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Original research paper

Further comprehension of natural gas accumulation, distribution, and prediction prospects in China

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Abstract

In-depth research reveals that the natural gas accumulation and distribution are characterized by cycle, sequence, equilibrium, traceability, and multi-stage. To be specific, every geotectonic cycle represents a gas reservoir forming system where natural gas is generated, migrated, accumulated, and formed into a reservoir in a certain play. Essentially, hydrocarbon accumulation occurs when migration force and resistance reach an equilibrium. In this situation, the closer to the source rock, the higher the accumulation efficiency is. Historically, reservoirs were formed in multiple phases. Moreover, zones in and adjacent to source rocks, unconformity belts, and faulted anticline belts are favorable areas to finding large gas fields. Apart from the common unconformity belts and faulted anticline belts, in-source and near-source zones should be considered as critical targets for future exploration. Subsequent exploration should focus on Upper Palaeozoic in the southeastern Ordos Basin, Triassic in southwestern Sichuan Basin, Jurassic in the northern section of the Kuqa Depression and other zones where no great breakthroughs have been made.

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Keywords: Large gas field; Distribution characteristics; Potential zone; Prospect

1. Introduction

Natural gas exploration in China began with the discovery of three gas fields in the Sichuan Basin in 1956, but it was always concomitant with oil exploration until 1979 [1−6]. In the early 1980s, along with the development of global natural gas industry, the Chinese prospectors devoted to the geological research and exploration of natural gas. Accordingly, some structural gas fields dominated by coal-related gas were discovered, such as Ya 13-1, Shenglijing, and Mizhi. Since the 1990s, a lot of natural gas generation, migration, and accumulation theories were adopted, innovated, and upgraded. Meanwhile, research [13−17] was made on seismic and drilling technologies, thus contributing to the recognitions on structural lithologies, carbonate palaeo-uplifts, foreland basins, and other fields represented by the discovery of such large gas fields, namely, Wubaiti, Kela 2, Wushenqi, and Sebei II. Since the beginning of the 21st century, the natural gas industry has ushered a blooming age. Great progress has been made in basic geologic theories, including hydrocarbon-generating mode, reservoir forming mechanism, and sealing mechanism of cap rocks [1−10]. Further advancement has been realized in geophysical exploration technologies, including the prediction of piedmont complex traps, tight sandstone reservoir, and heterogeneous carbonate reservoir. Previous researchers mainly put forward the palaeohigh, the theory of source control, enrichment of oil and large gas fields, etc. To promote the progress of exploration and development [11−17]. The engineering technologies of horizontal well

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drilling and (vertical well) staged fracturing became increasingly mature [18−29], which have contributed to the discovery of medium and large gas fields (e.g., carbonate karst, tight sandstone, shale gas, and coalbed gas), and played a critical role in the booming of the industry. Clearly, these discoveries demonstrate the exploration philosophy of "understanding − practice − re-understanding", and also reveal that it is necessary to initiate the re-understanding of natural gas geological theories, since numerous geological behaviors cannot be interpreted with traditional hydrocarbon accumulation theories, such as tight gas, shale gas, etc. [1−3]. In this paper, the natural gas accumulation and distribution characteristics of large gas fields are discussed, and then the potential zones and prospects for large gas fields are proposed in order to provide references for future natural gas exploration.

2. Natural gas accumulation and distribution characteristics

Many geologists [1−7] have put forward the natural gas accumulation and distribution theories, such as source control theory, palaeo-uplift theory, and regional seal theory. Practical operations, however, have been far beyond such traditional theories. By virtue of artificial reservoir stimulations, unconventional natural gas (e.g., tight sandstone gas, shale gas, and coalbed gas) can be recovered commercially. Through an intensive investigation, gas reservoirs discovered in recent years are discovered with some distinctive characteristics.

2.1. Cycle

The Chinese continent has long resided in the domains where kinetic systems are superimposed and intersected around the world. With multiple masses merged, the Chinese continent developed in multiple phases and contains a lot of basins, including Proterozoic-Palaeozoic marine cratonic, marine−continental transitional depression, Mesozoic continental faulted, Cenozoic continental faulted, and passive continental margin foreland basins. The present-day basins have the superimposed geological structures with different features which have greatly controlled the generation and distribution of natural gas.

