Advances in
Geo-Energy Research

Vol.12, No.2, p. 81-88, 2024

Perspective

Low-to-medium maturity lacustrine shale oil resource and *in-situ* conversion process technology: Recent advances and challenges

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Keywords:
Low-to-medium maturity
Lacustrine shale oil
in-situ conversion process
Organic matter super-rich accumulation
Shale oil exploitation
Onshore China

Cited as:
Zhao, W., Guan, M., Liu, W., Bian, C., Li, Y., Wang, X., Xu, R. Low-to-medium maturity lacustrine shale oil resource and *in-situ* conversion process technology: Recent advances and challenges. Advances in Geo-Energy Research, 2024, 12(2): 81-88.
https://doi.org/10.46690/ager.2024.05.01

Abstract:
Low-to-medium maturity lacustrine shale oil resources have enormous potential and are projected to play a crucial role in the massive scale-up of crude oil production in China in the near future. The *in-situ* conversion process is currently the only effective means of utilizing this resource. Nevertheless, significant scientific challenges and technological bottlenecks still exist. Under this circumstance, the National Natural Science Foundation of China approved an integrated project of the Enterprise Innovation and Development Joint Fund titled "The Mechanism of Low-to-medium Maturity Lacustrine Shale Oil Resource Formation and its *in-situ* Conversion and Exploitation". This project aims to systematically investigate the entire process of *in-situ* conversion for low-to-medium maturity shale oil resources and lay a solid scientific and technological foundation for advancing the smooth implementation of on-site pilot trials. This paper presents the latest progress in this field and summarizes the existing scientific and technological challenges that need to be addressed. With the foundational support of the above project, our research team has made significant progress in several fields, including the formation mechanisms of organic matter super-rich shale, low-to-medium maturity shale oil enrichment area evaluation, heat and mass transfer dynamics, coupled fluid field and hydrocarbon expulsion efficiency, exploitation methods, among others. Despite these theoretical advances, several major challenges were identified, which help to further focus on the critical scientific issues, determine the *in-situ* conversion technique-developing direction, and formulate a feasible implementation plan for future resource utilization.

1. Introduction

The significance of shale oil in China's expanding oil and gas production is increasingly prominent. With the aid of horizontal wells and hydraulic fracturing technology, large-scale development has been made possible for high-maturity shale oil in numerous lacustrine basins and medium-maturity shale oil in salinized lake basins (Zhao et al., 2023b). Shale oil production, which exceeded 400×10^4 t in 2023 (NEA, 2024), is expected to become an important supplementary resource for ensuring future crude oil production at 2×10^8 t/year (Wang et al., 2022). The resource potential of low-to-medium maturity (LMM) shale oil is enormous, with a preliminary estimate of the economic recoverable reserve at approximately $200\sim250\times10^8$ t of oil assuming a Brant oil price in the 60 to 65 dollar/barrel range (Zhao et al., 2018). It is gradually becoming a strategic resource for enhancing reserve growth, increasing production addition, and potentially achieving China's energy independence.

LMM shale oil comprises petroleum that has already formed underground, various bituminous substances, and solid organic matter (kerogen) that has not undergone thermal degradation (Vandenbroucke and Largeau , 2007). The *in-situ* conversion process (ICP) employs heating methods, preferably electrical heating, to transform heavy oil, bitumen and

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Received February 29, 2024; revised March 14, 2024; accepted March 23, 2024; available online March 25, 2024.

