



Sedimentary Microfacies and Exploration Prospect of Benxi Formation in Ansai Gas Field, Ordos Basin

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Abstract. Benxi formation is the main gas producing strata in Ansai gas field. In order to clarify the characteristics of sedimentary microfacies and exploration prospects in this area, based on the interpretation of core and logging data, combined with sample analysis and testing, the distribution characteristics of sedimentary microfacies and sand bodies in Benxi formation were studied. The results show that the sedimentary rocks in Benxi formation are mainly medium-fine grained quartz sandstone, with a small amount of debris quartz sandstone. Tidal flat sedimentary system is mainly developed in Benxi formation, and three sedimentary microfacies are further divided into sand flat, mixed flat and mud flat. The distribution of sand flats is limited, and the sand bodies are scattered in the sedimentary area in patch form, so the connectivity is poor. Only in the mid-west, the connectivity of sand bodies is relatively good. The distribution of sand bodies in Benxi formation is much more complicated than previously thought. Benxi formation is a tidal flat-delta composite sedimentary body, and tidal action has obvious destruction and redistribution effects on preexisting delta sand bodies. The favorable zones are mainly distributed in the vast middle sand flat.

Keywords: Ansai gas field, Benxi formation, sedimentary microfacies, exploration prospect.

1 Introduction

Under the action of Hercynian tectonic movement, the uplift and denudation of Ordos Basin ended, and Benxi formation, a transitional phase between land and sea, was deposited. The Upper Carboniferous Benxi formation is not only an important gas source series in Ordos Basin, but also a large-scale sand body. Although the discovery of oil and gas shows in Benxi formation has a long history, its oil and gas exploration is restricted by the lack of understanding of sedimentary microfacies and sand body development law. The preliminary study shows that the theory of natural gas accumulation in Benxi formation is completely different from that of large shallow-water delta sedimentary accumulation in Shanxi-Shihezi formation. Its sand body is obvi-

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ously affected by the current environment, and the tidal transformation has cut the sand body into sand dams, and its reservoir-forming mode is mostly internal reservoir-forming. Tidal flat-barrier island system can be used as a favorable reservoir sand body^[1-4]. The hydrodynamic conditions of the sedimentary system in Benxi formation are complex, which can be influenced by tides, waves and rivers at the same time, and its sedimentary lithology is changeable, which can form sandstone, mudstone and coal, making the sedimentary characteristics of the barrier coastal system one of the difficulties in research^[5-7].

The predecessors have done a lot of research on Benxi formation in Ordos Basin, and think that the southeast of the basin belongs to the barrier coastal sedimentary system, which consists of tidal flat in the west and barrier-lagoon and shallow shelf in the east, but most of the research is only based on the overall sedimentary distribution law, and the vertical sequence and sedimentary characteristics of tidal flat sedimentary microfacies have not been systematically summarized except barrier sand bars^[8-12]. Unclear understanding of the genesis of sand bodies leads to difficulties in sand body prediction and restricts exploration and deployment. In this study, the characteristics of sedimentary microfacies and the distribution of sand bodies in Benxi formation are analyzed comprehensively by using core and logging data and combining with outcrop investigation in adjacent areas, which provides geological basis for natural gas exploration in Benxi formation(Fig. 1).

