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EDITORIAL

Advances in Theoretical and Mathematical Modeling of Lacustrine Sedimentology

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1 Introduction

The characterization of lacustrine and continental subsurface reservoirs represents a frontier in modern geosciences, driven by the increasing global demand for energy resources from deep-buried and unconventional formations. Lacustrine basins—such as the Junggar and Ordos in China or the Melut in South Sudan—are characterized by extreme heterogeneity and complex diagenetic histories that challenge traditional modeling and prediction workflows. This special issue, "Advances in theoretical and mathematical modelling of Lacustrine Sedimentology," collects research that leverages sophisticated numerical simulations, rock physics modeling, and geostatistical inversion to bridge the gap between geological conceptualization and predictive accuracy.

2 Article summaries

The five articles in this collection provide a comprehensive overview of the current state of modeling in lacustrine environments.

2.1 Genetic mechanism of deep zeolite-rich reservoirs: a case study of the Lower Wuerhe Formation in Junggar Basin

Hu et al. (this issue) perform a comprehensive investigation into the Lower Wuerhe Formation in the Junggar Basin, where high-quality unconventional reservoirs exist at depths exceeding 4500 m. Through thin-section and stable isotope analysis, the authors demonstrate that debris flow microfacies are the primary hosts for these reservoirs. They reveal that the dissolution of laumontite by organic acids—sourced from maturing source rocks—is the pivotal genetic mechanism that creates secondary porosity, enabling high-quality reservoir development despite significant burial and compaction.

2.2 River patterns transition of subaqueous distributary channels in delta front and its significances for petroleum geology: an insight from Paleogene Yabus Formation in the Sag A of Melut Basin, South Sudan

Ma et al. (this issue) provide significant insights from the Melut Basin, using a sequence-stratigraphic framework to track the transition of subaqueous distributary channels within the delta front of the Yabus Formation. Their analysis of three intermediate base-level cycles identifies a vertical transition from braided patterns (characterized by vertical accretion and high connectivity) to meandering patterns (dominated by lateral accretion and isolated sandbodies). This

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transition is mathematically linked to changes in paleo-terrain slopes (decreasing from 0.54 to 0.21°) and sediment supply, offering a predictive roadmap for both structural and lithologic traps.

2.3 Application of pre-stack geostatistical inversion in prediction of thin high-quality conglomerate reservoir in Shawan Depression, Junggar Basin

Cheng et al. (this issue) demonstrate the utility of pre-stack geostatistical inversion for resolving thin interbedded conglomerate reservoirs in the Shawan Depression. Because traditional deterministic methods often fail when P-wave impedance overlaps between reservoirs and tight layers, the authors utilize the Markov Chain Monte Carlo (MCMC) algorithm to integrate logging and seismic data. This approach successfully resolves 7-m-thick high-quality conglomerate reservoirs using the Vp/Vs ratio, providing a robust foundation for field development.

2.4 Study on the law of elastic parameters of carbonate rock under differential burial history and diagenesis

Wang et al. (this issue) address the "multi-solution" problem in identifying thin dolomite reservoirs within the Majiagou Formation of the Ordos Basin. By coupling laboratory ultrasonic measurements with a multi-pore Differential Effective Medium (DEM) model, the authors establish quantitative interpretation templates that relate pore aspect ratios to elastic parameters. They identify two constructive diagenetic paths: dolomitization, which increases intercrystalline pores with large aspect ratios, and dissolution, which produces flattened pores that significantly decrease elastic parameters while simultaneously enhancing permeability.

2.5 Characteristics and controlling factors of deep-seated reservoir: a case study from the Fukang Sag of Junggar Basin

Wang et al. (this issue) provide a comparative analysis of the upper and lower slopes of the Fukang Sag, exploring why highly compacted deep reservoirs can still host substantial petroleum. Their results suggest that while the lower slope undergoes intense compaction, the synergy between multi-stage fluid dissolution and the development of micro-fractures is key to maintaining industrial oil flows. By modeling three stages of fluid mixing—deep thermal and basin fluids—they establish a comprehensive reservoir evolution model that emphasizes the protective role of high pore pressure in preserving small throat channels.

3 Summary and acknowledgment

We would like to thank the authors and reviewers for their rigorous contributions to this thematic collection. We hope these articles provide both immediate utility for practitioners and a theoretical foundation for future developments in lacustrine sedimentology.