



Original research paper

Formation and distribution of large lithologic-stratigraphic oil & gas fields (provinces)

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Abstract

Since the “Tenth Five-Year Plan”, lithologic and stratigraphic reservoirs have been the main contribution of both the discovery as well as reserve and production increase in China; there were about 80% of proven reserves. The typical reservoirs in six major basins in the eastern, central, and western China were adopted as reservoir forming models. The reservoir forming models in three types of slopes, three types of depressions, and three types of lithologic reservoir assemblages have been built on the basis of application of new technologies, physical modeling of reservoir forming mechanism, and investigation to the formation and distribution of the reservoirs. The evaluation methods for large lithologic reservoir provinces were established based on the forming mechanism and main controlling factors mentioned above. In addition, the study reveals the main controlling factors and the laws of enrichment of two types of stratigraphic reservoirs (pinch-out and weathered karst reservoirs) based on the evaluation methods for large stratigraphic reservoir provinces that have been established. By comprehensively understanding the laws of enrichment of lithologic-stratigraphic reservoirs in four types of basins, specific evaluation methods and fine exploration techniques have been developed. The findings led to an exploration direction in the “Thirteenth Five-Year Plan” period. The study supported the exploration and selection of oil and gas plays, as well as promoted the exploration of lithologic and stratigraphic reservoirs.

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1. Introduction

With the deepening exploration and research work, structural reservoirs have become challenging to find and explore. As a result, the exploration is moving to subtle lithologic and stratigraphic reservoirs and unconventional oil and gas fields. Foreign scholars usually classify lithologic and stratigraphic reservoirs into stratigraphic reservoirs [1]. However, their traps and hydrocarbon accumulation mechanisms are apparently different from each other; therefore, Chinese scholars classify

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them into unlike types. This paper argues that lithologic reservoirs are developed in a set of continuous sedimentary formations and accumulated in the traps formed with the changes of lithology or physical properties of formation rocks. Meanwhile, stratigraphic reservoirs are developed at the boundary of a set of continuous sedimentary formations, namely occurring above/below the unconformity and taking the unconformity as the main trap element.

Since the “Tenth Five-Year Plan” period, lithologic and stratigraphic reservoirs have been the main contribution to the discovery. The said discovery is accompanied by the reserve and production increase in China [1–5]. As mentioned earlier, there are about 80% of proven reserves, of which, large and extra-large lithologic and stratigraphic reservoirs contributed the most. During the “Eleventh Five-Year Plan” period, based on the achievements of China Petroleum Science and Technology Projects and National Key Science and Technology Major Projects, geological theories involving 14 types of “structure-sequence hydrocarbon accumulation systems”, “six lines and four sides”-controlled trap forming mechanism, and “three major interfaces”-controlled hydrocarbon distribution were proposed. Moreover, laws of hydrocarbon enrichment involving “large-area accumulation in delta fronts” in depression basins, “full sag oil” in oil-rich sags in continental faulted basins, “fan reservoirs in thrust belts” in continental foreland basins, and “bank and reef reservoirs in platform margin belts” in marine cratonic basins were revealed. Furthermore, they have shifted exploration direction from structural highs to the periclinal and synclinal [4,5]. New undertakings and challenges are emerging with the extensive exploration and research work. The problems include diverse developmental environments, complex accumulation mechanism, and unknown enrichment factors and strategic target fields in the exploration of lithologic reservoirs, how to understand main controlling factors, laws of enrichment and models of the distribution of stratigraphic reservoirs based on previous studies on trap types, and geological features. Therefore, during the “Twelfth Five-Year Plan” period, supported by the State Key Science and Technology Project “Study on the Formation and Distribution of Large and Extra-Large Lithostratigraphic Reservoir Provinces” (Grant No. 2011ZX05001-001), as well as supporting science and technology projects, the integrated work method of case study, foundation construction and field application was implemented. A large amount of real data from lithologic and stratigraphic reservoirs in different basins were collected and analyzed. Basic work involving case study on typical reservoirs, experiments with new technologies and methods, physical simulation to reservoir forming mechanism, evaluation and prediction of reservoir forming and distribution under the cooperation of oilfield companies with colleges and universities was carried out. Based on the results acquired, systematic and comprehensive studies have been done on reservoir and trap types, sedimentary environment (i.e., slope zone and sag center), reservoir assemblage, enrichment factors, as well as evaluation and selection of favorable plays of lithologic-stratigraphic reservoirs. It is also worth noting that the understanding of the aforementioned hydrocarbon

accumulation and distribution has been deepened. There is significant progress in the understanding of the large-area and low-middle abundance hydrocarbon accumulation in the “Eleventh Five-Year Plan” period up to the large-scale oil and gas fields/provinces in the “Twelfth Five-Year Plan” period [2,5].

Throughout the “Twelfth Five-Year Plan” period, focusing on lithologic and stratigraphic reservoirs, key forming conditions, and distribution and enrichment factors were investigated based on the extensive collection of data, tracking exploration performance, and major oil and gas discoveries [6–9]. By means of the case studies on typical reservoirs/oil fields, physical and numerical simulations, as well as experiments with new technologies, and based on which, the forming and distribution of lithologic reservoirs were illustrated in slopes and sag centers in continental lacustrine basins. Finally, a new understanding was proposed involving composite and coexistent reservoirs in sag center, concentrated accumulation in slope, as well as fault-favorable facies belt-pressure difference-controlled accumulation. These points developed the understanding of the geologic theory of large-area lithologic reservoirs and established the evaluation parameter system and workflow for vast oil and gas fields in lithologic reservoirs. Succeeding case studies were carried out on oil and gas reservoirs in stratigraphic formations with: different lithologies, two main controlling factors (pinch-out zone and unconformity) on the boundary scale of pinch-out reservoirs, three controlling factors (favorable reservoir, fault, and local structure) on the distribution and enrichment of proposed weathered karst reservoirs, and established evaluation methods and parameter systems for large-scale oil and gas fields in pinch-out and weathered karst traps. The research results led the exploration of lithologic and stratigraphic reservoirs from local traps and secondary positive tectonic belts to large oil and gas provinces as a whole. The research guided the exploration of lithologic reservoirs in the Ordos, Songliao, and Junggar Basins, as well as the exploration of stratigraphic reservoirs in the western and central superimposed basins [10].

Based on the primary research that took place at the time of “Tenth Five-Year Plan” period and the “Eleventh Five-Year Plan” period [11–15], including the advances during the “Twelfth Five-Year Plan” period, two major theoretical systems have been developed. In addition, the understanding of geological theory has been improved in lithologic and stratigraphic reservoirs (Table 1), and two sets of exploration and evaluation methods and technologies (geological evaluation methods and supporting exploration technologies) have been proposed. This paper summarizes the results of the “Study on the Formation and Distribution of Large and Extra-Large Lithostratigraphic Reservoir Provinces” in the “Twelfth Five-Year Plan” period. Due to limited space, it is difficult to demonstrate cases and basic data in detail. As a result, instead of summarizing main points, findings, and conclusions for readers' reference, this paper focuses on the formation, distribution, and evaluation of typical lithologic and stratigraphic reservoirs. Lithologic-stratigraphic and stratigraphic-lithologic reservoirs will not be discussed separately here.

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