Research Status and Prospects of Numerical Simulation of Hydrocarbon Source Rock Development Process

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Abstract

The numerical simulation of the development process of source rocks is a key technical means for the analysis of sedimentary basins and the evaluation of oil and gas resources. This paper systematically reviews the four core methods of this type of simulation: organic matter factory model, three-dimensional stratigraphic forward simulation, organic facies numerical simulation, and quantitative prediction model of source rocks. It deeply analyzes the technical principles, application examples, advantages and disadvantages of each method, and looks forward to future development directions. The organic matter factory model comprehensively analyzes the formation mechanism of source rocks from the "production - sedimentation - preservation - burial" entire chain, emphasizing the coupling control of paleo-productivity, redox conditions and sedimentation rates; the three-dimensional stratigraphic forward simulation (such as DionisosFlow) reconstructs the evolution and sediment filling process of the basin to achieve three-dimensional quantitative prediction of the spatial distribution of source rocks, and has successfully revealed the TOC enrichment patterns in applications such as the Natih Formation in Oman and the Paris Basin; the organic facies numerical simulation (such as OF-Mod) focuses on the detailed characterization of the quality of source rocks, through distinguishing the organic matter sources of marine and terrestrial, coupling preservation conditions with sequence stratigraphic background, to achieve three-dimensional prediction of TOC, hydrogen index and hydrocarbon generation potential, and has been verified in Norway's Barents Sea and Brazil's Camamu-Almada Basin; the quantitative prediction model of source rocks integrates geochemistry, basin simulation and re-deposition models to construct a forward prediction link from paleoenvironmental parameters to TOC calculation, effectively overcoming the fragmentation and strong experience nature of traditional methods. Current research still faces challenges such as paleo-productivity recovery, multi-scale process coupling, and model universality. Future development directions include high-resolution paleoenvironmental reconstruction, artificial intelligence-assisted parameter inversion, and multi-disciplinary integration, to promote the transition of source rock simulation from "form description" to "process analysis" and "quantitative prediction", providing theoretical support for deep and unconventional oil and gas exploration.

Keywords

Source Rock, Development Process Simulation, Three-dimensional Stratigraphic Forward Simulation, DionisosFlow, OF-Mod, Organic Facies Simulation