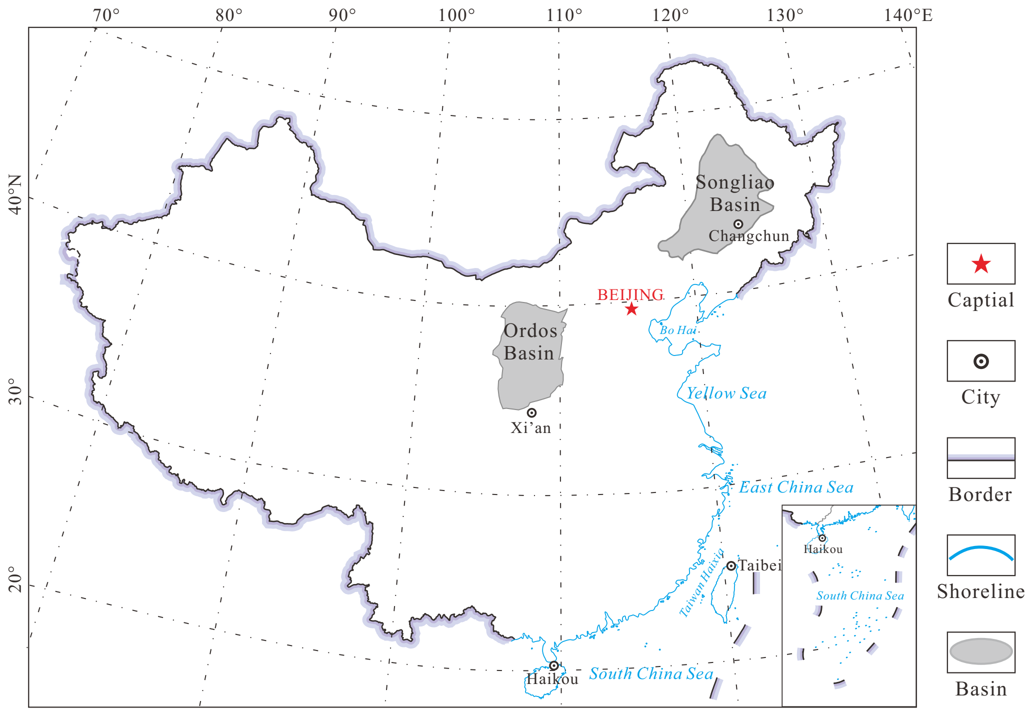

Fig. 1. The locations of the Songliao Basin and the Ordos Basin.

undegraded kerogen into light oil and gas, enhancing shale oil fluidity (Zhao et al., 2018). The effective utilization of LMM shale oil resources comprises aiming for optimal heating targets, high energy utilization efficiency, and great production volume to assure economically viable, large-scale exploitation. The utilization of thicker shale intervals with low-maturity and high content of organic matter is crucial to maximize retained oil and solid organic matter within shales (Zhao et al., 2023a). Thermal maturity has been suggested as vitrinite reflectance (R_o) values ranging from 0.5% to 0.9% for lacustrine shales in freshwater basins, mainly for the third sub-member of the Chang 7 member of the Triassic Yanchang Formation (hereinafter referred to as Chang7_3) in the Ordos Basin of Central China, and the first and second members of the Cretaceous Nenjiang Formation (hereinafter referred to as Nen1+2) in the Songliao Basin of Eastern China (Figs. 1 and 2) (Zhao et al., 2018; Zhao et al., 2023b). The depth range for LMM shale oil resources is 300-3,000 m, whereas oil shale resources are typically distributed in sequences shallower than 300 m (Zhao et al., 2018).

The National Natural Science Foundation of China (NSFC) has attached great importance to LMM shale oil resources and the ICP. On April 22-23, 2021, the 281st "Shuangqing Forum" was held in Beijing with the theme "Scientific Issues and Key Technologies of the LMM Lacustrine Shale Oil Accumulation and its *in-situ* Conversion". By exchanging ideas, colliding viewpoints, and reaching scientific consensus in the forum, three key scientific fields were summarized: (1) The mechanisms of lacustrine organic-rich shale formation and LMM shale oil accumulation; (2) Heat transfer and the *in-situ* conversion mechanisms of LMM shale oil; (3) The energizing effect of solid/liquid/gas phase organic matter transformation and the multi-phase and multi-field coupling flowing mechanism (Zhao et al., 2023c). Subsequently, an integrated project of the NSFC's Enterprise Innovation and Development Joint Fund titled "The Mechanism of Low-to-medium Maturity Lacustrine Shale Oil Resource Formation and its *in-situ* Conversion and Exploitation" was approved in October 2022. Five themes were set up to bolster and advance on-site pilot trials through major theoretical breakthroughs, including:

1) The environmental response and external substance interaction mechanisms for organic matter super-rich accumulation.
2) The controlling factors of LMM shale oil formation and methods for enrichment area evaluation.
3) The energy field evolution characteristics of solid/liquid/gas phase organic matter conversion and the heat transfer dynamics mechanism.
4) The multi-phase and multi-field coupling flow mechanisms of hydrocarbon substances and the displacement efficiency of the ICP.
5) The ICP exploitation methods of LMM shale oil.

