

XU Zhengyu, XIONG Shaoyun, WANG Gaocheng and LIN Ge, 2014. Lower Paleozoic Shale Gas Preservation Condition Analysis and Evaluation in the Yangtze Block. *Acta Geologica Sinica* (English Edition), 88(supp. 2): 1700-1702.

## Lower Paleozoic Shale Gas Preservation Condition Analysis and Evaluation in the Yangtze Block

XU Zhengyu<sup>1</sup>, XIONG Shaoyun<sup>1</sup>, WANG Gaocheng<sup>2</sup> and LIN Ge<sup>3</sup>

*1 Hangzhou Research Institute of Petroleum Geology, PetroChina, Hangzhou, 310023;*

*2 Zhejiang Oilfield company, PetroChina, Hangzhou, 310013*

*3 Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, 510640;*

### 1 Introduction

Research and evaluation of hydrocarbon formation and preservation conditions about of the Yangtze block marine stratum have been explored for a very long time (Li, 1988; Lou, et al., 2006), in recent years, by evaluation and selection play of the South China shale gas (Zhang, et al., 2008), geologists pay closely attention to the shale gas preservation conditions (Nie, et al., 2012; Liu, et al., 2013).

Basis on multi episodic orogeny( activated craton, DIWA)(Chen, et al., 1998; Chen, et al., 1997) and multi period formation basin characteristics in the Yangtze block, the author makes a preliminary analysis and discussion on the Yangtze shale gas preservation conditions of the Lower Paleozoic by field geological survey results for some years.

### 2 Shale Sedimentary Tectonic Environments

During early Paleozoic, by Rodinia super-continent cracking (Li, et al., 2007) and then orogenic event, the Yangtze block has gone through two types of basin formation and evolution (Yu, et al., 2000; Wang, et al., 2007), so there developed two sets of organic rich shale of the Lower Cambrian Niutitang Formation and the Upper Ordovician Wufeng formation – the Lower Silurian Longmaxi Formation.

Niutitang shale mostly deposited in the environment of the passive continental margin and the expansion background, due to upwelling and anoxic event, its organic rich shale enriched in the North and Southeastern margin of the Yangtze block deep shelf and slope facies, where there was the maximum thickness and the most highest organic carbon content of the shale. Wufeng –

Longmaxi shale mostly deposited in peripheral foreland basin environment during Guangxi orogenic event, and mostly deposited in the shallow shelf and the closed bay, its organic rich shale enriched in the Southeastern margin of the Yangtze block deep shelf, where there was the maximum thickness and the most highest organic carbon content of the shale.

### 3 Shale Burial and Generation Hydrocarbon

Niutitang shale has experienced 4 periods of burial and 3 stages of hydrocarbon generation. I period buried in Early Cambrian to Early Silurian, I stage hydrocarbon generated in Early- Middle Ordovician to Early Silurian. By impacting of Guangxi orogenic event, the shale depth of burial got shallow, and hydrocarbon generation ended. Early Permian to Early Triassic, the shale went into II burial period and II stage hydrocarbon generation, the Upper Yangtze shale delayed to Late Permian and Triassic. By the influence of Indosinian peripheral orogenic event, the shale mostly rose again, burial depth got shallow, hydrocarbon generation ended. Late Triassic to Jurassic, the shale of the Upper Yangtze region (Sichuan Mesozoic foreland basin) has entered into III burial stage, and entered the high to over mature stage, the shale organic matter generated a large number of condensate oil, gas and dry gas. In the Lower Yangtze and other uncovered Mesozoic stratum region, the shale hydrocarbon evolution was basically at a standstill. During Late Jurassic to Early Cretaceous, by the influence of Yanshanian event, the shale burial depth gradually became shallow, hydrocarbon generation ended. After Late Cretaceous, the shale burial and geothermal factors increased in any local area overlying Mesozoic and Cenozoic stratum, these shale went into IV period burial and phase III hydrocarbon generation, and finally cracked

\* Corresponding author. E-mail: xuzh\_yz@petrochina.com.cn

and formed dry gas.

The Wufeng-Longmaxi shale burial and hydrocarbon generation process as similar as the Niutitang shale, it roughly has experienced 3 burial period and 3 stage hydrocarbon generation. I burial period happened in Early Permian to Early Triassic, the shale started hydrocarbon generation in the same period. Late Triassic to Jurassic, the shale entered into the II burial period and II hydrocarbon generation stage. After late Cretaceous, the shale went into III burial period and stage III hydrocarbon generation, and finally cracked and formed dry gas.

