Resource and development prospect of widespread low-permeability sandstone gas in Ordos basin

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ABSTRACT

Ordos basin is the second largest basin in China. Natural gas is rich in this basin. Total gas resource in Ordos basin is 151.6 trillion cubic meters. Of which, gas in Upper Paleozoic may be up to 100 trillion cubic meters accounting to 70% of total gas resource. Exploration of low permeability to tight sandstone gas in multi-layer series of Upper Paleozic in Ordos basin obtained great result. Several giant low permeability to tight sandstone gas fields have been found in recent years, such as Wushenqi, Zizhou, Yulin, Shenmu etc. Sulige gas field has been proved to be the largest low permeability to tight sandstone gas field in China. It shows the great exploration prospect of low permeability to tight sandstone gas in Upper Paleozoic in Ordos basin. Now, people care about low permeability to tight sandstone gas resource and its exploration potential in Upper Paleozoic in Ordos basin. In this paper, based on through analysis of present petroleum resource and exploration result, the author discussed Resources potential and development prospect of large-area low permeability sandstone gas in Ordos basin. The author proposed that low permeability to tight sandstone gas in Upper Paleozoic in Ordos basin had the following characteristics. Coal-measure source rocks are wide spread and the generation potential is great. Sand body of braided river delta in gentle slope of Craton distributes widely. Source rocks and reservoir rocks are widely overlaying. Net system of pore and fractures formed the transporting system for gas. Gas was near-source accumulated. Accumulation ratio is high. The author suggested that exploration potential of low permeability to tight sandstone gas in Upper Paleozoic in Ordos basin is great. Production of low permeability to tight sandstone gas could reach 30 billion cubic meters in 2015. Upper Paleozoic in Ordos basin will be the largest gas production province then.

Key words: Ordos basin; large-area; low permeability sandstone; exploration potential

Introduction

Ordos basin locates in northern China. It covers Shanxi province, Gansu province. Ordos Basin is surrounded by Yin Mountain in the north, the Qinling Mountains in the south, Helan Mountain in the west and Lvliangshan in the east (Fig.1). Ordos basin is the second largest basin in China. Natural gas is rich in this basin. Total gas resource in Ordos basin is 151.6 trillion cubic meters. Of which, gas in Upper Paleozoic may be up to 100 trillion cubic meters accounting to 70% of total gas resource.

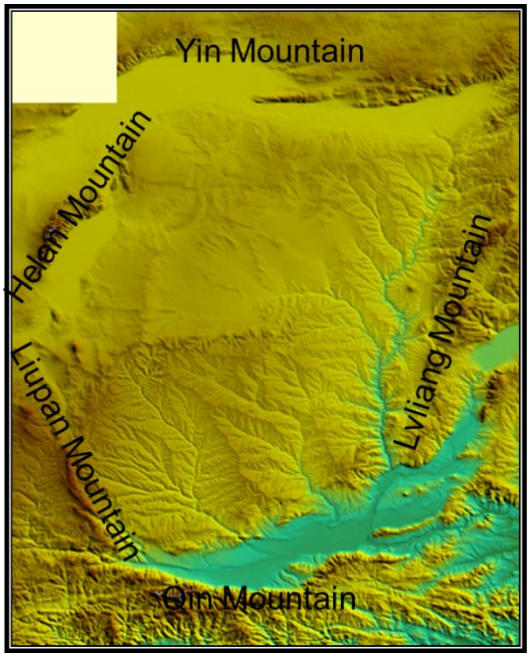

Fig.1 Geographical map of Ordos basin

Geological background

Basement of Ordos Basin is the Archean and Proterozoic metamorphic rock. Sedimentary cover only missed the Silurian and Devonian. Upper Proterozoic and lower Paleozoic are mainly marine carbonate sediments with the thickness of 600 ~ 4600m. Upper Paleozoic is mainly river and lake mash sediments with the thickness of 600 ~ 1700m. Mesozoic is mainly in inland rivers and lake mash sediments with thickness of 500 ~ 3000m. According to tectonic and paleogeographic development characteristics, tectonic evolution of Ordos Basin can be broadly divided into five stages: middle-late Proterozoic depression, early Paleozoic shallow marine platform, late Paleozoic costal plain, Mesozoic inland lake basin and Cenozoic peripheral fault depression (Fig.2).