An annual academic exchange conference was organized on January 3, 2024, which focused on the latest research progress in lacustrine LMM shale oil formation mechanisms, favorable area evaluation criteria, heat transfer mechanisms, hydrocarbon displacement behavior, and exploitation methods. Accordingly, this review presents the latest progress of project research and summarizes the existing scientific and technological challenges, to provide suggestions for future research and development avenues for ICP-LMM shale oil resources.

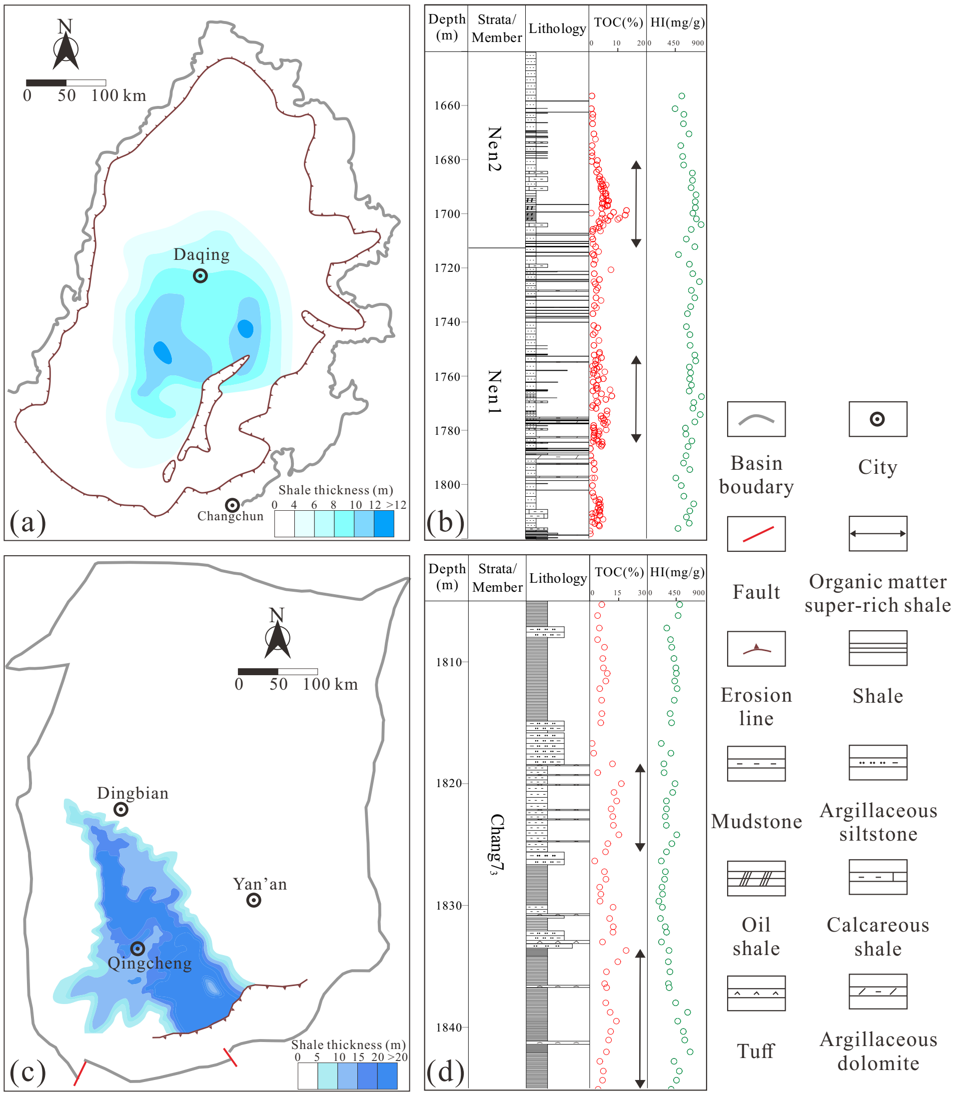

Fig. 2. Organic matter super-rich shale thickness of (a) the Chang7$_3$ and (c) the Nen2, and lithological and geochemical vertical variation of (b) the Chang7$_3$ and (d) the Nen1+2.

