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Hydrocarbon accumulation characteristics and differential accumulation mechanisms in the low-maturity lacustrine shales of Late Eocene Shahejie Formation, Bohai Bay Basin

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The Tertiary lacustrine shales in China exhibit low to moderate maturity, yet demonstrate significant shale oil resource potential compared to North American marine shales. The hydrocarbon accumulation mechanisms in these shales are crucial for resource evaluation and exploration. This study synthesizes suite of geological and geochemical methods to analyze the hydrocarbon accumulation characteristics and differential accumulation mechanisms in the low-maturity lacustrine shales of the late Eocene Shahejie Formation (EOS shales) in the Bohai Bay Basin. Key findings include: (1) The EOS shales display a complex mineral composition dominated by clay and quartz, followed by calcite and ankerite, with lesser plagioclase and K-feldspar. Pyrite content is relatively low, likely due to sulfate deficiency in the water. The lithofacies consist of mixed shale, clay shale, and felsic shale, lacking calcareous-dolomitic shale. Micro pores and fractures provide space for hydrocarbon enrichment. The EOS shales exhibit high organic matter content and favorable organic matter types, indicating significant hydrocarbon generation potential. (2) Differential hydrocarbon enrichment in the EOS shales is characterized by top enrichment and bottom depletion, quantifiable through ΔS1 and OSI values. Strata with ΔS1 values less than or close to 0 favor hydrocarbon enrichment, typically associated with higher OSI values. (3) Hydrocarbon migration influences shale oil enrichment. PI and Sat/Aro ratios help characterize migration features. Decreasing PI values with maturity suggest short-distance migration, while decreasing Sat/Aro ratios with increasing ΔS1 indicate migration. ΔS1 serves as a quantitative indicator of migration extent. (4) Minerals, lithology, and lithofacies impact hydrocarbon enrichment. Halite presence positively correlates with organic matter content, suggesting its role in organic matter enrichment. Ankerite promotes hydrocarbon enrichment, possibly by altering pore structures and trapping hydrocarbons. Dark gray mudstone favors shale oil enrichment, and mixed shale is most conducive to shale oil enrichment. Differential enrichment in low-maturity lacustrine shale oil is categorized into three groups (I, II, III), with Group II being particularly favorable for hydrocarbon enrichment. This study elucidates the differential enrichment characteristics of hydrocarbons in low-maturity lacustrine shales and proposes an enrichment model, providing substantial support for in-depth exploration and effective development of lacustrine shale oil resources.