Sedimentary facies characteristics of Yan 9 oil-bearing formation of Yan'an Formation in D area of northern Shaanxi

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Abstract. In order to promote the exploration and development of oil reservoirs in northern Shaanxi, the study of sedimentary facies characteristics in D area was carried out. Using core, logging and logging data, the Yan 9 oil layer group in the D area is divided into two small layers, Yan 91+2 and Yan 93. Based on the core description, the analysis of single-well sedimentary facies, continuous-well sedimentary facies, and planar sedimentary facies is carried out. It is believed that the Yan 9 member of the study area is a delta plain deposit, which is mainly composed of distributary channels, natural embankment and inter-branch swamp microfacies. Vertically, the sand bodies in the Yan 9 oil-bearing group are discontinuous, with distributary channels and inter-branch swamps mainly developed. Horizontally, the channels of the Yan 9 oil layer group spread out in strips on the plane, extending in the northwest-southeast direction. There are 6 main rivers in the study area of Yan93 stage and 7 main rivers in Yan91+2 stage. Channel deposits constitute the main body of the sand body skeleton and are also the main oil and gas enrichment area.

1. Introduction

The Ordos Basin is the second largest basin in China. The Jurassic Yan'an Formation in the basin made a major breakthrough in the early stage of exploitation, and has been the main target layer for oil and gas exploration ever since [1,2]. The Yan’an Formation in the basin is a set of coal-bearing rock series, belonging to fluvial marsh facies deposits. It is a proliferation-type multi-cycle deposit composed of sandstone, mudstone, coal or carbonaceous mudstone in the vertical position. In the early stage of deposition, it is mostly a thick multi-stage braided river coarse clastic rocks filled with sediments[3,4]. The rock and mineralogical characteristics are mainly gray-white and light gray feldspar quartz sandstone, and the rock structure is mature. Kaolin is cemented with voids, and more muscovite flakes can be seen, and sandstone has good oil storage properties[5].

Area D is located in the northern Shaanxi area of the Ordos Basin. It is a loess hilly and mountainous area with an altitude of 1500 ~ 1800m. The sedimentary system is located on the southwest bank of the lower reaches of the ancient Ningshaan river. This area is a favorable zone for oil and gas generation and storage. The Jurassic Yanchang Formation in the Ordos Basin consists of 10 oil layer groups. Among them, the Yan 9 oil layer group is the main oil-bearing interval in the study area. Sedimentary facies is a combination of the sedimentary environment and the characteristics of the sedimentary rocks formed in the environment. Sedimentary facies not only determine the production status of the reservoir,
including the horizon, reservoir cap conditions, reservoir scale and distribution form, but also determine
the internal structure and rock type of the reservoir, thereby controlling the distribution of oil and gas[6].
Therefore, the study of sedimentary facies is of great significance to the exploration and development
of oil fields. In this paper, using core, logging and logging data, a detailed study of the sedimentary
facies characteristics of the Yan 9 oil layer of the Yan'an Formation in the D area of northern Shaanxi is
carried out to provide a theoretical basis for the further exploration and development of the oilfields in
the study area.

2. Stratigraphic characteristics
For the D area of northern Shaanxi, the Yan 9 oil layer group was finely divided and compared using the
marker layer method, the principle of equal thickness, and the sedimentary cycle analysis method.
According to the results of the stratigraphic division, the plan view of the thickness of the small layer
and the structure of the top of the strata were drawn. It is believed that the Yan93 and Yan91+2 strataums
are relatively complete in the whole area and have not suffered denudation. The overall thickness of the
formation does not vary widely, and the thickness of the two small layers is mainly about 20m. The
nose-like structure at the top of Yan 9 is densely developed, forming multiple rows of nearly east-west
nose-like structures, with a structural amplitude less than 25m, and the distribution of rhinoplasty has a
certain difference. The distance between rhinoplasty is 3-8km. These nose structures provide favorable
trap conditions for hydrocarbon accumulation. The study of the stratigraphic and structural
characteristics of the Yan 9 oil-bearing group provides basic geological data for the later sedimentary
facies and sand body distribution characteristics.