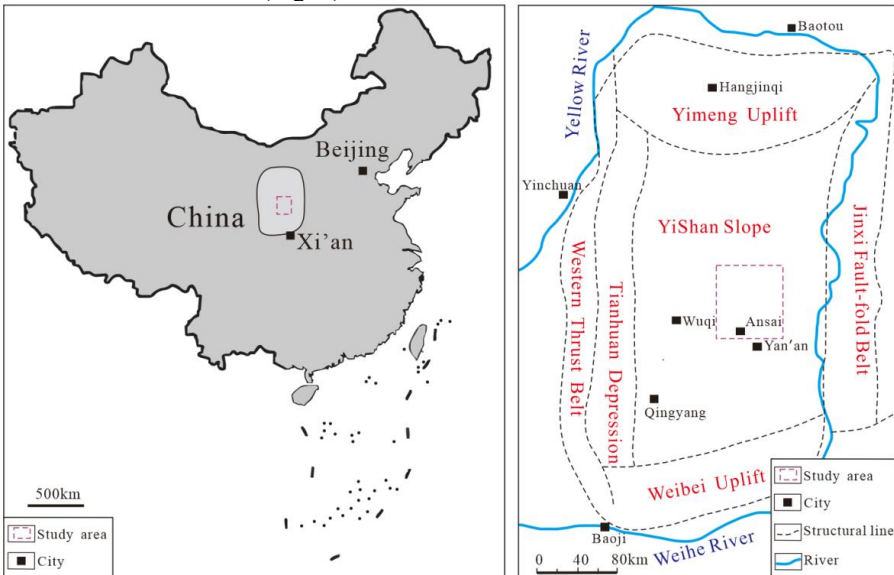


Fig. 1. The geotectonic division of Ordos basin and the location of the study area

2 Geological Setting

The sedimentary filling of Ordos basin in the late Paleozoic was mainly controlled by the subduction and subduction of the oceanic plate in the Xingmeng trough on the

north, the Qinqi trough on the south and the southwest. At the end of Ordovician, influenced by Caledonian tectonic movement, Ordos area and even the main body of North China Craton evolved into uplift area. Benxi formation is covered on the weathering crust at the top of carbonate rocks in Majiagou Formation of Ordovician. The lithology is mainly dark gray or grayish black shale and light gray or grayish white quartz sandstone, with limestone and coal seams, and iron-aluminum clay rocks at the bottom. The total sedimentary thickness is generally 40-70m. Its distribution is controlled by the central paleouplift of the basin, and it is semi-circular with an opening to the east on the east side of the paleouplift, and its thickness gradually increases from west to east. The Late Paleozoic strata are Benxi formation, Taiyuan, Shanxi, Shihezi and Shiqianfeng from bottom to top. Benxi formation is the first set of strata dominated by clastic rocks after the end of carbonate-dominated sedimentary strata in the early Paleozoic in the epicontinental sea of North China, which was formed in the background of re-transgression after the North China Craton was exposed and weathered by about 150Ma in the late Caledonian^[5-7].

3 Sedimentary Characteristics

Combined with the regional sedimentary background, according to the comprehensive analysis of rock type, sedimentary structure, structure, sedimentary cycle, rock-electricity combination and logging data, it is considered that tidal flat sedimentary system is mainly developed in Benxi formation, Ansai gas field, and its sedimentary sand bodies mainly come from the remoulding of northern delta sand bodies by waves and tides^[8-10].

3.1 Petrology

The sedimentary rocks in Benxi formation are simple, mainly terrigenous clastic rocks, accompanied by a small amount of carbonate rocks. Clastic rocks in Benxi formation include mudstone, siltstone, sandstone and gravelly sandstone, etc(Fig. 2). Its lithology is mainly quartz sandstone, with a small amount of lithic quartz sandstone. Thin coal measures developed in the upper part of the formation, indicating that the sedimentary environment was humid and warm at that time. Clastic rocks are mostly medium-grained, with less coarse-grained debris relative to medium-grained, medium-sized sediments, and good roundness of particles, most of which are sub-circular and round, indicating that the hydrodynamic conditions in its sedimentary environment are strong. Most of the sediments are supported by particles, but few are supported by hetero-groups.