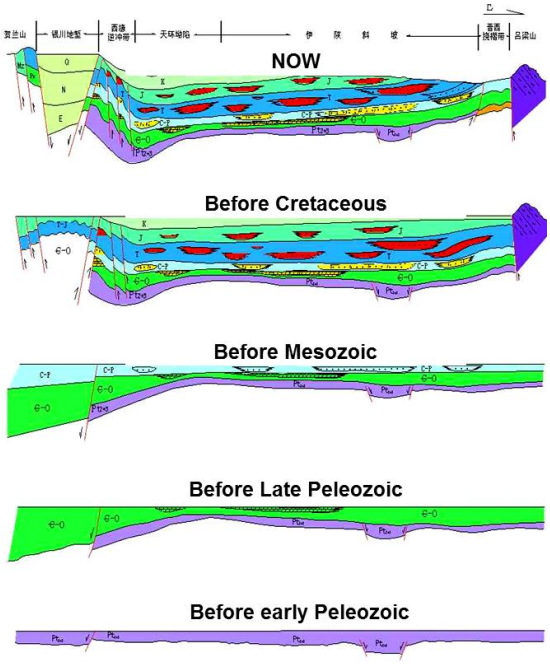

Fig.2 Section map of tectonic and sedimentary evolution of Ordos basin

Prototype of basin formed during the middle-late Proterozoic depression stage. Lower Paleozoic gas reservoir formed during early Paleozoic shallow marine platform stage. Gas reservoir formed during Late Paleozoic coastal plain stage. Jurassic oils reservoir formed during Mesozoic inland lake basin stage. Current tectonic and petroleum reservoir finalized during Cenozoic peripheral fault depression stage.

Ordos basin develops 5 gas bearing assemblages: insider gas bearing assemblage of Ma4 formation, gas bearing assemblage of weathering crust of Ma5 formation, gas bearing assemblage of Taiyuan – Shan1 formation, gas bearing assemblage of upper Shan1 – lower Shihezi formation and gas bearing assemblage of upper Shihezi - Shiqianfeng formation(Fig.3).