3. Sedimentary facies characteristics

3.1. Sedimentary facies type in the study area
Area D is located in the Yishan Slope, which is the broadest in the Ordos Basin, and is one of the main
areas for oil exploration and development in the basin. According to previous research results and
regional sedimentary background, Yan 9 oil layer of Yan'an Formation in area D is comprehensively
analyzed as a delta plain subfacies, which is divided into three microfacies: distributary channel, natural
embankment and interbranched swamp (Table 1).

| Sedimentary facies | Sedimentary subfacies | Sedimentary microfacies |
|-------------------|----------------------|-------------------------|
| Delta             | Delta plain          | Diversion channel       |
|                   |                      | Branch swamp            |
|                   |                      | Natural embankment      |

(1) Diversion channel
The distributary channel is the main sand body deposition unit on the delta plain and the most
important oil and gas reservoir. It is mainly composed of clastic sandstone, with extremely well-
developed parallel bedding, including horizontal bedding (Figure 1) and oblique bedding (Figure 2).
There are often interlayer erosion surfaces, and thin layers of fine conglomerate or gravel coarse
sandstone lenses are often associated with the erosion surface, and the upward trend of grain size is not
obvious. In the middle part, there is a large slab-like cross-beded gravel-bearing coarse sandstone. The
bottom surface and interlayers are common with scour-filling structures. There are often thin
conglomerate lenses on the scour surface, which are the products of lateral sand dams. The electrical
characteristics are characterized by rich response patterns of channel sedimentation logging curves. The
most typical logging patterns are: the spontaneous potential and natural gamma are box-shaped with
mid-to-high amplitude and micro-toothed box.
(2) Natural embankment

natural embankments are developed on both sides of the distributary channel, and are mainly characterized by fine sand (Figure 3), silt sand and thin muddy interbeds. Far away from the river bed, the sediments become finer and mud content increases. Common wavy bedding, wavy bedding and flowing water wave marks. Carbonized plant fragments can be seen.

(3) The swamp between branches

The branch swamp is located in the low-lying area between the distributary channels of the delta plain. Due to the luxuriant vegetation and poor drainage of the swamp, it is a stagnant and reductive environment, so its sediments are mainly dark organic clay, layered silt and carbonaceous Mezzanine (Figure 4). Often developed massive bedding and horizontal bedding. The biggest sedimentary feature of the delta plain is the wide distribution of marsh deposits. Therefore, the extensive and stable distribution of layered organic matter swamp deposits can be used as a marker layer for the stratigraphic contrast of the delta plain.

3.2. Single-well facies analysis in the study area

Based on the classification of sedimentary facies and the study of sedimentary microfacies characteristics, in order to reveal the law of vertical evolution and planar distribution of sedimentary facies of Yan 9 oil layer group in the study area, single-well sedimentary facies analysis was carried out on two wells in the study area.

(1) Single-well facies analysis of Yan 9 oil layer group in Well G137

Well G137 is located in the middle of the study area. From the bottom to the upper delta plain, the distributary channels, inter-branch swamps and natural embankments frequently overlap each other, and the top coal seam of Yan 9 is developed. Yan93 mainly developed distributary channel microfacies, and Yan91+2 developed distributary channel and inter-branch swamp microfacies. The sand body of Yan93 is thicker, and the curve is mostly box-shaped. In comparison, the Yan91+2 sand body is slightly thinner.
(2) Single-well facies analysis of Yan 9 oil layer group in Well G213

Well G213 is located in the eastern part of the study area. The distributary channels, inter-branch swamps and natural embankments frequently overlap each other from the bottom to the upper delta plain. Coal seams are developed in the upper part of Yan 93 and the top of Yan 91+2. Yan 93 developed distributary channel and inter-branch swamp microfacies, the lower part of Yan91+2 was distributary channel, and the upper part was natural embankment microfacies. In comparison, the sand body of Yan93 is thicker, and the sand body of Yan91+2 is thinner.

3.3. Analysis of the connected profile of the sand body in the study area

Profile facies analysis is based on the analysis of single well sedimentary facies, making full use of electrical logging data for comparison, establishing the phase sequence relationship between adjacent wells, and determining the distribution characteristics of sedimentary facies in two-dimensional space. Phase analysis method.

Combining the structural location and geological evolution background of the study area, based on a large number of exploration and development practices, three continuous well profiles that can reflect the sedimentary facies of the area have been established. The two sections show that the Yan 9 oil layer group has little undulation, and the sand bodies of Yan 93 and Yan 91+2 are good, with a thickness of more than 10 m, and the sand bodies have good connectivity. On the whole, the Yan 9 oil-bearing group mainly develops distributary channels and inter-branch swamps. The river channel is mainly composed of medium and fine sandstone deposits, and the sand bodies are distributed in the river channel in a lens shape. The inter-branch swamp is mainly composed of fine sandstone, siltstone, and mudstone. The prominent feature in the vertical direction is the thin interbedded sand and mudstone.