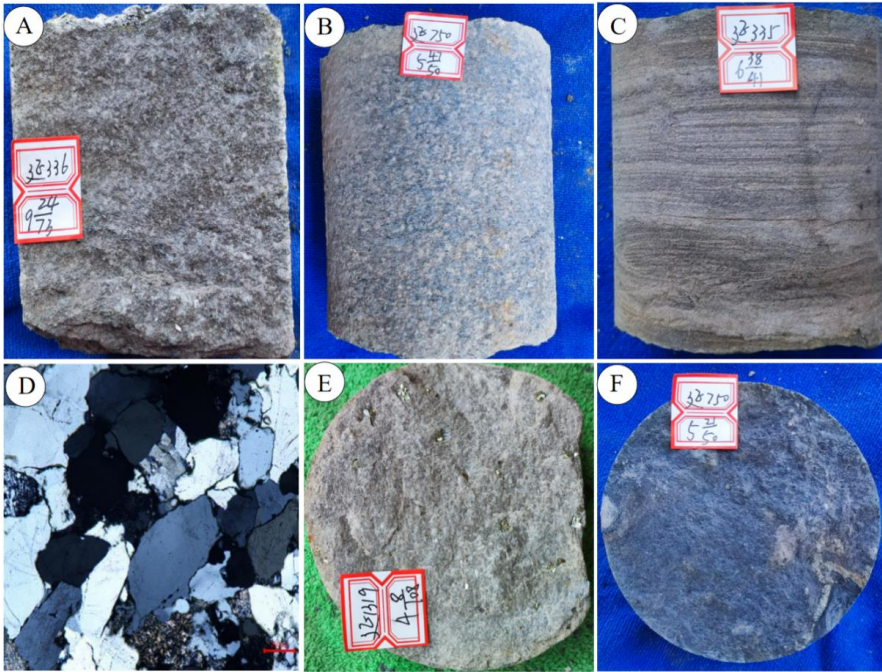


Fig. 2. Sedimentary Characteristics of Benxi formation in Ansai gas field

Coarse-medium sandstone with fine gravel, Y336, sand flat; B-Gray medium sandstone, Y750, sand flat; C-Argillaceous sandstone, wave bedding, Y335, mixed flat; D-Medium quartz sandstone, Y1307, sand flat; E-Gray medium sandstone with high pyrite, sand flat; F-Dark gray mudstone, Y750, mud flat.

3.2 Sedimentary Microfacies

Clastic tidal flat deposits are developed in Benxi formation of Ansai gas field, mainly including sand flat and sand-mud mixed flat, and a small amount of mud flat microfacies (Fig.3).

The microfacies of sand flat are gray quartz, debris quartz coarse sandstone and medium coarse sandstone, with a slight positive cycle. The grain size gradually changes from coarse sandstone to medium coarse sandstone from bottom to top, and the particle sorting is general, and the roundness is sub-circular, mainly supported by particles. The common sedimentary structure combinations are pinnate cross bedding, trough cross bedding, plate cross bedding and sand cross bedding. Plate cross bedding and feather cross bedding are common in the lower part of sand flat deposition, while sand grain bedding is more common in the upper part. GR of sand flat deposits is mostly box-shaped or toothed bell-shaped with medium and high amplitude, and natural gamma of thin sandstone section is finger-shaped (Fig.3).

Mud flat microfacies are mainly gray mudstone, silty mudstone and shale, with thin siltstone and fine sandstone. Horizontal bedding and wave bedding are developed, which are sedimentary products under weak hydrodynamic conditions. Thin coal seams can also be seen in some areas. The GR curve of mud flat deposit is basically toothed with low amplitude, but in thin sandstone or limestone sections and coal seams, natural gamma rays show high amplitude peaks.

The mixed flat deposits are interbedded with gray mudstone and argillaceous siltstone, siltstone and fine sandstone, and transition upwards to black mudstone and coal seam. This interbedded deposit is the result of alternating sandy deposits in tidal activity period and muddy deposits in diverticular period. From bottom to top, due to the gradual weakening of hydrodynamic conditions and the gradual increase of argillaceous content, there are often changes in vein bedding, wavy composite bedding and lenticular bedding.

