

## Research Advances

# Source Rock and Cap Rock Controls on the Upper Ordovician Wufeng Formation–Lower Silurian Longmaxi Formation Shale Gas Accumulation in the Sichuan Basin and its Peripheral Areas

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## Objective

The Upper Ordovician Wufeng Formation–Lower Silurian Longmaxi Formation is one of the priority interval for shale gas exploration in the Sichuan Basin and its peripheral areas, and commercial shale gas has been discovered from this interval in Jiaoshiba, Changning and Wei yuan shale gas fields in Sichuan Province. However, there is no significant discovery in other parts of the basin due to the different quality of black shale and the differences of tectonic evolution. Based on the progress of shale gas geological theory and exploration discoveries, as well as the theory of “source rock and cap rock controls on hydrocarbon accumulation”, the main controlling factors of the Upper Ordovician Wufeng Formation–Lower Silurian Longmaxi Formation shale gas enrichment in the Sichuan Basin and its peripheral areas were analyzed, and the source rock and cap rock controls on the shale gas were also discussed. The results can provide new insights for the next shale gas exploration in this area.

## Methods

The study conducted geochemical, petrological, mineralogical and reservoir tests on the Wufeng Formation–Longmaxi Formation, especially graptolite identification and fine formation correlation for key wells. The source rocks, reservoir, cap rock and preservation conditions and also the dynamic evolution and the matching relation between source rock and cap rock were further analyzed.

## Results

(1) The “source control” mainly includes large

thickness, wide distribution and high total organic carbon content (TOC), which controls the shale hydrocarbon generation capacity and storage capacity (organic matter pores, micro-cracks and bedding fissures). The shale of the Wufeng Formation to the lower part of the first member of Longmaxi Formation (WF2-LM4 graptolitic zone) is featured by a slow deposition rate, favorable or beneficial organic matter type, high TOC and high hydrocarbon generation capacity, which are all favorable hydrocarbon source conditions for shale gas development. The organic matter type is beneficial to the development of organic-matter pores because the planktonic algae tends to generate large amounts of hydrocarbon and form many organic-matter pores. Moreover, the high TOC ensures a large number of organic-matter pores and results in a three-dimensional interconnected organic-matter pore network, which provides good storage spaces and migration channels for natural gas.

(2) The cap rock can be divided into direct cap rock and indirect cap rock (regional cap rock). The direct cap rock refers to the middle and upper part of the first member of Longmaxi Formation (LM5 and the above graptolitic zone), which seals the shale gas in the Wufeng Formation to the lower part of the first member of Longmaxi Formation (WF2-LM4 graptolitic zone) (Fig. 1). The indirect cap rock refers to the gypsum rock and mudstone of the Lower–Middle Triassic, which effectively seals the Wufeng Formation and Longmaxi Formation to form over-pressured shale gas reservoirs in Jiaoshiba, Fushun–Yongchuan and Changning areas. In areas lacking the Lower-Middle Triassic gypsum rock and mudstone, the over-pressure was released and the shale gas preservation conditions were also destroyed too, where low-normal pressure shale gas reservoirs were formed (e.g., Pengshui in southeast Chongqing and Zhaotong in Yunnan).

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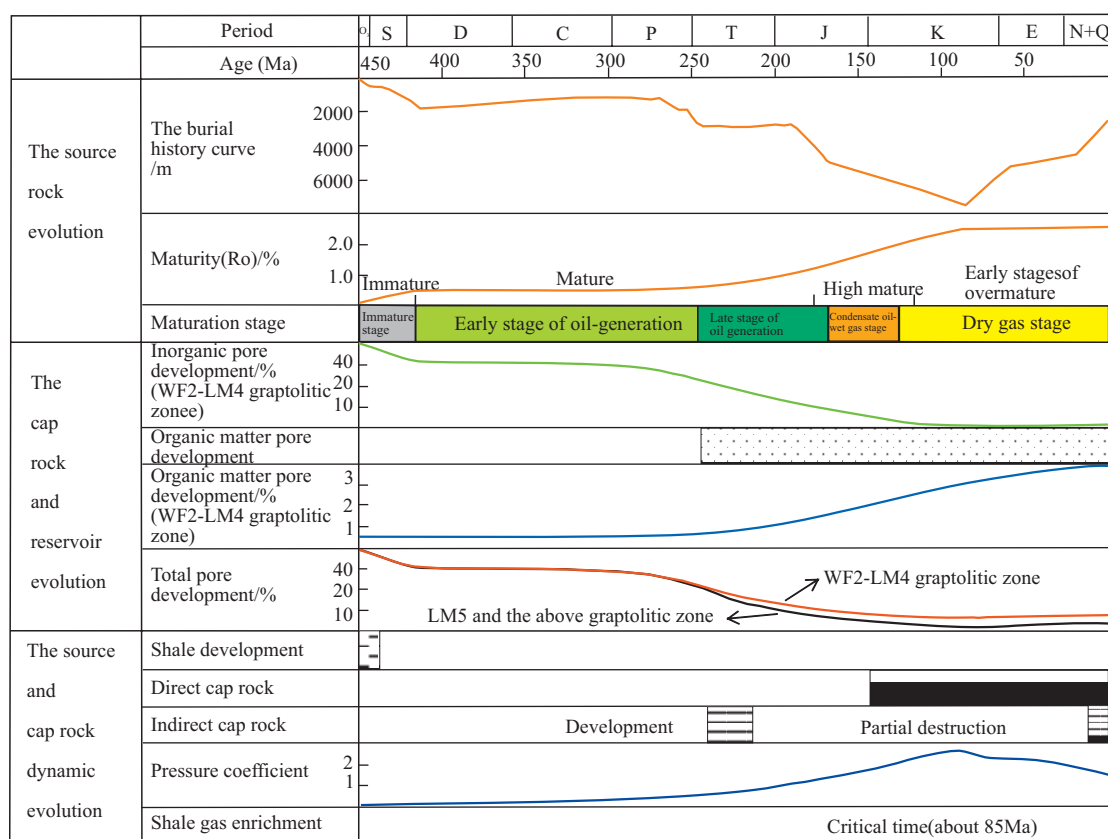


Fig. 1. Enrichment events of the Wufeng Formation–Longmaxi Formation shale gas reservoir in the Jiaoshiba shale gas field of east Chongqing.

## Conclusion

The theory of “source rock and cap rock controls on shale gas accumulation” provides new technical ideas and methods for the shale gas assessment. It promotes the shale gas evaluation from static parameters evaluation to the “source rock and cap rock” dynamic evaluation, and focuses on the important role of source rock material base and cap rock in the process of shale gas enrichment. The quantity configuration (static matching) and quality configuration (dynamic matching) of the distribution of source-cap rocks exert a critical control on the enrichment location and degree of shale gas enrichment. In the

Sichuan Basin and its peripheral areas, the favorable areas for shale gas accumulation are those with large shale thickness of the Wufeng Formation to the lower part of the first member of Longmaxi Formation (WF2-LM4 graptolitic zone) and the existence of the Lower-Middle Triassic gypsum rock and mudstone, with the main gas accumulation period being J<sub>3</sub>-K<sub>1</sub> and/or after J<sub>3</sub>-K<sub>1</sub>.

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