3.4. Sedimentary microfacies and distribution characteristics of sand bodies

The study of the planar characteristics of sedimentary microfacies is an important geological basis for reservoir development and analysis. It is a key step in the study of reservoir heterogeneity and remaining oil distribution. It is also the main purpose of microfacies research. It is restricted by a series of factors, including Factors such as paleo-climatic conditions, source area direction and paleo-topographic features, as well as the development status and energy of river systems. On the basis of determining sedimentary facies, subfacies, and microfacies, following the point-line-plane research method, starting from the single-well facies diagram analysis, the well facies diagram analysis is connected again, and finally the sedimentary microfacies of the target layer in the study area is carried out. Accurate analysis and summary of phase plane characteristics.

(1) Yan93 sedimentary microfacies and sand body distribution characteristics

The Yan93 stage sedimentation was formed in the river-controlled delta plain environment. Drawing the Yan93 stage sand body thickness map (Figure 5) and the sedimentary microfacies plan (Figure 6) shows that the study area developed 6 river channels in this stage, which are strips on the plane. It is spread out in a shape of a northwest-south east direction. The widest part of the river is about 7.86km, and the narrowest part is about 0.73km.

In plane, these rivers flow in from the northwest direction and flow out from the southeast direction. The area where the sand ratio is between 0 and 0.2 develops inter-branch swamps, the area where the sand ratio is between 0.2 and 0.4 develops natural embankments, and the area where the sand ratio is greater than 0.4 develops channel deposits, and most of the study area has a well-sand ratio. Above 0.4, channel deposits constitute the main body of the sand body skeleton and are also the main favorable enrichment area.
(2) Yan91+2 sedimentary microfacies and sand body distribution characteristics

The Yan91+2 stage deposits in area D were formed in the river-controlled delta plain environment. Drawing the Yan91+2 stage sand body thickness map (Figure 7) and the sedimentary microfacies plan (Figure 8) shows that there are 7 river channels in the study area during this period. It is distributed in strips on the plane, and the extension direction is northwest-southeast. The widest part of the river is about 7.78km, and the narrowest part is about 0.61km.

In plane, these rivers flow in from the northwest direction and flow out from the southeast direction. The area of the study area with a sand ratio of 0 to 0.2 develops inter-branch swamps, the area with a sand ratio of 0.2 to 0.4 develops natural embankments, and the area with a sand ratio of greater than 0.4 develops channel sedimentation, and most of the study area has a well-sand ratio of more than 0.2, Channel sediments constitute the main body of the sand body skeleton and are also the main favorable enrichment area.

4. Conclusion

The Yan 9 oil-bearing group in the study area is developed with delta plain distributary channels as the dominant facies. The development of sand bodies is strictly controlled by sedimentary microfacies. The main channels are diversion channels, natural embankments and swamp microfacies between branches, and two to three main channels are developed in the two small layers of Yan 9 in the study area.

(2) Vertically, the two sedimentary cycles of Yan91 and Yan91+2 are mainly developed by distributing channels, and the sand body of Yan91 is more developed than Yan91+2. The thickness of the sand body can reach more than 10m, and the sand body has good connectivity. On the whole, the Yan 9 oil-bearing
group mainly develops distributary channels and inter-branch swamps. The river channel is mainly composed of medium and fine sandstone deposits, and the sand bodies are distributed in the river channel in a lens shape. The inter-branch swamp is mainly composed of fine sandstone, siltstone, and mudstone. The prominent feature in the vertical direction is the thin interbedded sand and mudstone.

(3) On the plane, the Yan 9 stage sedimentation was formed in the river-controlled delta plain environment. The sand body of Yan 93 is more developed than that of Yan 91+2, and the channel width is larger. The channels of the Yan 9 oil layer group spread out in strips on the plane, extending in the northwest-south east direction. There are 6 main rivers in the study area of Yan93 stage and 7 main rivers in Yan91+2 stage. Channel deposits constitute the main body of the sand body skeleton and are also the main oil and gas enrichment area.

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