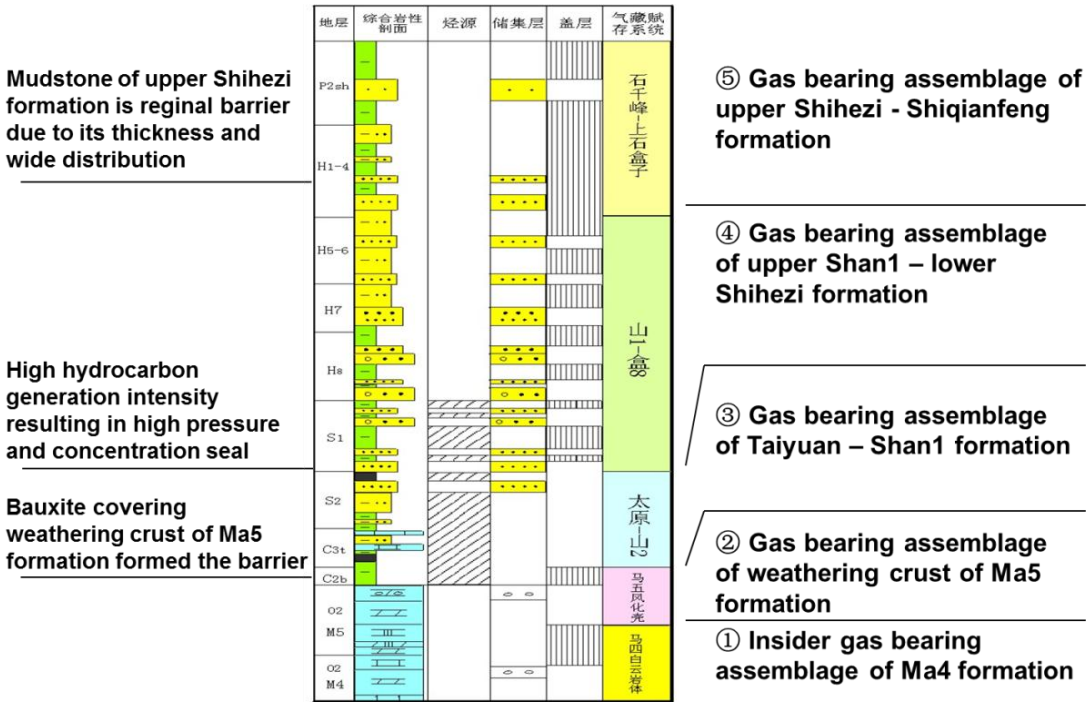

Fig.3 Five gas bearing assemblages in Ordos basin

Main controlling factors on reservoir formation

1. Widespread coal-measure source rock generated huge amount of hydrocarbon

Ordos basin Paleozoic source rocks mainly developed two sets of source rocks: Upper Paleozoic marine carbonate source rocks and Upper Paleozoic Carboniferous-Permian source rocks. Present study suggests that Carboniferous - Permian source rocks are the main source rocks. Carboniferous - Permian coal-bearing strata is widely distributed. The main hydrocarbon source rocks are coal seams and dark mudstone in Shanxi, Taiyuan and Benxi formation. Source rocks in the basin are thick, widely distributed with high abundance of organic matter.

Hydrocarbon generating intensity of Upper Paleozoic source rocks in Ordos basin varies from $10\times108m^3/km^2$ to $40\times10^8m^3/km^2$(Fig.4). The area in which hydrocarbon generating intensity is greater than $20\times10^8m^3/km^2$ accounts for 55.2 percent of total area of the basin. Hydrocarbon generating intensity of Upper Paleozoic source rocks in north western and eastern Ordos basin is greater than $40\times10^8m^3/km^2$.

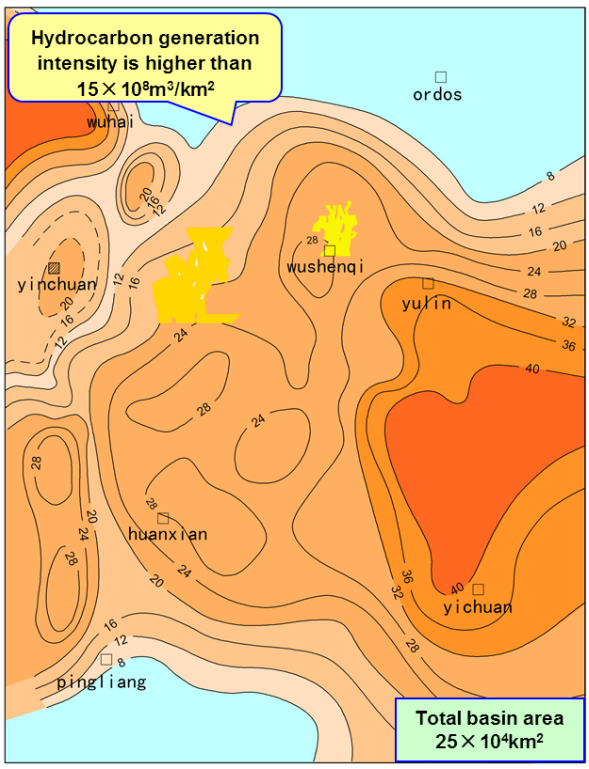

Fig.4 Overlaying map of hydrocarbon generation intensity and gas fields in upper Paleozoic in Ordos basin

Formation of Upper Paleozoic giant gas fields are controlled by hydrocarbon generating intensity. Latest exploration experience indicates that hydrocarbon generating intensity being from $10\times108m^3/km^2$ to $20\times10^8m^3/km^2$ is favorable for formation of giant gas fields.

2. Braided river delta sand of gentle slope in the context of steady Craton background is widespread

Due to the impact of Late Caledonian movement, Ordos Basin has experienced up to 150 Ma of weathering and erosion. Ordos Basin began accepting new deposits until the Late Carboniferous. During the end of Taiyuan period, North China platform had undergone the overall uplift. Regional tectonic and sedimentary environment pattern changed significantly.

Sea water rapidly retreated to the southeast Ordos Basin. The nature of the basin changed from offshore basin to epicontinental basin. Sedimentary environment changed from marine to land phase. Regional deposition background analysis showed that the northern part of the Ordos Basin source area uplift was fast, source supply was adequate, its provenance was mainly controlled by basement rocks and overlying Devonian to Carboniferous strata and affected by by the ancient river from north to south during Shan1 and He8 period.