2. Main advances

2.1 Mechanism of organic matter super-rich shale formation

Organic matter super-rich shales lay the foundation for LMM shale oil formation and are potential heating targets for the ICP. The organic matter super-rich shales require a high hydrocarbon generation potential, which implies that the shale intervals should feature high organic matter abundance and are mainly oil-prone. Based on the correlation between the hydrogen index (HI) and the total organic carbon (TOC), organic matter super-rich shales were identified with TOC exceeding an estimated range of 6%-8% and HI surpassing 300 mg/g for Chang7$_3$ and with TOC above 3.5% and HI exceeding 600 mg/g for Nen1+2 (Figs. 2(b) and 2(d)). The organic matter super-rich intervals have a concentrated thickness of about 10∼20 m and 5∼15 m for Chang7$_3$ and Nen1+2 (Figs. 2(a) and 2(c)), respectively. This indicates that the super-rich accumulation of organic matter (SRAOM) caused by abrupt sedimentary environmental changes were likely related to volcanic activities in Chang7$_3$ and marine incursions in Nen1+2 (Liu et al., 2022, 2024). These phenomena transported a flux of nutrient elements (copper, zinc and phosphorus) into lacustrine basins, which promoted the thriving of photosynthetic bacteria and algae and thus contributed to substantial organic matter crucial for the super-rich accumulation intervals. The intervals impacted by strong volcanic activities do not correspond to the highest TOC because more tuff in these intervals diluted organic matter and triggered stronger organic matter mineralization via bacterial sulfate reduction. Hence, the volcanic activity index (VAI, calculated as the product of airborne tuff thickness, its tuff compaction coefficient, and divided by tuff layer numbers) was proposed to quantify the impact of volcanic activities on the SRAOM in Chang7$_3$. Moderate intensity of volcanic activity within a VAI range of 0.2∼0.5 was found to be most conductive to the SRAOM,

Table 1. Oil and gas yields of the Chang7$_3$ and Nen2 from pyrolysis experiments.

Member	Sample	TOC (%)	HI (mg/g)	R_o (%)	Maximum oil yield (kg·HC/t·Rock)	Gas yield (kg·HC/t·Rock)	Oil-gas valent weight (kg·HC/t·Rock)
Chang7$_3$ (Zhao et al., 2018)	Li38	23.7	347	0.82	36	18	54
	HJF*	24.7	405	0.51	52	21	73
	MQ*	13.9	412	0.69**	52	9	61
Nen2	CY6801	10.3	699	0.60**	75	5	81

Notes: * denotes outcrop samples, ** represents the equivalent vitrinite reflectance calculated from $R_o = 0.0180 \times T_{\max} - 7.16$ (Jarvie et al., 2001).

corresponding to high TOC values up to 10%∼30%. Furthermore, intermittent and persistent marine invasions were identified through biomarkers and inorganic element proxies during the sedimentary period of Nen1+2. Marine incursions bring nutrient elements and trigger bottom water reduction condition due to pycnocline stratification, enhancing the SRAOM in Nen1+2.

2.2 Evaluation of LMM shale oil enrichment area

At present, it is impractical to conduct the ICP on all organic-rich shales; only those with higher hydrocarbon generation potential and greater concentrated thickness are ideal heating targets. Pyrolysis experiments have demonstrated high hydrocarbon generation potential in Chang7$_3$ and Nen2 (Table 1), which have maximum total hydrocarbon yields of 54-73 kg·HC/t·Rock and 81 kg·HC/t·Rock at peak oil generation window, respectively. Furthermore, the hydrocarbon-generation quality index (HQI, calculated as the product of the concentrated thickness of organic matter super-rich shales and the sum of light hydrocarbon loss content (S$_L$), free hydrocarbon (S$_1$), and thermal cracking hydrocarbon (S$_2$)) was introduced to assess LMM shale oil resource abundance and prioritize favorable areas for the ICP. The HQI value exceeding 273 was recommended as a prerequisite for favorable areas of Chang 7$_3$ and Nen1+2. Maceral groups closely correlate with hydrocarbon products and transformation ratios, and their heterogeneous occurrence in organic matter super-rich shales influences the determination of heating targets. Algae are predominant in Chang7$_3$ and Nen1+2. Lamalginites in the lower part of the Nen2 have a significant contribution to organic matter accumulation and have higher hydrocarbon generation potential with high activation energies over telalginites. They predominantly exhibit long-axis shapes in Chang7$_3$, and have relatively low hydrocarbon generation potential compared to those with short-axis shapes. Maceral identification and spatial distribution characterization are crucial for establishing evaluation criteria for LMM shale oil. Furthermore, the heating process can enhance the shale reservoir properties and reduce the adsorption oil content. The number of pores and fractures significantly increases when the vitrinite reflectance-equivalent exceeds 0.75% following heating. Heating triggers smectite illitization and generates light hydrocarbon components, both contributing to reduced adsorption and enhanced shale oil fluidity.

