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RESEARCH PAPER

Classification and hydrocarbon distribution of passive continental margin basins

WEN Zhixin[1,*], XU Hong[2], WANG Zhaoming[1], HE Zhengjun[1], SONG Chengpeng[1], CHEN Xi[1], WANG Yonghua[1]

1. PetroChina Research Institute of Petroleum Exploration & Development, Beijing 100083, China;
2. China National Oil and Gas Exploration and Development Corporation, Beijing 100034, China

Abstract: Sixty-six passive continental margin basins around the world were compared comprehensively from the aspect of seismogeology on the basis of plate tectonics. According to their textural and structural differences, passive continental margin basins were classified into seven subdivisions, i.e., rifted basin, non-saline faulted depression basin, saline faulted depression basin, non-saline depression basin, saline depression basin, delta reformed basin and positive reverse deformed basin. The passive continental margin basins around the world have been generated with the formation of Mesozoic and Cenozoic Atlantic and Indian Oceans and they have experienced superimposition of three prototypes, including intra-continental rift in rifting period, intercontinental rift in transitional period and passive continental margin in drifting period. In rifted basins, the petroleum systems are mainly located in the lower lacustrine/marine rift series of strata and the thinner depression series of strata at the upper part are only regional cap-rocks. Large oil and gas fields are mainly concentrated in structural traps of rift series of strata. In non-saline faulted depression basins, hydrocarbon generation and expulsion peaks occur in both upper thicker marine depression series of strata and lower rift series of strata. Reservoirs are formed in the structures of rift series of strata, and oil and gas are highly concentrated at slope fans in depression series of strata. In saline faulted depression basins, large oil and gas fields are mainly distributed in the lagoon carbonate rocks of subsalt series of strata and the deepwater slope fans of suprasalt depression series of strata. In saline depression basins, only petroleum systems in depression series of strata are active, and various traps are developed, such as slope fan, salt structure and bioherm. In non-saline depression basins, large oil and gas fields are mainly located in submarine fan groups of depression series of strata because this type of basins are of narrow continental shelf and steep continental slope. In delta reformed basins, four major ring-like structure belts (i.e., growth faulting-mud diapir-thrust nappe-foredeep gentle slope) are formed from the shore to the deepwater and large oil and gas fields can be formed in each belt. Positive reverse reformed basins are the passive continental margin basins which are influenced by global orogenesis since the Miocene. In this type of basins, oil and gas are concentrated in compressional anticlines of reverse series of strata.

Key words: passive continental margin; prototype basin; basin structure; basin classification; large oil and gas field; distribution rules

Introduction

Passive continental margin basins are widely distributed around the world. Totally, there are 130 passive continental margin basins, with total sedimentation area of 3 350×10^4 km^2, including 3 016×10^4 km^2 offshore area, of which three-fourths are located in deepwater (water depth over 500 m)[1]. These offshore basins are dominantly covered by the ocean, so they are explored and developed later than those onshore. Hydrocarbons have been discovered successively in 55 basins along both sides of North and South Atlantic since the operations were firstly started in the Gulf of Mexico, USA, in the 1960 s[1]. Since 2000, the ratio of hydrocarbons discovered in offshore passive continental margin basins (especially in deepwater) to the global new reserves has been increasing with the advancing of offshore oil and gas exploration theories and technologies. It has been kept above 40% since 2008, even over 80% in 2012[2]. Nevertheless, the exploration degree of offshore oil and gas, especially deepwater oil and gas, is still very low. The latest resource evaluation of CNPC in 2014 shows that the undiscovered recoverable hydrocarbon resources of offshore passive continental margin basins (including 712×10^8 t oil and 445×10^{12} m^3 gas) accounts for 50% of total undiscovered recoverable hydrocarbon resources around the world, and 80% of them are endowed in deepwater[3]. It is indicated that passive continental margin basins, especially those in deepwater, have good oil and gas explora-

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*** Corresponding author.** E-mail: wenzhixin@petrochina.com.cn
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tion prospects. At present, the published researches on passive continental margin petroleum geology and hydrocarbon enrichment laws only focus on several areas with higher exploration and development degree, such as both sides of South Atlantic, the Gulf of Mexico and the Australia northwest shelf[4–6]. In this paper, 66 passive continental margin basins with exploration and development activities around the world were compared comprehensively from the aspect of seismogeology, in order to analyze the formation and distribution of passive continental margin basins around the world. Passive continental margin basins were subdivided according to their structural and sedimentary filling differences. The formation conditions and main control factors of large oil and gas fields (2P reserves of oil over 6 850×10^4 t and gas over 850×10^8 m^3) were investigated. The petroleum geological characteristics and distribution rules of 7 types of passive continental margin basins were further analyzed so as to define the exploration targets and provide the reference for strategic zone selection and new project evaluation on deepwater passive continental margin areas where exploration degree is low and data is not accessible.