Ordos basin developed large shallow delta system. Its formation requires a "stable tectonic conditions, shallow water, gentle palaeo-geomorphology rich provenance" and other conditions. The delta is characterized by shallow deposition water, large area sandy sediment.

3. Near-source migration and widespread accumulation with high efficiency

There are good correspondence between Ro distribution and gas content of Shan1 formation. This phenomenon indicates near-source migration of gas. The consistency between composition and carbon isotope property of gas and source rock maturity also indicated near-source characteristics. Near-source migration and widespread accumulation with high efficiency have nothing to do with time. High efficiency means that the amount of migrated and accumulated gas accounts for high proportion of total generated gas. Due to low permeability, it

is difficult for gas to loss after it accumulated. So, migrating and accumulating efficiency is high compared with conventional gas reservoir. Study on typical gas reservoir shows that migrating and accumulating efficiency can reach 3.0%～3.8%.

4. Fluid inclusions data indicated continuous charge and one-period accumulation

Inclusion data shows that Upper Paleozoic tight gas charged continuously and accumulated during one period. FiG.5 shows that the scale of homogenization is wide with its main frequency range of 90～160℃. This indicates continuous charge. Main peak temperature is 100～145℃. Gas was charged mainly during this period.

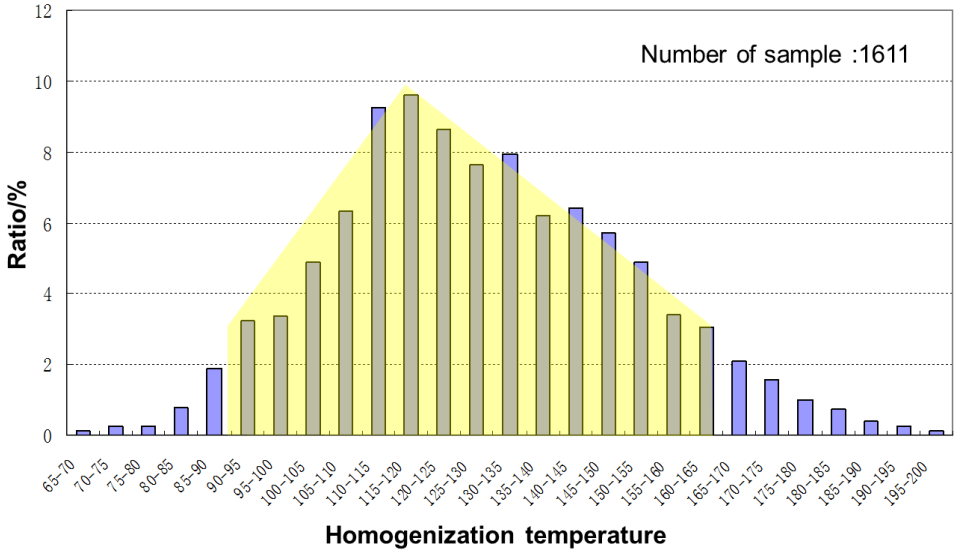

Fig.5 Homogenization temperature of saline inclusions

5. Exploration potential is great

Total gas resource in Ordos basin is 151.6 trillion cubic meters. Of which, gas in Upper Paleozoic may be up to 100 trillion cubic meters accounting to 70% of total gas resource. But, proven rate of widespread low-permeability sandstone gas is low. So, the author suggested that exploration potential of low permeability to tight sandstone gas in Upper Paleozoic in Ordos basin is great. Production of low permeability to tight sandstone gas could reach 30 billion cubic meters in 2015. Upper Paleozoic in Ordos basin will be the largest gas production province then.

Conclusion

Low permeability to tight sandstone gas in Upper Paleozoic in Ordos basin had the following characteristics. Coal-measure source rocks are wide spread and the generation potential is great. Sand body of braided river delta in gentle slope of Craton distributes widely. Source rocks and reservoir rocks are widely overlaying. Net system of pore and fractures formed the transporting system for gas. Gas was near-source accumulated. Accumulation ratio is high. Exploration potential of low permeability to tight sandstone gas in Upper Paleozoic in Ordos basin is great.