2.3 Heat and mass transfer dynamics

The heat and mass transfer theory for ICP-LMM shale oil primarily aims to present the precise thermal field distribution and energy field evolution as well as determine the optimal heating methods. Thus far, a high-temperature (up to 500 °C) and high-pressure (up to 15 MPa) visualization experimental system has been built to investigate multi-component heat and mass transport in nanochannels with pore depths ranging from 20 nm to 180 nm during the heating process (Fig. 3) (Lu et al., 2022). Using this experimental system, the flow characteristics of hydrocarbons in nanochannels revealed that the actual flowing velocity is lower than that of the theoretical prediction at nanochannel depths less than 100 nm. The shallower the channel depth, the more significant the confinement effect is on the fluid flow process. Based on the deviations in capillary flow caused by various temperatures, carbon numbers and hydrocarbon molecular structures, a capillary filling model for hydrocarbons in a single nanochannel was developed, and permeability was adjusted using the determined adsorption layer thickness (Lu et al., 2019). The capillary filling model of hydrocarbons in porous nanochannels was constructed using the adjusted permeability and porous structure tortuosity, which provides a basis for establishing a heat and mass transfer model of confined fluids in shale pores. Additionally, the thermal decomposition behavior of Nen1+2 was clarified by pyrolysis experiments employing various heating rates and thermal cracking product analysis. A three-stage reaction mechanism for pyrolysis in Nen1+2 was proposed, with the following points: (1) The first stage includes water evaporation at pyrolysis temperatures below 300 °C; (2) The second stage entails the thermal cracking of organic matter into oil/gas, with an intermediate product of asphaltene, occurring between 300-600 °C; and (3) The third stage involves mineral decomposition within a pyrolysis temperature range of 520-750 °C. Furthermore, an energy conservation equation suitable for ICP-LMM shale oil was developed to characterize the energy field evolution (Zhao et al., 2022). Mass and momentum conservation equations were formulated to describe the ICP while considering skeletal strain, chemical reactions, and pore wall adsorption. Solid-

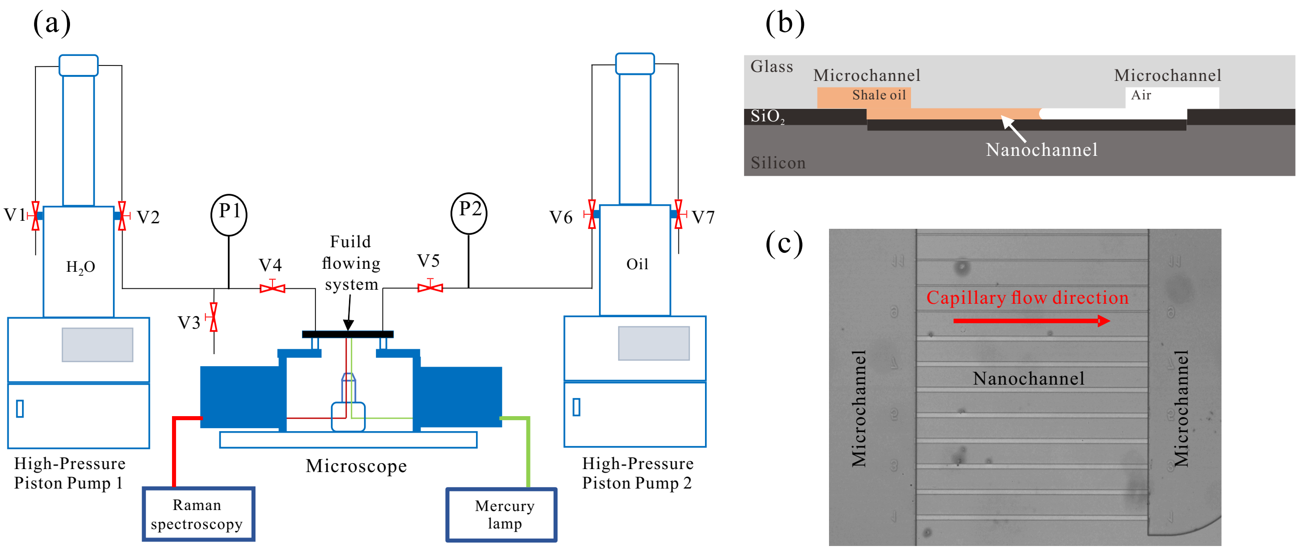

Fig. 3. High-temperature and high-pressure fluid-flow visualization experiment system. (a) Schematic diagram of fluid-flow visualization experiment platform, (b) schematic diagram of fluid-flow experimental system and (c) microscope image of the nanofluidic experiment.