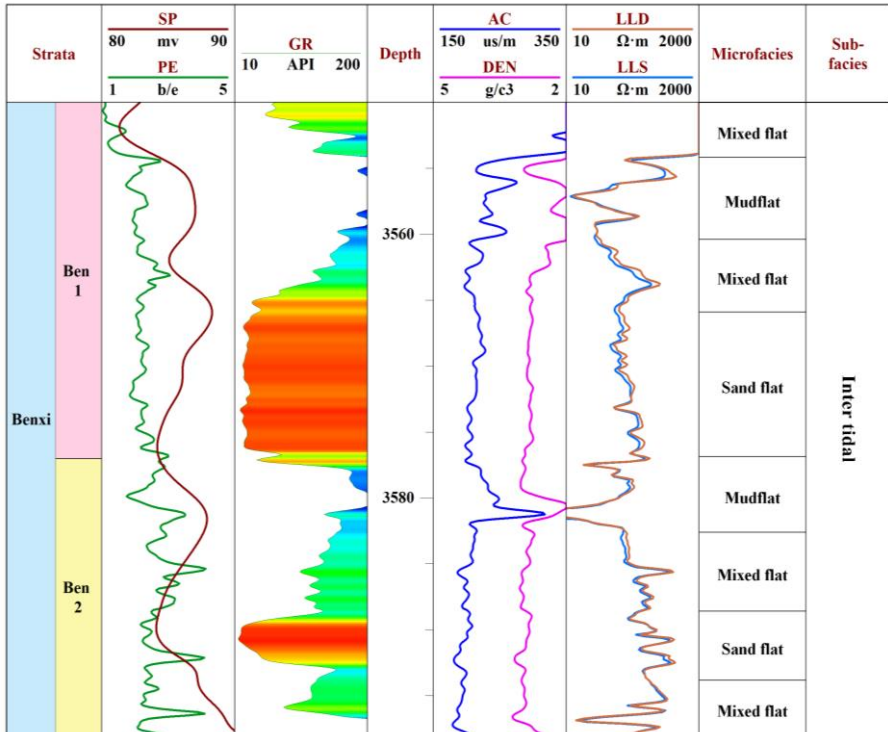


Fig. 3. Sedimentary microfacies analysis of single well in Benxi formation, Ansai gas field

3.3 Distribution characteristics of sand bodies and sedimentary microfacies

The correlation profile and sedimentary microfacies distribution map of sand bodies in Benxi formation show that the distribution of sand flats is limited, and the sand bodies are scattered in the sedimentary area in patches, with poor spatial connectivity. Relatively large sand bodies are only developed in the southern and northern margins,

representing two main provenance inlets, and the original delta sand bodies have been completely transformed into scattered lumps by tidal and wave actions. The deposition range of sand flat in Benxi formation 1 member is slightly expanded, and the difference between the east and the west of sand bodies is obvious. The connectivity of sand bodies in the middle and west is relatively good, showing a strip shape in the north-south direction. Mixed flat and mud flat deposits occupy most areas of Ansai gas field (Figs. 4 and 5).

