Petroleum Research xxx (2017) 1–12

Contents lists available at ScienceDirect

Petroleum Research

journal homepage: http://www.keaipublishing.com/en/journals/petroleum-research/

Full Length Article

Characteristics of shale gas reservoirs in Wufeng Formation and Longmaxi Formation in Well WX2, northeast Chongqing

Jin Wu [a, b, c, *], Feng Liang [a, b, c], Wen Lin [a, b, c], Hongyan Wang [a, b, c], Wenhua Bai [a, b, c], Chao Ma [a, b, c], Shasha Sun [a, b, c], Qun Zhao [a, b, c], Xiaojiang Song [a], Rongze Yu [a, b, c]

[a] PetroChina Research Institute of Petroleum Exploration and Development, Langfang 065007, China
[b] National Energy Shale Gas R & D (Experiment) Centre, Hebei 065007, China
[c] PetroChina Unconventional Oil & Ges Key Laboratory, Hebei 065007, China

ARTICLE INFO

Article history:
Received 5 January 2017
Received in revised form
19 May 2017
Accepted 25 May 2017
Available online xxx

Keywords:
Shale gas reservoirs
Graptolite biozone
Micropore
Gas-bearing capacity
Wufeng Formation and Longmaxi Formation
Northeast Chongqing

ABSTRACT

To further understand shale reservoir characteristics of Wufeng Formation and Longmaxi Formation in the Wuxi area, northeast Chongqing, based on drilling data of Well WX2, and taking the graptolite biostratigraphy as the standard marker of stratigraphic division and comparison, the geochemistry, petrology, reservoir space and properties of organic-rich black shale were well investigated, and its gas-bearing capacity and controlling factors were also analyzed. The result shows that in the Wufeng Formation and Longmaxi Formation of Well WX2, the organic-rich shale is 89.8 m thick and is characterized by good kerogen type, high organic abundance, moderate maturity and favorable hydrocarbon-generation condition, and the graptolite sequence is developed completely and continuously; the organic abundance is influenced by depositional rate, and the slow depositional rate is favorable for accumulation of organic matter in the black graptolite shale; from top to bottom, content of siliceous minerals increases and content of clay minerals decrease, therefore the brittleness increases; the organic-rich siliceous shale and clay siliceous shale are favorable lithofacies for development of shale reservoirs; the nanopore is dominated by the parallel-plate pore with four open sides and has good connectivity; the pore size distribution curve has the multimodal characteristic, and the pore diameter mainly is in the range of 0.42–0.62 nm and the range of 3–5 nm; organic pores and interlayer pores of clay minerals make the greatest contribution to the total pore volume, while pores of brittle minerals have the least contribution; from top to bottom, organic pores gradually increase while interlayer pores of clay minerals gradually decrease; the on-site core gas content exceeds 8 m^3/t, and the gas-bearing capacity is jointly controlled by hydrocarbon generation, reservoir and preservation conditions; and the WF2-LM6 biozone of the Katian to the early Aeronian is the high-quality shale reservoir, where the LM1 biozone of the Hirnantian was the best "sweet spot" which is the target of horizontal well drilling.

1. Introduction

The black shale in the Upper Ordovician Wufeng Formation-Lower Silurian Longmaxi Formation is widely distributed in the Sichuan Basin and its periphery, and is characterized by large thickness, high abundance of organic matter and high degree of thermal evolution, so it is the key formation for exploration and development of marine shale gas. In recent years, exploration and development of the shale gas is strengthened (Dong et al., 2014; Wang et al., 2015a; Zhang et al., 2015; Nie et al., 2016; Zhao et al., 2016; Zou et al., 2016), and some commercial breakthroughs in the Changning area (Changning-Zhaotong area), Weiyuan area and Fushun-Yongchuan area in southern Sichuan, and the Jiaoshiba area in eastern Sichuan are made, meanwhile it also prove that the Sichuan Basin is rich in shale gas resources and has good industrial production capacity of shale gas. However, studies of shale gas exploration in the basin margin are relatively less, and no high-yield gas reservoirs are found, therefore, it is necessary to carry out some basic theoretical researches in the basin margin (Wu et al., 2015; Xiong et al., 2015; Liang et al., 2016). Located in the northeast margin of the Sichuan Basin, the Wuxi area in the

* Corresponding author. PetroChina Research Institute of Petroleum Exploration and Development, Langfang 065007, China.
E-mail address: wujinouc@petrochina.com.cn (J. Wu).

https://doi.org/10.1016/j.ptlrs.2017.05.002

northeast Chongqing is new area for shale gas exploration without detailed description and characterization of the shale gas reservoir, so the gas-bearing capacity and controlling factors is unclear, leading to poor understanding of shale gas potential and more difficulty in favorable target selection and resource evaluation. Therefore, a shale gas well (Well WX2) was drilled by Langfang Branch of PetroChina Research Institute of Petroleum Exploration and Development in the Wuxi area in 2013–2014. The well was drilled through the Upper Permian Changxing Formation and Wujiaping Formation, the Lower Permian Maokou Formation, Qixia Formation and Tongkuangxi Formation, the Middle Silurian Xujiaba Formation, the Lower Silurian Longmaxi Formation, the Upper Ordovician Wufeng Formation, Linxiang Formation, where the Upper Silurian, Devonian and Carboniferous strata were lost. The organic-rich shale in the Wufeng Formation and Longmaxi Formation are characterized by large thickness and high gas content in the on-site well test.