In respect to geological evolutionary history, the natural gas distribution demonstrates four cycles, where the gas reservoirs differ significantly in the types and distribution (Fig. 1).

2.1.1. The cycle of gas accumulation in deeply buried marine basin

Typically, in the Proterozoic-Palaeozoic marine cratonic basins, natural gas is generated from kerogens in the marine shale or from the cracking of crude oil in the palaeo-oil reservoir. The threshold of massive cracking gas generation is only possible under the conditions of deep burial and elevated temperature. Moreover, the early-formed carbonate rocks usually evolve to carbonate residual weathering crust gas reservoir and inter-layer karst gas reservoir after frequent tectonic movements, where diverse dissolution fracture/cavity systems serve as the reservoir spaces. In marine facies, (i.e., Sichuan Basin) the Gaoshiti-Moxi large gas field in Sinian-Cambrian formation was found in the TazhongIgas field in the center of the Tarim Basin. Multi-source rock, high-intensity hydrocarbon-generating, development reef, large-area dissolution porosity, fracture, and erosion groove form the translocating system.

2.1.2. The cycle of gas accumulation in the entire marine−continental transitional basin

The expansion and closure of the Paleo-Tethys Ocean and southward growth of the Siberian continent in the Late Palaeozoic gave rise to the large-scale marine−continental transitional depressions in the Chinese continent. These depressions are characterized by large superimposition of delta sand bodies and swamp coal-measure source rocks, providing good conditions for natural gas generation and accumulation. Moreover, the superimposed and continuous distribution of sandstone in such large area weaken the control of such structures as an anticline over hydrocarbon accumulation to a certain extent, and the high capillary force of massive tight

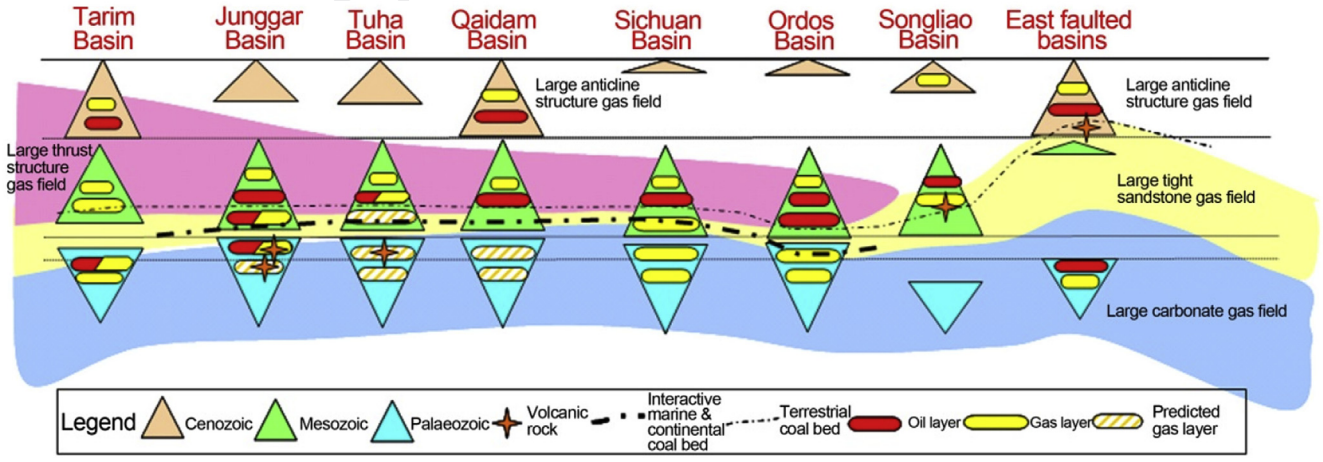

Fig. 1. The relationship between the distribution of China's major large gas fields and structural evolution cycle.

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