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RESEARCH PAPER

Genetic connection between mud shale lithofacies and shale oil enrichment in Jiyang Depression, Bohai Bay Basin

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Abstract: By using microscope, argon ion polishing technology, nuclear magnetic resonance (NMR), scanning electron microscopy, and hydrocarbon generation and expulsion simulation, reservoir properties, oiliness and shale oil mobility of different mud shale lithofacies were examined with the mud shale in Jiyang Depression, Bohai Bay Basin as the example. The relationship between lithofacies type and shale oil enrichment was analyzed. Based on the rock composition, sedimentary structures and abundance of organic matter, a mud shale lithofacies classification standard for the upper submember of the 4th Member to the lower submember of the 3rd Member of Paleogene Shahejie Formation (Es4s-Es3x) was established. Six lithofacies are developed in the target formation, in which the laminar organic-rich lithofacies formed in the alternating mechanical transportation deposition and chemical deposition, not only has the highest TOC, S_1, oil saturation, movable oil saturation, content of low-carbon light components and oil generation and expulsion rate, but also has various types of reservoir space, abundant pores, and organic network system and interlayer micro-fracture system which can serve as high-speed channels for shale oil and gas migration, so this lithofacies is favorable for shale oil enrichment.

Key words: mud shale; shale oil; lithofacies; oiliness; reservoir properties; organic network; microcracks; Jiyang Depression, Bohai Bay Basin

1. Overview of the study area

With an exploration area of about 2.62×10^4 km^2, Jiyang Depression in Bohai Bay basin is composed of a series of uplifts and depressions (Fig. 1). By the end of 2015, in the shale source rock of Member 1 of Paleogene Shahejie Formation (hereafter referred to as Es1), the Lower Member 3 of Shahejie Formation (hereafter referred to as Es3x) and the Upper Member 4 of Shahejie Formation (hereafter referred to as Es4s) in Jiyang Depression, oil and gas shows were found in over 800 wells, among which industrial oil and gas flows and low yield oil and gas flows were found in over 40 wells, in almost every depressions and layers, mostly in Zhanhua and Dongying sags. These wells produce oil primarily and gas secondarily. Since 2012, coring wells Well Ny1, Well Fy1 and Well Ly1 and a horizontal Well Ly1HF have been deployed successively in Dongying Depression. All the wells and Well Ly1 after fracturing were tested and obtained low yield oil and gas flows, showing the promising potential of shale oil in Jiyang Depression. According to the statistics of producing wells in the research area, shale oil mainly produces from organic-rich laminated lithofacies, occupying 70% of the oil production intervals, in which organic-rich laminated argillaceous limestone lithofacies accounts for 37%, organic-rich laminated tuffaceous mudstone lithofacies accounts for 33%, organic-rich layered argillaceous limestone lithofacies accounts for 19%, organic-rich layered tuffaceous mudstone lithofacies accounts for 9% and organic-moderate laminated argillaceous limestone lithofacies accounts for 2%. The exploration results show there is a correlation between the mud shale lithofacies of Jiyang Depression and the enrichment of shale oil. As the mud shale lithofacies in lacustrine basin are various in type and fast in variation, it is of guiding significance for the exploration in this area to study the relationship between different types of lithofacies and the enrichment of shale oil.

2. Types and characteristics of lithofacies

Through laboratory analysis of core samples and comparison, we found that lithology, sedimentary structures and abundance of organic matter are the main factors affecting the oiliness, physical property and shale oil mobility of shale in Es4s-Es3x of Jiyang Depression (Fig. 2). Therefore, based on

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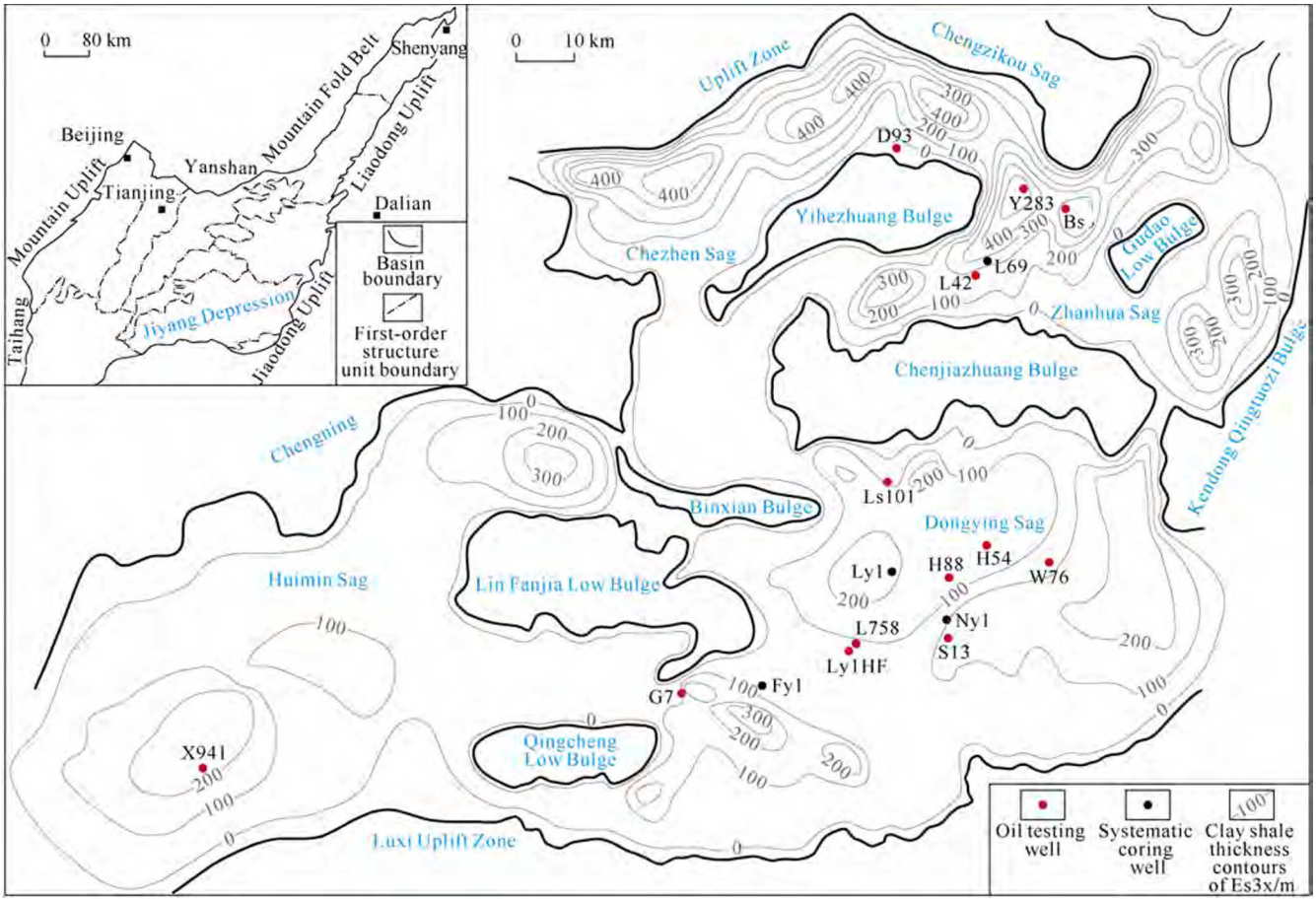