Based on previous researches, detailed observation and systematic sampling of cores from the target strata in Well WX2 were carried out. Moreover, the graptolite biozones were taken as the division and correlation standard for Ordovician and Silurian black shale to perform stratigraphic division, qualitative and quantitative description of the shale gas reservoirs, and analysis of the gas-bearing characteristics and controlling factors; and the single well reservoir evaluation was made to provide theoretical basis for exploration and development of the shale gas in this area.

2. Geological background

The Wuxi area is located in the northeast margin of the Sichuan Basin, tectonically, it is mainly located in the middle section-east section of the southern Dabashan thrust-fold belt between the Baping fault zone and the Tiexi-Wuxi hidden-fault zone, and typical Jura-type partitioned folds are developed, the Permian-Triassic strata are exposed (Li, 2006) (Fig. 1). The Well WX2 is located in the Chaoyang Town of Wuxi County; structurally, it is located on the north wing of the core of the Tianba anticline in the Wuxi depression. The structure of the anticline core is relatively gentle with no development of faults; the south wing is steep, and the stratigraphic dip of the north wing is 1–50°.

From the Late Ordovician to the Early Silurian, under the intense compression of the Cathaysian Plate toward the Yangtze Plate, the ancient continent was lifted to form numerous uplifts, leading to form an extensive semi-enclosed deepwater bay with the northward open in the Sichuan Basin and its surrounding area; in addition, due to two large-scale global transgressions, the rapid sea-level rise caused formation of the anoxic and undercompensation water during this period, thus the organic-rich black graptolite shale were deposited extensively (Mu et al., 2011; Wang et al., 2014b; Zou et al., 2015). The target interval of Wufeng Formation and Longmaxi Formation in Well WX2 is composed of siliceous shale, carbonaceous shale intercalated with silty shale and argillaceous siltstone with laminated beddings, massive graptolites are developed and enriched along beddings, and pyrite which occurred in strip, tuberculosis or grain shape, indicated a stagnation and anoxic deep shelf sedimentary environment.

3. Methods

In the Yangtze area, since the black shale of the Wufeng Formation and Longmaxi Formation has similar appearance, strong vertical heterogeneity and different reservoir properties in different intervals, it is difficult to subdivide small layers vertically

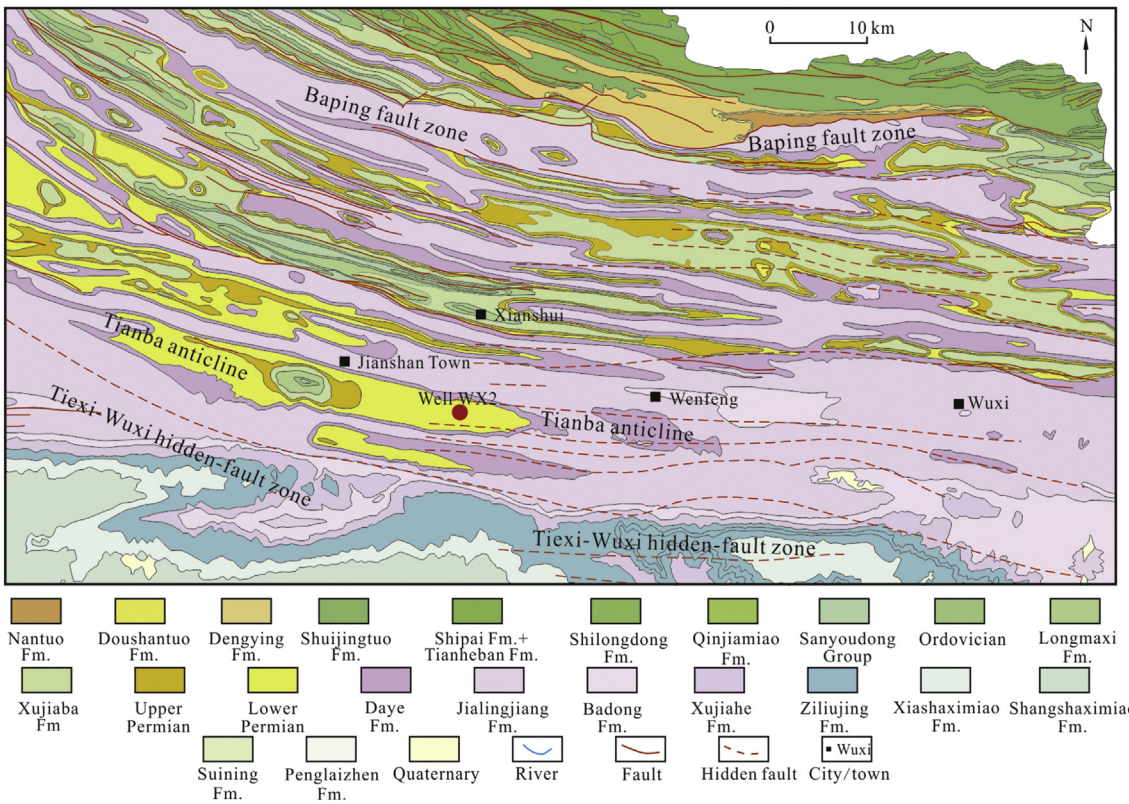

Fig. 1. Geological characteristic of the Wuxi area and location of Well WX2 in northeast Chongqing.

Please cite this article in press as: Wu, J., et al., Characteristics of shale gas reservoirs in Wufeng Formation and Longmaxi Formation in Well WX2, northeast Chongqing, Petroleum Research (2017), https://doi.org/10.1016/j.ptlrs.2017.05.002