) account for more than 80% of the total heavy mineral content. Then, there are anatase (0% ~ 20%), cassiterite (0% ~ 1.8%), epidotite (0% ~ 3.9%) and a small amount of magnetite. the content of heavy minerals accounts for about 20% of the total content. Among them, the stable heavy minerals are mainly zircon and tourmaline, which do not contain rutile, and the secondary heavy minerals are garnet and white titanium. The content of stable heavy mineral zircon is generally high, and the average content is about 85%.

The higher ZTR index value indicates the higher maturity of heavy minerals, and the farther away from the source area. Therefore, according to the variation trend of ZTR index value, the transport direction and distance can be roughly determined to analyze the direction of matter source. The ZTR index contour map (figure 1) was compiled based on the analysis and identification results of 29 samples of heavy mineral data measured in Honggang bei – Da-an bei area. It can be clearly seen from the figure that the ZTR index value is generally distributed from the northwest to the west to the southeast to the east and gradually increased from the southwest to the northeast, indicating that the provenance in the sedimentary period of the study area is mainly from the western source (Honggang and *yingtai river systems*), and the secondary provenance is from the southwest.

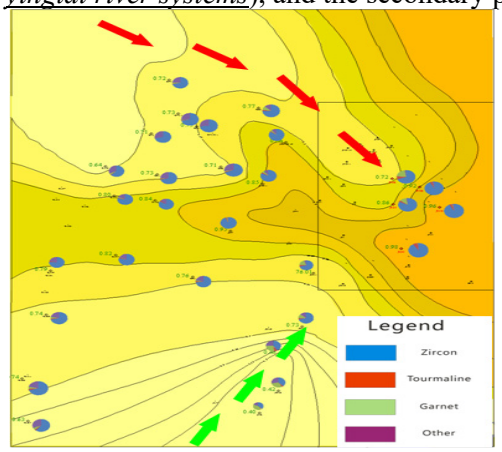

Figure 1. contour map of ZTR index

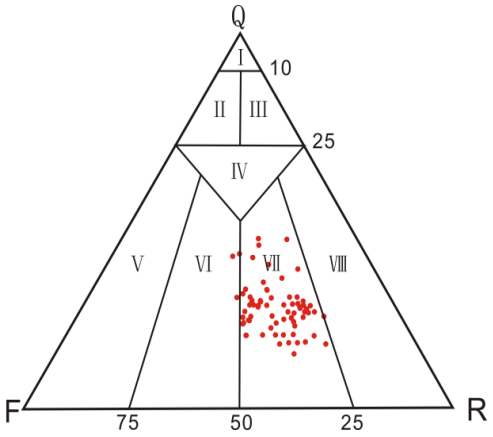

Figure 2. sandstone composition classification of Quansan and Quansi in Daanbei oilfield

2.2. Classification of sedimentary facies makers

2.2.1. lithology

According to the core observation of 8 cored Wells in the study area and the analysis results of 148 rock slice identification (figure 2), the detrital composition of the sandstone in this area is mainly composed of detritus and feldspar, followed by quartz, the type of sandstone is mainly feldspar lithoclastic sandstone, and has small amount of lithic-feldspar sandstone.

2.2.2. particle size distribution

The PQ-QR-RS section on the C-M diagram (figure. 3).

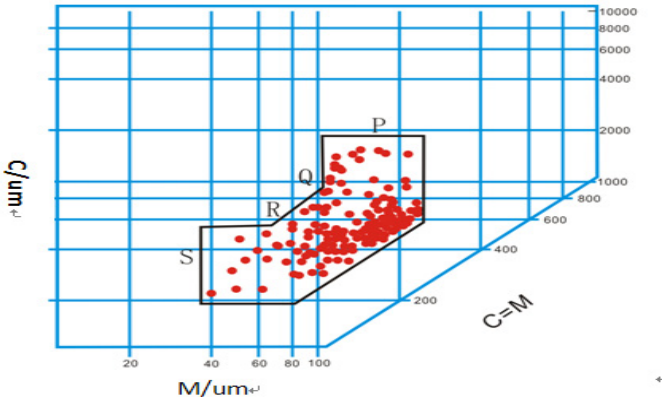

Figure 3. C-M diagram of the sandstone reservoir of Quansan and Quansi member in Da-anbei oilfield