Fig. 1. Location of Jiyang Depression.

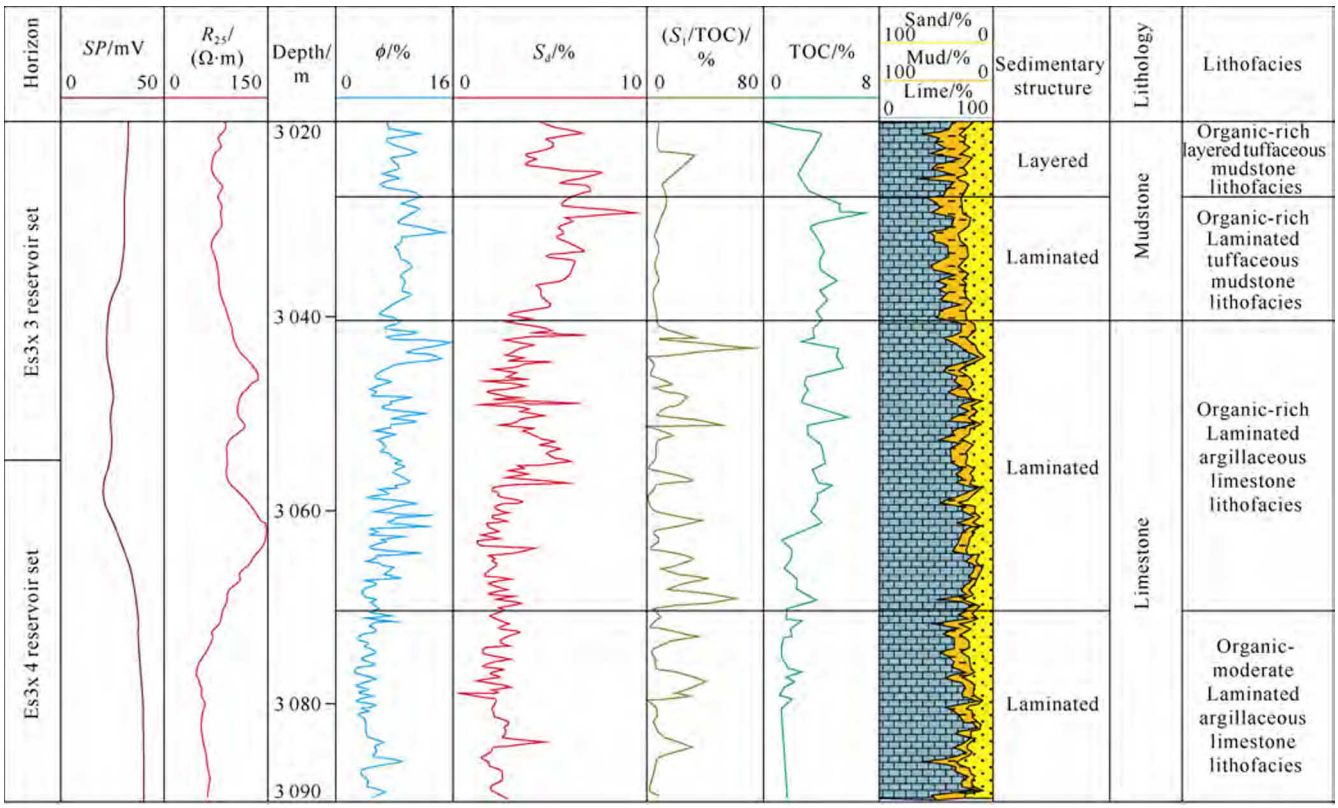

Fig. 2. Characteristics of Es3x shale in Well L69. S_d—The ratio of effective porosity oil volume to total volume of the rock sample; ϕ—Porosity; *SP*—Spontaneous potential; R_{25}—2.5 inches resistivity; TOC—Total organic carbon; S_1—Free hydrocarbon content.