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RESEARCH PAPER

# Play types, geologic characteristics and exploration domains of lithological reservoirs in China

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**Abstract:** By dissecting thirty-six representative oil-gas reservoirs and analyzing accumulation conditions of giant oil and gas provinces in four prototype basins, including the Songliao Rift and Depression Basin, the Mesozoic Ordos Depression Basin, the Bohai Bay Rift and Depression Basin, the Mesozoic Junggar Depression Basin, the West Sichuan Foreland Basin and the Tarim Craton Basin, the hydrocarbon plays classification scheme of lithologic reservoirs is established and improved from the perspective of oil-gas accumulation zone and exploration target. The results reveal the accumulation characteristics and controlling factors of lithologic reservoirs including three kinds of slopes, three kinds of sag centers,three kinds of hydrocarbon accumulation assemblages and multiple genetic types. Based on the understandings on reservoir formation mechanisms and enrichment regularities of different hydrocarbon provinces, six major assessment indexes, parameter system and grading standard of lithologic plays are established, including hydrocarbon source rock condition, transportation pathway, reservoir condition, reservoir-cap assemblage, fluid property, and time-space configuration etc. Through comprehensive analysis of burial history, hydrocarbon-generation history, digenesis history, tectonic history, trap-forming history and accumulation history, plays of lithologic reservoirs are evaluated and optimized. The results show that the middle-shallow layers in the slope zones of the Songliao and Bohai Bay Basins oil-rich sags, the Mesozoic in the Ordos Basin, the Permian-Jurassic in the Junggar Basin, etc. are the major oil exploration areas in the future, with oil resources of about $42\times10^8$ t–$67\times10^8$ t; the deep volcanic rocks of the Songliao Basin, the Carboniferous of the Junggar Basin, the Cambrian of the Tarim and Sichuan Basins, the Permian-Triassic reefs and shoals within the platform and on the platform margin of the Sichuan Basin are the major gas exploration areas in the future, with gas resources of about $1.5\times10^{12}$ m$^3$–$2.0\times10^{12}$ m$^3$.

**Key words:** lithological reservoirs; lithological trap; play types; play assessment method; accumulation regularity; exploration area

## Introduction

Although lithologic and stratigraphic reservoirs are usually classified as stratigraphic reservoir in foreign countries[1–2], they are normally deemed to be two different types in China because of their distinctly different trap origins and hydrocarbon accumulation mechanisms[3–5]. Both continental and marine basins in China have geological conditions to form lithologic reservoirs. In particular, clastic sedimentary system in continental basins, which may vary greatly in lithology and lithofacies, is favorable for widespread clustered lithologic reservoirs[6–7]. In recent years, a number of oil and gas breakthroughs and discoveries have been made in four kinds of continental basins in China (i.e., fault depression basin, depression basin, foreland basin and marine cratonic basin), three kinds of lithologic bodies (i.e., clastic rock, carbonate rock and volcanic rock), and two domains (i.e., sag center and slope belt). Twelve oil and gas regions have been built from 2011 to 2014, including the middle-shallow layer and west slope in the Songliao Basin, the Chenghai and northern Qikou regions in the Bohai Bay Basin, the Jiyuan and Huaqing regions in the Ordos Basin, and the west slope of the Mahu depression and the Fudong slope in the Junggar Basin, with newly increased proved oil reserves of $4.6\times10^8$ t and gas reserves of $760\times10^8$ m$^3$, newly increased controlled reserves and predicted oil reserves of $25\times10^8$ t, showing a great exploration

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prospect of lithologic reservoirs.

Relying on the national key and special science and technology research project of lithologic and stratigraphic reservoirs, this study examines representative oil and gas reservoirs and analyzes hydrocarbon accumulation conditions of oil and gas provinces to get a deeper understanding on formation and distribution pattern of lithologic reservoirs and to find out the accumulation characteristics and main controlling factors of lithologic reservoirs of various origins in three kinds of slopes, three kinds of sag centers, three kinds of accumulation assemblages. A method evaluating lithologic oil and gas provinces is established in the hope of promoting the exploration and increasing the reserves of lithologic oil and gas provinces.