The PQ section deposition is dominated by rolling transportation. The QR section is parallel to the C=M baseline, representing the sedimentary mechanism of progressive suspension. In the fluid, the suspended substance gradually becomes finer in particle size from bottom to top and lower in density. It is usually located at the bottom of the flow and is often caused by eddy currents. But when the eddy velocity decreases, a rapid roll occurs. The biggest characteristic of the progressive suspended material is the increase of C in proportion to M. The RS segment is mainly distributed in homogeneous suspension transportation. Although RS segment occurs, its development is poor, indicating that the water in the channel is shallow. The analysis of C-M diagram and particle size probability curve shows that the sediment transport in this area is mainly the mechanism of traction flow.

2.2.3 Logging curve characteristic

The target layer of the study area can be divided into 4 categories, namely fine siltstone, argillaceous siltstone, silty mudstone and mudstone, according to its main lithologic characteristics. As the reservoir in this area is a low porosity and low permeability reservoir, the lithology is relatively compact, the fluctuation of acoustic time difference is not big, and the response to lithology is not sensitive. Although resistivity curve is affected by many factors such as lithology, physical property and fluid property, it can reflect lithologic characteristics better in the research area. The natural gamma logging curve of mudstone mainly reflects the rock particles size and shale content in the stratum and is sensitive to the lithology. Therefore, the research mainly applies the natural gamma ray log and the dual-lateral resistivity log to analyze the lithology and distinguish different types of rocks and sedimentary facies. The main logging facies characteristics of Quansan and Quansi in Daanbei oilfield are established through research and analysis (table 1).

Table 1. Sedimentary microfacies electrical characteristics (reference) of the main oil-bearing layer of Daanbei oilfield

microfacies	Curve shape	Sandbody thickness (M)	Double lateral resistance rate (ΩM)	Gamma-ray value(API)
Main distributary channel	Thick box or toothed box - bell - shaped compound, thick ~ extra thick layer	5～15	15～38	70～95
Distributary channel	typical bell (or box), abruptly change at bottom , gradual change on the top, smooth - slight teeth	3～10	15～26M	70～100
Distributary channel marginal	Box, middle layer, bottom mutation, top gradient,dentate	2～5	10～22M	75～105

bank	features			
Abandoned distributary channel	Bottom high amplitude, middle upper middle amplitude, long bell shape, middle thick layer protruding gradually, jugged or slight jugged characteristics	1～4	10～20M	80～105
crevasse channel	Flat bell - shaped, middle, bottom – protruding,top-change gradual, smooth - characteristic	2～5	10～20M	80～105
natural levee	box- shaped, middle, bottom and top– protruding- change gradual, smooth - characteristic	1～3	5～10	80～110
crevasse splay	Middle amplitude/Flat funnel shape, extremely thin layer, top protruding – gradual change feature	1～3	10～15	75～100
overbank lamina sandbody	Single - finger or finger interlayer, very thin layer, top - bottom mutation	1～3	5～15	80～100
interdistributary bay	Low amplitude, linear or directly pinched finger, thick layer features	0	5～8	110～135

3. Types of sedimentary microfacies

3.1 distributary channel

Distributary channel microfacies is the main reservoir facies for researching delta plain subfacies. The lithology is medium and thick layer of fine grain arkose, lithic arkose, forming the underlying coarser particle size of positive rhythm. Sand body morphology on the transverse section are a lenticular or cuneate, it tends to thin-out toward river channel, the plane shaped like a tongue, the top siltstone with wavy bedding, parallel bedding contact with the underlying layer in alluvial fill. Log curve shows that the characteristics of the spontaneous potential curve are box, tooth box and bell