fluid coupling was achieved by linking the fluid density change caused by pyrolysis with the skeleton stress and strain. Through combining the key multi-component conversion and heat transfer with the established capillary filling model, the fundamental framework of the energy field evolution model was established to precisely describe changes in the heat and mass transfer parameters, which has implications for revealing the characteristics of energy field evolution during the ICP.

2.4 The coupled fluid field and hydrocarbon expulsion efficiency

The hydrocarbon flow mechanism during the ICP lays the solid foundation of determining the heating temperature range. An experimental apparatus was assembled for testing the phase state of pyrolysis hydrocarbon products, from which the phase state parameters of these products were acquired under different temperature and pressure conditions. Subsequently, a phase state characterization model suitable for high temperature was developed using experimental results to illustrate the phase state variation during the ICP (Baled et al., 2012). Moreover, a flow simulation model was preliminary formulated by integrating the mass conservation equation, the nonlinear seepage equation, and the rock mass governing equation. Utilizing the established flow simulation model that considers the characteristics of Chang7$_3$ and Nen1+2, an oil/gas displacement prediction model was constructed through statistical analysis and artificial intelligence. A preliminary production prediction model was developed to effectively forecast the production capacity, leveraging the oil/gas displacement prediction characteristics (Liu et al., 2023). Furthermore, a novel nano-catalyst with particle sizes of 60-80 nm was synthesized by low-temperature hydrothermal crystallization and wet impregnation methods (Jin et al., 2023). This catalyst can decrease the initial pyrolysis temperature by 54 °C and increase the oil and gas yield after catalytic treatment.

2.5 Exploitation methods

Currently, there are various individual technologies for the ICP that have matured. These include long-distance magnetic ranging offset directional technologies that enable the drilling of horizontal wells with small distances (~5 m), magnesium oxide-encapsulated stainless steel armored coiled tubing electric heaters with high-power and high-temperature resistance, tungsten alloy-coated tubes offering high-temperature and corrosion resistance, high-temperature and high-pressure monitoring technologies using thermocouple measurement and capillary manometry, etc. These technologies will effectively support the implementation of on-site pilot trials for the ICP in lacustrine shales (Zhao et al., 2023c). In addition, numerous experiments and analog simulations have been completed to analyze the technical feasibility and energy utilization efficiency, evaluate the economic benefits, and design implementation plans for the ICP. A non-steady state multiple heat transfer theoretical model has been developed to account for multiple coupling nodes, including heater, annulus, wellbore, and formation. This model determines heat and temperature at any point from heater to shale formation and can be used to ascertain the heat transfer characteristics over time. It is suggested to use a stacked multiple heating well configuration to enhance the ICP efficiency. Moreover, the impact of well column diameter and heat-conducting fluid (water, N$_2$, and CO$_2$) on heat transfer was elucidated by a combination of physical experiments and analog simulations (Zhang et al., 2022), providing key parameters for the optimization of wellbore processes. To prolong the lifespan of heaters, it is recommended to utilize well columns exceeding 5 inches and inert gas as heating conduction media.

3. Current challenges

LMM shale oil is a strategic resource that is expected to contribute significantly to China's future oil/gas energy independence. It represents a substantial resource potential; however, effective exploitation still faces several challenges:

3.1 The connotation of LMM shale oil through ICP technology

Low-maturity shale oil has been defined as having a R_o range of 0.50%∼0.75% in freshwater basins. Their counterparts in brackish or saline conditions do not fall into this category due to their high-quality reservoir conditions and large hydrocarbon generation rates at this stage. The distinction between low and medium maturity and the applicability of the ICP for medium-maturity shale oil are yet to be clarified. Therefore, a deeper understanding for the ICP is essential to enrich the definition of LMM shale oil, which directly influences the formulation of exploration strategies, the assessment of shale oil resource potential, and the optimization of shale exploitation targets for different shale oil types.