## 1. Types of lithologic oil and gas plays

The oil and gas province refers to a large-scale oil- and gas-bearing area, consisting of multiple oil and gas reservoir (field) groups or belts with a type of dominant reservoir that are vertically superimposed, laterally merged and controlled by similar hydrocarbon accumulation conditions, under the same large-scale tectonic setting[2]. In general, a oil and gas province should hold $10\times10^8$ t or more of proved oil in-place and (or) $5\ 000\times10^8$ $m^3$ or more of proved gas in-place[2]. There are three marks that can be used to determine the factors that control the oil and gas provinces and define their scope: spatial mark, accumulation mark and resources mark[2]. Factors affecting and determining oil and gas provinces (hydrocarbon enrichment degree) and oil and gas accumulation plays (resource abundance) are similar, and the latter are a part of the former. With the ongoing exploration, an evaluation shift from the oil and gas accumulation play to the overall oil and gas province is an inevitable trend.

The play is a basic place within the basin for hydrocarbon to accumulate, a geologic unit between the petroliferous basin and trap, and a unified combination of a series of traps and discovered reservoirs (fields) geographically adjacent to each other, which exist in the same structural belt within a basin, share the same genesis and hydrocarbon generation, migration and accumulation laws[8]. There are a number of classification schemes for plays, for example, a classification according to the exploration and discovery status, in which plays are grouped into play with oil and gas field, play with oil and gas discovery, and play with no oil and gas discovery; and another classification according to trap/reservoir type in which plays are grouped into structural-type, nonstructural-type and mixed- type.

Similarly, there are various classification schemes for lithologic oil and gas plays[9]. In this paper, a classification system for giant lithologic oil and gas plays has been established from the perspective of hydrocarbon accumulation-distribution area and exploration zone selection, by dissecting four kinds of basins, three kinds of lithologic bodies and a wide variety of representative lithologic reservoirs, and through reservoir rock type, hydrocarbon accumulation assemblage, position relationship of source and reservoir, accumulation process, and structural position (Table 1).

Table 1 shows that, various schemes are available for classification of giant lithologic oil and gas plays from different perspectives and thus can produce different results. In a real comprehensive evaluation of giant lithologic oil and gas places, an applicable classification scheme should be selected based on the study objects, geographical area and geological characteristics.

## 2. Main controlling factors of hydrocarbon accumulation in typical lithologic giant oil and gas plays

Different types of lithologic reservoirs have different accumulation characteristics and main controlling factors[9–11]. In this paper, we only present a brief discussion on different accumulation assemblages, position relationships of source and reservoir, accumulation processes, reservoir types and structural positions.

### 2.1. Accumulation and main controlling factors of lithologic reservoirs with different accumulation assemblages

According to vertical position relationship of source and reservoir, the accumulation assemblage of lithologic reservoirs can be divided into three types: above-source, inner-source and under-source assemblages. Based on dissection of representative oil and gas reservoirs and examples, accumulation characteristics and main controlling factors of lithologic reservoirs with different accumulation assemblages have been sorted out:

#### 2.1.1. Above-source assemblage

Buoyancy and potential difference are major driving forces for hydrocarbon accumulation. Above-source oil reservoir can be classified as the "lower-generation & upper-storage" fault-lithologic reservoir, and its formation is controlled primarily by faults (conduit system) in source rock and favorable trap. The distribution of this kind of reservoir is controlled by the flooding surface, fault surface and sequence boundary. The flooding surface controls the distribution of source rock, the fault surface controls the migration of hydrocarbon, and the sequence boundary controls the distribution of reservoir.

Potential energy acts as a driving force in above-source accumulation, and the fluid density difference enables upward migration of hydrocarbon under the effect of buoyancy. Abnormal high pressure is common in argillaceous source rock as a result of compaction and hydrocarbon-generation. Undoubtedly, this abnormal high pressure can act as one of the driving forces. Under the condition that there is a potential difference between source and reservoir, the residual pressure in source rock makes it easy for oil and gas to migrate upward. However, during the hydrocarbon migration driven by potential difference, the pressure also exists.