3.2 marginal bank microfacies

The microfacies of the marginal bank are mainly composed of medium-thick grey siltstone and fine sandstone with large and medium-sized trough or slab interlacing bedding, and parallel bedding. occasionally can be seen. The marginal bank microfacies are mainly developed in the concave bank of river. One side is adjacent to the sand body with the thickness of distributary channel, and the other side is mostly connected with the depression between distributary channels. This microfacies zone is most likely to form lithologic oil and gas reservoir. The morphological features of natural gamma curve in this zone are basically the same as that in the distributary channel, except that the amplitude of natural gamma curve is relatively low, which is in the shape of box, tooth box or bell.

3.3 natural levee microfacies

The natural levee in the study area is not well developed, and its lithology is dominated by gray-dark gray fine-grained arkose and siltstone, followed by argillaceous siltstone and silty mudstone, and the thin layer of mudstone is locally sandwiched. The natural potential curve is serrated, the lower part of the curve amplitude is higher than the upper part, and the natural levee sand body in the study area is dry layer and non-permeable reservoir.

3.4 crevasse splay

The sediments are mainly grey fine sandstone, siltstone and argillaceous siltstone, the mineral content is quartz, detrital and feldspar with low maturity. Sand layer is generally 1m ~ 3m thick. The log curve showed that the amplitude of spontaneous potential curve was mostly medium to high, and the center was convex serrated. It is shown that the mean value of the formation is poor and hydrodynamic instability occurs during deposition.

3.5 upperwater interdistributary bay

The lithology is mainly fuchsia, grey-green mudstone and silty mudstone with thin layers of siltstone. The mudstone is more and less sandstone in the microfacies, and its natural potential curve is close to the baseline, with low fluctuation and high natural gamma curve value. Compared with natural potential curve of distributary channel or point bar, its curve undulation is obviously low and gentle.

4. plane characteristic of sedimentary microfacies and sedimentary evolution law

During 18-21layer sedimentation time, the crust decline was slow, at this time, under the influence of regional arid climate conditions in Da-anbei and the control of the Yingtai-Honggang river system which mainly developed the far-bank river dominated shallow water delta plain (high-energy), the overall positive cycle characteristics were obvious. The river energy and sand carrying capacity is strong, large scale, strong vertical and plane cutting ability, and a large amount of detrital materials are deposited, forming a large-area meander (branch) channel sand body. The bottom scour discontinuity surface is distinct, lag deposit is developed (It mainly shows directional arrangement of boulder clay and a small amount of silty gravel). Fine sandstone and siltstone developed upward, cross bedding and large oblique bedding developed. The interdistributary bay is mainly composed of fuchsia mudstone, pure, brittle, with conchoidal fracture and striation, which reflects the weak-medium oxidizing environment and is rare in grey-green mudstone. All of this shows that the climate of this period is more arid, and the weak reductive sedimentary environment such as the inter-distributary depressions is less. (figure 4)

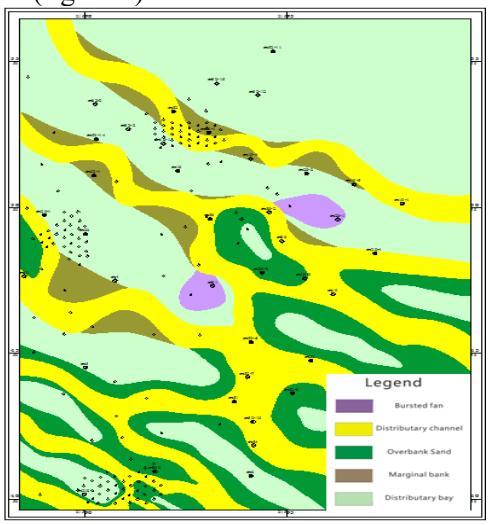

Figure 4. F19 small-bed sedimentary microfacies plan in the Quansan section, Da-an Bei

