Coexistence and inheritance of diverse energy resources in the Ordos Basin, China*

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Abstract The Ordos Basin is abundant in oil, natural gas, coal, coalbed gas and sandstone-type uranium deposits. Oil pools are hosted mainly in the Triassic and Jurassic systems in the southern part of the basin. Gas reservoirs which occur dominantly in the northern part of the basin are situated vertically beneath the oil pools. Coal measures are widely distributed in the Carboniferous, Permian, Jurassic and Triassic systems. Developed at the margin of the basin are the sandstone-type uranium deposits and coalbed gas. The investigations of sources and timing of various energy resources indicated that there are certain genetic connections among them. Especially the contributions of coal measures to natural gas, the supplement of coalbed gas to deep basin gas and the reduction of uranium deposits by natural gas are relatively remarkable.

Key words oil; natural gas; coal measure; coal-bed gas; sandstone-type uranium deposit; coexistence; inheritance

1 Introduction

In recent years rapid economic development badly needs energy resources. Exploration and exploitation of more kinds of energy resources should be intensified to meet this need. According to present literature, oil/gas fields, coal fields as well as uranium deposits discovered in the world all occur in sedimentary basins, especially in Paleozoic and Mesozoic basins. As a Mesozoic-Cenozoic craton basin, the Ordos Basin possesses accumulatively discovered oil and gas reserves which exceed billions of tons and trillion steres, respectively. In addition the Ordos Basin is one of the biggest coal-bearing basins rarely seen in the world. Affluent coalbed gas and uranium deposits are buried underground in the basin. Based on the distribution characteristics of these organic and inorganic ores, research on their origin, formation mechanism and genetic connections is of great significance in exploring the mechanisms of their coexistence and enrichment.

2 Occurrence and distribution of individual ore deposits

2.1 Oil reservoirs

Oil fields so far discovered are mostly hosted in the Upper Triassic Yanchang Formation and Jurassic Yan’an Formation, and they are laterally distributed in the central and southern parts of the Ordos Basin (He Zixin, 2003). Triassic oil fields are dominated by delta-sedimentary sandstone reservoirs, such as the Ansai, Zhiluo, Xiasiwan, Yanchang, Yongping, Zichang and so on, including one oil-bearing series comprised of ten oil beds. Jurassic oil fields are dominated by fluvial-sedimentary sandstone reservoirs, including the Maling, Yuancheng, Huachi, Chenghao, Wuqi, Lizhuangzi, Hongjingzi and so on, with an oil-bearing series consisting of fourteen oil beds. The discovered oil reserves in this formation amount to 84% of the total Mesozoic oil reserves.

A common understanding of the sources of oils in the Ordos Basin was established through exploration activities. It is indicated that oils in the Mesozoic are generally of the oil-type, which were derived from mature humic-sapropelic source rocks of semi-deep lake to deep lake facies in the Nos. 2 and 3 members of the Yanchang Formation. Permian oils originated from Permian coal-series source rocks. It is possible for Carboniferous coal measures to have generated some liquid hydrocarbons (Guan Deshi et al., 1993; Zhang Wenzheng and Li Jianfeng, 2001).

2.2 Gas reservoirs

Gas reservoirs in the Ordos Basin are distributed predominantly in the Paleozoic strata. Lower Paleozoic carbonate gas reservoirs occurred in the
Ordovician paleo-karst area on the eastern slope of the central rise, including one gas-bearing series and a gas formation. While Upper Paleozoic sandstone reservoirs of fluvial facies are mostly hosted in the Permian Shanxi and Shihet formations in northern Ordos Basin, with one gas-bearing series and five gas formations. Generally speaking, gas reservoirs are located predominately in the central and northern parts of the Ordos Basin with the Sulige, Yulin, Jingbian and Wushenqi giant gas fields as typical examples.

There has long been a strong controversy over the sources of central gas fields in the Ordos Basin. There are three different representative hypotheses. (1) Guan Deshi et al. (1993) and Zhang Shiyi (1994) believed that natural gases in the central gas fields were derived from the Upper Paleozoic coal series, so belonging to the coal-type gas. (2) In terms of stable carbon isotopes, Chen Anding (2002), Huang Difan et al. (1996) considered that the Ordovician system was the main source of natural gases in the central gas fields, mixed gas only occurred in the eastern gas field with another source from the Carboniferous system. Even the contribution by the Ordovician was evaluated to be 80%-90% (Chen Anding, 2002). (3) Gas pools in the Ordovician karst strata possess the characteristics of a mixed source. The coal-type gas originated from Permian coal series, while the oil-type gas was derived from the Lower Paleozoic (Zhang Wenzheng and Li Jianfeng, 2001; Xia Xinyu et al., 1999; Dai Jinxing et al., 2005) or Carboniferous limestones (Li Xianqing et al., 2002, 2003). Generally, the hypothesis of mixed source is more commonly accepted, and the debates only focus on the differences in contribution rate between gas rocks and Carboniferous limestones.

2.3 Sandstone-type uranium ore deposits

Uranium ores were discovered in the Dongsheng area of northern Ordos Basin and the uranium ores are irregularly plate-shaped. These uranium ores occurred in the Middle Jurassic Zhilou Formation sandstones directly overlying the Middle Jurassic Yan’an Formation coal measures. In addition, local uranium mineralization is seen in the Middle Jurassic Anding Formation, Cretaceous and Lower Triassic strata in northern Ordos, as well as on the western and southern margins of the basin.

Some ore geologists held that the basement of the Ordos Basin is composed of metamorphic rock, chlorismite and granite gneiss of Achaean and Lower Proterozoic ages. The dominant acid and intermediate-acid rocks have high contents of uranium and may act as the uranium source rocks (Di Yongqiang, 2002). Others considered that the contents of uranium in Upper Paleozoic coal measures in the Ordos Basin are so high as up to 4.5×10^6–5.0×10^6, and some uranium abnormalities were found in the adjacent outcrops. Uranium was found to be present in the form of oxide or was adsorbed on organic matter (Zhang Ruliang, 2004).

2.4 Coal measures

The Carboniferous-Permian, Triassic and Jurassic are the three major coal-bearing series in the Ordos Basin. Carboniferous-Permian coal measures occurred largely in the Taiyuan and Shanxi formations widely spread in the whole basin. Their coal ranks varied from one location to another. Coal measures in the northern part of the basin belong to lignite or coal gas, in the central part, coking coal, and in the southern part, dry coal or lean coal or anthracite (Fig. 1). Triassic coal measures mostly occurred in the Wayao Formation around the Huanglin, Fuxian Yan’an, Zichang and Zizhou districts. As for their coal rank, they belong to gas coal. Jurassic coal measures are distributed predominantly in the Middle and Lower Jurassic series, especially in the Yan’an Formation. They belong to low-grade metamorphic lignite and coal which are widely spread in the basin.

2.5 Coalbed gas

The potential regions of coalbed gas generation in the Ordos Basin are distributed along the margins (Gao Ruqi and Zhao Zhengzhang, 2001; Feng Sanli et al., 2002). Carboniferous-Permian coal measures are high-grade metamorphic coals that have high gas...