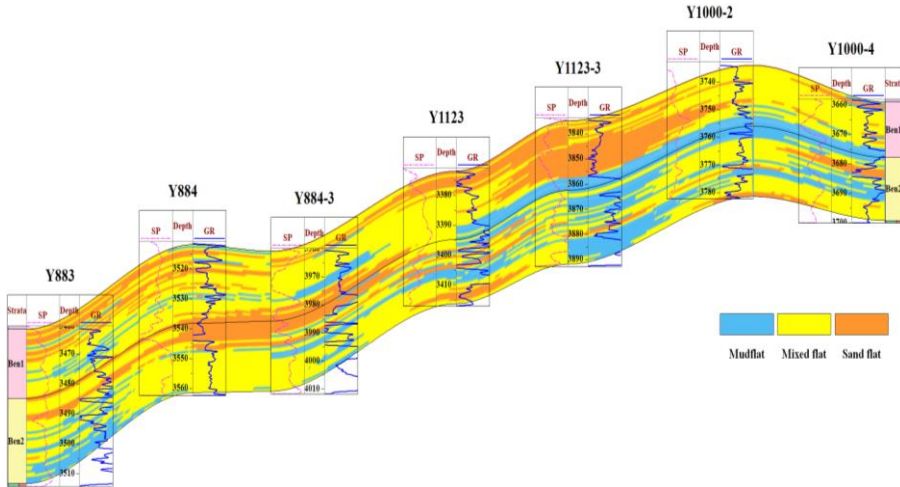


Fig. 4. Sedimentary Microfacies Profile of Benxi formation in Ansai Gas Field

3.4 Main controlling factors of sand body distribution and exploration prospect

There are many types of cross bedding in Benxi formation, especially sedimentary structures reflecting tidal sedimentation. Feather cross bedding, vein bedding, wavy bedding, lenticular bedding, soft sediment deformation structure and quartz boulders in mudstone show that the intensity of tidal action is greater than previously thought, and the range of high-energy tidal action covers almost the whole study area. On the other hand, the existence of the northern delta in Ansai gas field shows that the sand body is the result of the interaction of tides and rivers. It can be seen that the sedimentary background of the whole study area was a relatively open tidal sand bar-delta composite sedimentary environment in Benxi period. Judging from the development degree of tidal bedding, the south may have reached the background of tidal range, and the distribution of sand dams is mainly controlled by tidal current. The northern part may have a moderate tidal range background, and the sand body still retains the face of the delta well. The tidal bar-delta composite system with open bay background is helpful to re-understand the development and distribution law of sand bodies in Benxi formation, and also implies that the exploration in Benxi formation may need to break through the previous ideas in the future. The distribution of sand bodies in Benxi formation is much more complicated than previously thought. From the point

of view that the high-quality sand bodies of this system are mainly developed in the lower part of intertidal zone and the upper part of subtidal zone, the favorable zones are mainly distributed in the vast middle sand flat. In the search for future exploration targets, it is necessary to strengthen the study on the change of tidal current and its transformation degree to the delta and the migration track of low tide surface during the sea level change in Benxi period.

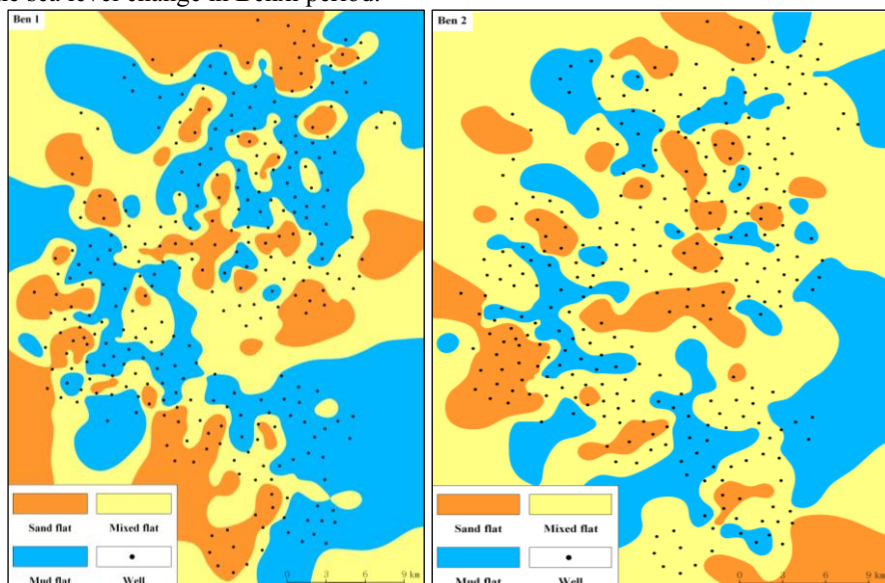


Fig. 5. Distribution characteristics of sedimentary facies in Benxi formation of Ansai gas field

4 Conclusion

(1)The sedimentary rocks in Benxi formation of Ansai Gas Field are mainly medium-fine grained quartz sandstone, with a small amount of lithic quartz sandstone, and the sediments are moderately sorted, with good particle roundness and particle support, which reflects the strong hydrodynamic conditions in the sedimentary environment.

(2)Tidal flat sedimentary system is mainly developed in Benxi formation in the middle of Ordos Basin, and three sedimentary microfacies are further divided into sand flat, mixed flat and mud flat.

(3)The correlation profile of sand bodies in Benxi formation and the distribution map of sedimentary microfacies show that the distribution of sand flats is limited, and the sand bodies are scattered in the sedimentary area in patches, with poor spatial connectivity. Only in the central and western regions, the connectivity of sand bodies is relatively good, showing a strip shape in the north-south direction.

(4)The distribution of sand bodies in Benxi formation is much more complicated than previously thought. The favorable zones are mainly distributed in the vast middle sand flat. In the search for future exploration targets, it is necessary to strengthen the

study on the change of tidal current and its transformation degree to the delta during the sea level change in Benxi period.

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