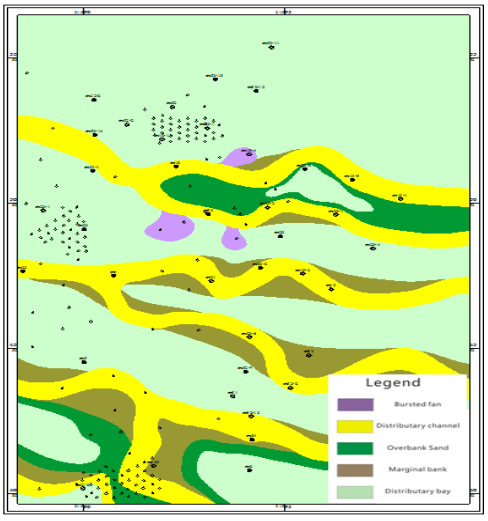

Figure 5. F17 small-bed sedimentary microfacies plan of the Quansan section, Da-an Bei

13-17 Small stratum sedimentation: during this period, the crust in the Da-anbei area was still in a slow decline stage, and the study area was still under the arid climate condition, it mainly developed high-energy → (low-energy) river-controlled shallow-water delta plain subfacies under the control of the Yingtai-Honggang river system. In this sedimentary stage, the river is still relatively developed, and the river's energy and sand carrying capacity are still strong, and its vertical and planar cutting ability are strong. A large amount of debris materials are deposited, and a number of meander branching channel sand bodies are formed in the study area. The lithology of interdistributary bay is

mainly red mudstone, which reflects the dry, weak and moderate oxidation environment. (figure 5)

6-12 small stratum sedimentation: during this period, the crust in the Da-anbei area was in a period of shock and decline. As the topography was gentle at that time, large areas of the crust were submerged by shallow water when it was decling and relatively large areas of the crust were exposed when it was raised. Under the control of the Yingtai-Honggang river system, low-energy nearshore (shallow water) delta plain subfacies developed. The characteristics of distributary channel are still obvious, mainly with straight branching distributary channel, and its vertical direction is relatively developed, with monocline and cross bedding. Medium - weak oxidation, river overbank and road diversion were strengthened. The mudstone between the interdistributary area mainly is fuchsia, gray-green and variegated colors,pure and brittle, and has the characteristics of conchoidal fracture and striation. Local calcium gravel and grey-green mudstone began to increase, reflecting that the slowly rising base level led to the continuous rise of the underground water level and the increase of the depression area in the interdistribution area. (figure 6)

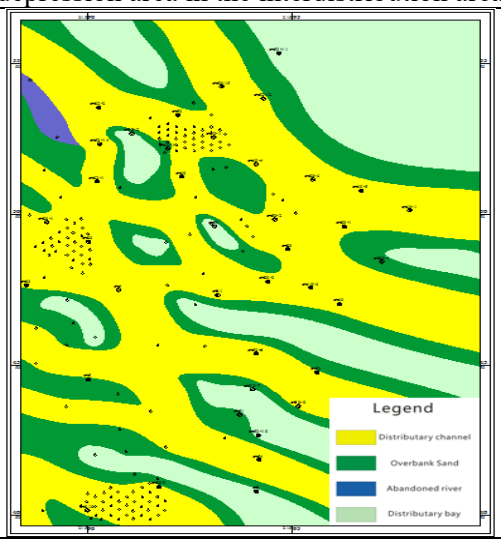

Figure 6. F12 small-bed sedimentary microfacies plan in the Quansi section, Da-an Bei

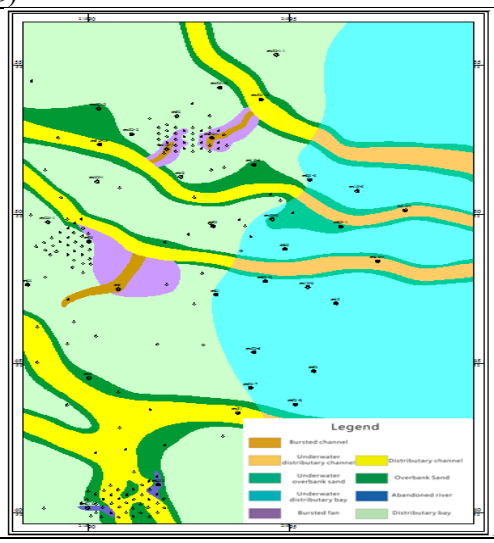

Figure 7. F5 small-bed sedimentary microfacies plan in the Quansi section, Da-an Bei