3.2 The formation mechanism and evaluation of LMM shale oil resources

Shales with high organic matter abundance, large hydrocarbon generation potential, and low maturity are preferred targets for the ICP, corresponding to organic matter super-rich intervals in Chang7_3 and Nen1+2. Apart from volcanic activities and marine incursions, there has been insufficient systematic investigation into the impact of other factors on organic matter accumulation in Chang7_3 and Nen1+2, including hydrothermal fluids and radioactivity. Moreover, a precise quantitative relationship between the intensity of geological events and the amounts of external material input has not been established, making it difficult to clarify the detailed mechanism of how geological events control the depositional process of shale and the SRAOM. The VAI value links the average single-layer tuff thickness with the intensity of volcanic activities, thereby classifying its impact on the SRAOM. Nevertheless, different tuff layers may exhibit varying element abundance due to volcanic ash origins and particle sizes, such as crystal tuff and vitric tuff. These variations could potentially affect the shale depositional processes and organic matter accumulation.

Variations in TOC, HI, and transformation behaviors have been observed among different macerals, which will inevitably result in differences in hydrocarbon generation amounts and product compositions after investing the same heating energy. This in turn will change shale oil production and fluidity; therefore, targeting shales with high hydrocarbon generation potential and easily convertible kerogens is expected to be the most effective strategy for the ICP. To this end, it is necessary to identify easily convertible kerogen, ascertain their hydrocarbon generative potential, and map their spatial distribution, which could aid in reducing energy input and obtaining higher shale oil production yields. The established criteria for prioritizing favorable areas and evaluating LMM shale oil resource rely predominantly on experimental results and theoretical knowledge. These criteria require further refinement through the implementation of on-situ pilot trials. The HQI, representing the shale oil resource abundance, is instrumental in prioritizing favorable areas. Other parameters must also be considered when determining the optimal heating target, such as TOC that is widely available and usually positively correlated with LMM shale oil content (the sum of S_L, S_1 and S_2) in specific kerogen types. Moreover, a preliminary resource evaluation method for LMM shale oil has been proposed by integrating the hydrocarbon generation theory with the chemical kinetics theory. The geological reserve of Chang7_3 is 494.0×10^8 t, with a recoverable reserve of 321.1×10^8 t based on the reference recovery rate of 65% from the Shell ICP field pilot (Guo et al., 2022). The resource evaluation system for LMM shale oil needs to be refined by synthesizing multiple models, e.g., resource analogies.

3.3 Heat and mass transfer model and hydrocarbon flow law

The flow behavior of hydrocarbons within micro/nanoscale pores is profoundly impacted by the nanoscale confinement effect. Multi-component aliphatic hydrocarbons have been used to understand the capillary flow behavior. Future research should focus on shale oil flow behavior and obtain more precise shale oil flow and occurrence characteristics. The evaluation of shale oil micro-migration is of great importance in shale oil flow studies, which is differential oil enrichment in the micro-source-reservoir structure within shales. The hydrocarbon expulsion potential method, established based on the mass balance principle, chemical kinetics and data-driven model, could identify and evaluate the oil micro-migration quantitatively (Hu et al., 2024). This will enhance the comprehension of heat and mass transfer processes in shale nanopores during the ICP and facilitate the development of an accurate energy field evolution model, with the aim to depict the energy field distribution after the ICP and determine the heating range and energy transfer efficiency. The established energy field evolution model has laid the groundwork for understanding fluid heat and mass transfer during ICP when considering the impact of capillarity, adsorption, stress variation, and micro/nano confinement effects on heat transfer. However, the variations in pore structure and hydrocarbon components can affect porosity, permeability, and the adsorption-diffusion behavior of hydrocarbons during the heating process. Thus, a comprehensive mathematical model of fluid heat and mass transfer needs to be developed by integrating the adsorption-diffusion-seepage behavior with the component-temperature-stress fields. In addition, the thermal conduction approach and the heat transfer efficiency of other heating methods need to be analyzed, such as sub-and super-critical water heating and high-temperature CO_2 heating. It is worthwhile to conduct thorough research to determine whether the current energy field evolution model derived from the electric heating method is equally applicable to sub-and super-critical water heating or high-temperature CO_2 heating. Lastly, a comprehensive heating method is necessary that considers the heating efficiency and the energy input-output ratio.