1. Formation and distribution of passive continental margin basins

Based on slope gradient, passive continental margin basins can be divided into three tectono-sedimentary units from the continent to the sea, including continental shelf, continental slope and continental rise[7].

At the end of Paleozoic, global plates were basically amalgamated together in the tectonic pattern of one supercontinent (Panchia), one ocean (paleo-Pacific) and one bay (Paleotethys)[8]. In the Triassic, the supercontinent began to split, kicking off the formation of present passive continental margin basins around the world[9–10]. Global passive continental margin basins were generated with the formation of Mesozoic and Cenozoic Atlantic, Indian, Arctic and Neotethys Oceans (Fig. 1). Totally, 7 major basin groups were formed in order of time, i.e., both sides of Central Atlantic Ocean, periphery of Gulf of Mexico, southeastern margin of Mediterranean, periphery of Indian Ocean, both sides of South Atlantic Ocean, both sides of North Atlantic Ocean and periphery of Arctic Ocean (Fig. 2).

2. Subdivisions of passive continental margin basins and their sedimentary filling

Comprehensive seismogeology comparison and interpretation indicate that passive continental margin basins around the world are different texture and structure (Table 1, Fig. 3). The passive continental margin basins are firstly classified into 4 divisions (i.e., rifted, faulted depression, depression and reformed basins) according to the principal series of strata in the basins, i.e., the dominant stages in the process of basin evolution. Then, based on the structural differences of the basins (i.e., reversal structure, unique ring-like structures of high constructive delta, salt structure and transform fault), the faulted depression, depression and reformed basins are classified further into 6 subdivisions, including saline faulted depression basin, nonsaline faulted depression basin, transform nonsaline depression basin, tensional saline depression basin, delta reformed basin and positive reverse deformed basin. In this way, there are totally 7 subdivisions of passive continental margin basins. Their sedimentary filling characteristics are investi-

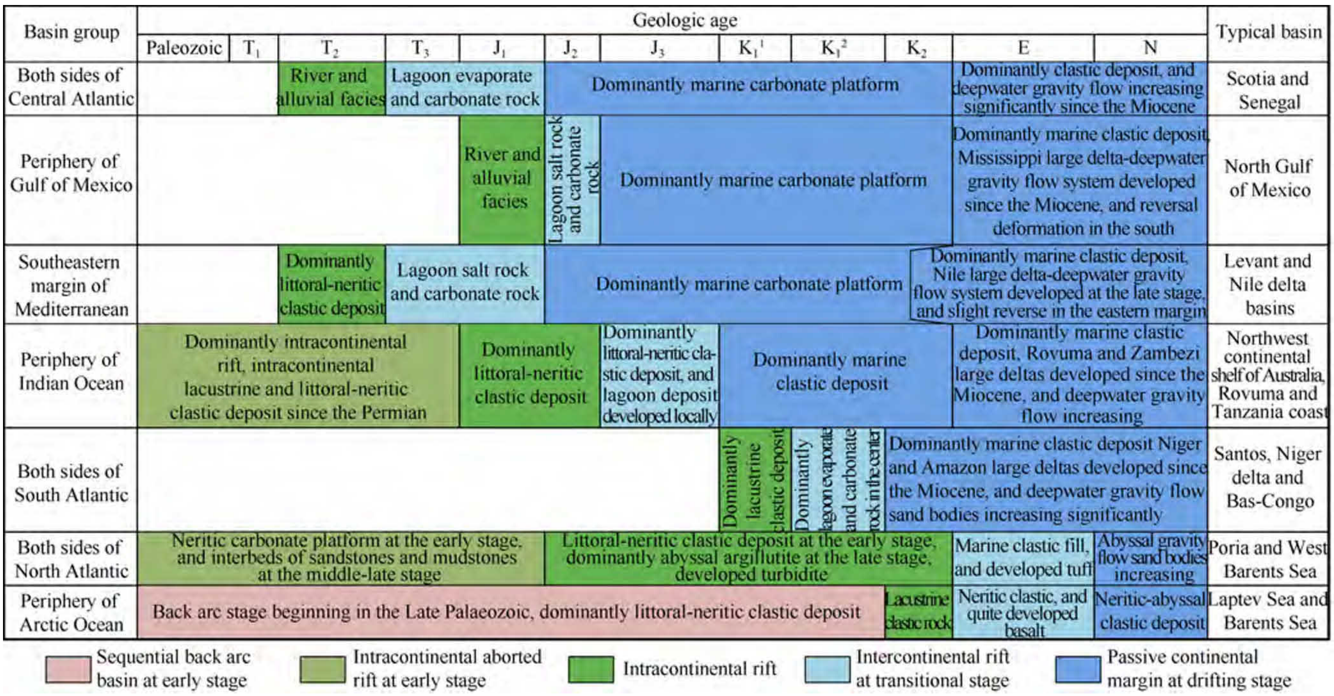

Fig. 1. Formation, evolution and sedimentary characteristics of seven major passive continental margin basin groups around the world (modified from References [4–5, 11–18]).