4-5 small layers of sedimentary period: Da-anbei areas was affected by crustal shock to decline, the ancient landscape is relatively flat, far away from the source, having the dual characteristics of oxidation environment on land and underwater reductive environment, the study area is located in the interaction sedimentary area of lake and shore, water system under the control of Yingtai – Honggang river system, low-energy nearshore shallow water delta plain and delta front subfacies deposition was developed. The mudstone is mainly of fuchsia, gray-green and variegated colors. It is pure and brittle, and it has the characteristics of conchoidal fracture and striation. The gray-green mudstone began to increase, reflecting that the gradual rise of the base level led to the continuous rise of the underground water level, and the area of the depression between the inter-distribution increased. The distributary channel is weak in energy and small in scale, Small single - branch channel often flow into the lake. (figure 7)

1-3 small layers of sedimentary period: mainly river-dominated shallow water delta front subfacies in the area, underwater distributary channel microfacies relative well developed, but its carrying sand capacity and flushing capacity decreased significantly, boulder clay at the bottom is of the small or disappear, the obvious fluctuant scour surface on land changes into a flat lithologic mutation, cycle amplitude decreases, and particle size is finer. the general lithology is mainly siltstone, Thin interlayer in river channel is developed.Underwater inter-distribution area mainly consists of grey-green massive mudstone, crumpled structure can be seen ,which reflects a weak reduction-reduction sedimentary environment. The end of the deposit, controlled by the overall

development trend of the Songliao basin, the base level is rapidly rising, the sediments supply is rapidly decreasing, the front delta subfacies deposition is mainly developed, At the bottom of Qingyi section, a thick layer of grey-black horizontal bedding mud (page) is deposited with a thin layer of siderite (bearing pyrite powder), showing the fossils of ostracean and fish fragments. The ostracean locally enrich into layers, and the bottom contains silty mudstone, forming extremely well-developed and widely distributed source rock and regional cap. (figure 8)

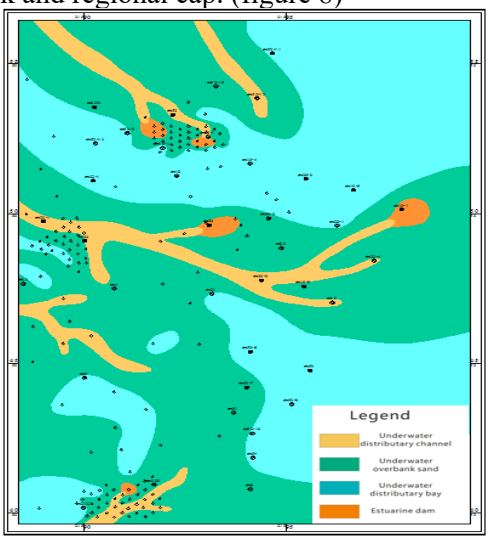

Figure 8. F3 sedimentary microfacies plan in the Quansi section, Da-an Bei

5. Conclusion

Under the background of overall crustal decline, the depositional period of Quansan and Quansi has been experienced five stages of change: The Quansan sedimentation period is in a slow decline stage of crust. During the early and middle depositional stage of the Quansi, the crust declining rate is accelerated, and the crust of the middle and late stage is in a slow decline stage and the rapid fall stage is in the late stage. During the change of these five stages, the Quansan and Quansi successively developed the (high-energy) far-shore delta distributary plain, (low-energy) far-shore delta plain, nearshore delta plain, interactive sedimentary area of lake and shore and the delta front sedimentary area.

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