3.4 Oil/gas displacement mechanism and ICP methods

The established oil/gas displacement prediction model attempts to reveal the flow patterns and displacement mechanism of ICP-LMM shale oil by integrating the flow simulation with the geological characteristics of Chang7_3 and Nen1+2. Data from subsequent pilot trials will improve the model, such as production yields and phase behaviors, enabling more accurate production prediction and fluidity evaluation. Furthermore, it seems feasible to stimulate shale and deliver nanocatalysts into reservoirs by injecting super-critical CO_2. This approach aims to decrease the initial pyrolysis temperature of organic matter, reduce the energy input, and improve the ICP efficiency. However, this incurs extra costs before the implementation of the ICP, which must therefore be carefully considered.

Electric heating is currently given priority due to the high development level of individual technologies and its suitability for deep tight shale strata (300-3000 m). The current emphasis is on expediting on-site pilot trials to form a comprehensive technological sequence as well as identifying and addressing potential risks at this stage. Besides the electric heating method, the suitability of other heating approaches for deep shale strata (Kang et al., 2020), such as sub-critical (near 374.2 °C and 22.1 MPa) and super-critical ($\geq$374.2 °C and $\geq$22.1 MPa) water (Li et al., 2024), topochemical reaction (involving the introduction of preheating air to shale reservoirs) (Guo et al., 2023), and steam injection ($\sim$650 °C) (Zhao et al., 2022), remain uncertain. Thus, more efforts should be devoted to evaluating the suitability of various heating methods, including comparing their pros and cons, and eventually determining the optimal heating method or combination of technologies that can notably enhance the conversion efficiency and lower the heating energy input. It is also essential to develop a comprehensive criterion for evaluating favorable area/intervals while considering geological and engineering factors. A series of key parameters should be taken into account and combined, including the hydrocarbon generation potential, the hydrocarbon conversion rate, the concentrated thickness of organic matter super-rich shale, the heating transfer efficiency, variations in porosity and permeability, variations in Poisson's ratio and Yang's modulus, electricity consumption, etc. Consequently, the geological model should be integrated with the thermal field distribution, the product prediction model, and the engineering model to determine the optimal heating target and achieve maximum economic efficiency.

3.5 Other issues

Uncertainties persist regarding the success of ICP-LMM shale oil due to the strong heterogeneity of lacustrine shales, the complex underground environment, and the prolonged heating process during ICP. Basic emergency protocols are indispensable for managing engineering mishaps, including heater and casting corrosion, the generation and leakage of harmful gases, bore-hole instability, well wall collapse, etc. Additionally, the utilization of LMM shale oil resource must align with the objectives of "carbon peaking" and "carbon neutrality". Further efforts must be made to ensure energy-efficient utilization and mitigate greenhouse gas and harmful emissions during on-situ pilot trials. The ICP has been believed as a feasible technology for effectively exploiting LMM shale oil resources, supported by successful experiments and pilot trials in oil shale (R_o<0.5%) and low-maturity shale oil both domestically and internationally (Ryan et al., 2010; Sun et al., 2023). Governments, industries, and academia have all shown growing interest in the vast resource potential of LMM shale oil and the practical significance of ICP, which inspires us to make it into reality. Despite the promising returns, the primary obstacle to conducting on-situ pilot trials is the substantial initial investment. Therefore, it is advised that governments and industries intensify their focus on the development and prospects of this field, offer policy and financial backing, and advance the implementation of pilot trials for ICP-LMM shale oil.

4. Prospects

The promising perspective of LMM shale oil resources and the high application value of the ICP have attracted increasing attention from the NSFC and petroleum industries. With the support of the NSFC Enterprise Innovation and Development Joint Fund, various theoretical studies have been carried out, including those on organic matter super-rich accumulation, enrichment area evaluation, heat and mass transfer, multi-field and multi-phase coupling flow, and optimal exploitation methods. These efforts have laid the basic theoretical principles for the execution of pilot trials. Once these trials succeed, the technical hurdles will be overcome and reliable parameters will be acquired. Furthermore, technological optimization iterations and the development of industrial processes will lead to cost reduction and efficiency improvement, unlocking the true resource potential of LMM shale oil.

Acknowledgements

This work was funded by the National Natural Science Foundation of China (No. U22B6004).

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Conflict of interest

The authors declare no competing interest.

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