#### 4 Shale Deformation and Reformation

With the multi-stage formation basin and multi-epoch orogenic event, the Yangtze block shale of the Lower Palaeozoic has gone through four periods (Guangxi, Indosinian, Yanshan, Himalaya) reformation (Wang, et al., 2007). Among them, Guangxi and Indosinian epoch showed weak orogeny and weak reformation characteristics, the shales mainly reflected in folding deformation and uplifting erosion. Yanshanian and Himalaya period showed the characteristics of strong reformation and strong deformation, the shale widely was suffered folding, thrusting and uplifting erosion.

Overall, reformation of the Western Yangtze region is relatively weak, reformation superimposed the least number (2 ~ 3 period orogeny), the shale of continuity and integrity is good, where the shale has been buried under the freshwater free alternation zone, the shale gas preservation conditions is better. In the Lower Yangtze and Southeast of the Yangtze block reformed intensity and reformation superimposed second (3~4 period orogeny), the part of shale continuity and integrity has been broken down, or exposed in the surface, where the shale was buried under the freshwater free alternation zone, preservation conditions of the shale gas got bad. In peripheral Yangtze block, the shale has the maximum number (4 epoch orogeny) and the strongest intensity of reformation, and has been metamorphosed into slate, phyllite, and along deep faults distribution, local magmatic intrusion, the shale was completely destroyed, the shale gas preservation condition is mostly worst.

#### 5 Shale Preservation Condition Evaluation

In the Upper Yangtze region, because of the Lower Palaeozoic shale has experienced less orogenic event and weak deformation, its dip is relatively flat, and has a good lateral continuity and integrity, the shale completely was preserved in the groundwater potential free zone to the

zone of stagnation, the shale gas content is highest.

In the Middle Yangtze region, the part shale is characterized thrust fold style, and the fault development of trough like folds and high angle, the shale was preserved in the groundwater potential free zone to the zone of stagnation, preservation condition is relatively worse.

In the Lower Yangtze region, the shale has experienced strong orogeny and strong deformation, doesn't have a good lateral continuity and integrity by a large number of faults (thrust and cutting), by the development of closed fold, even overturned fold and high angle thrust fold and fractured, by the late magmatic thermal hydraulic disturbance, it was preserved in the free latent zone of groundwater to the alternation zone, the shale reservoir combination is not conducive to preservation of the shale gas, the shale gas content is the lowest.

#### 6 Conclusions

The Niutitang shale mainly developed in the Northern and Southeast margin of the Yangtze block, and it has experienced 4 burial stage and 3 phase hydrocarbon generation process. The Wufeng - Longmaxi shale mainly distributed in the Southeastern margin of the Upper - Middle Yangtze region, it has experienced 3 burial stages and 3 phase hydrocarbon generating process.

These two sets of shale now have entered into high mature and over mature evolutionary phase, and there is a good shale gas formation and enrichment of the geological conditions. By the influence of multi-orogenic event, reformation of the West region of the Yangtze block is relatively weak, so there is the best conditions for the shale gas preservation. Comprehensive evaluation think that the Southeastern margin of the Yangtze block and Sichuan Basin have the best preservation conditions, and enrich resource potential, the Midwest area of the Middle Yangtze region second, the East area of the Middle Yangtze area and the Lower Yangtze region have the poor preservation conditions, resource potential is limited. The Yangtze block shale gas often is saved at the syncline residual area, where becomes the most favorable play.

#### Acknowledgements

This study is in part supported by subject (CNPC, No.2012B-0504). We devote this paper to professor CHEN Guoda in memory of the 10<sup>th</sup> anniversary of his death.

#### Reference

- Li Shangwu, 1988. Hydrocarbon preservation concept and evaluation unit division principle of the South China sedimentary area [J]. Marine Sedimentary Area of Oil

- and Gas Geology, 2 (2): 1-6 (in Chinese).
- Lou Zhanghua, Ma Yongsheng, Guo Tonglou, Zhu Rong, 2006. The preservation conditions for marine strata in South China evaluation of oil and gas [J]. Natural gas industry, 26(8):8-11 (in Chinese with English abstract).
- Zhang Jinchuan, Nie Haikuan, Xu Bo, Jiang Shengling, Zhang Peixian, Wang Zongyu, 2008. Geology conditions of shale gas accumulation in Sichuan Basin [ J]. Natural gas industry, 28 (2):151-156 (in Chinese with English abstract).
- Nie Haikuan, Tang Xuan ,Bian Ruikang, 2009. Controlling factors for shale gas accumulation and prediction of potential development area in shale gas reservoir of South China [ J]. Acta Petrolei Sinica, 30(4):484-491 (in Chinese with English abstract).
- Liu Honglin, Wang Hongyan, 2012. The factors for shale adsorption characteristics and influence of marine strata in South China [ J]. Natural gas industry, 32(9):1-10 (in Chinese with English abstract).
- Chen, G.D., et al., 1998. Crustobody Geotectonics of Asian Continent and Adjacent Seas [M]. Changsha: Hunan education Publishing House, 91-129 p (in Chinese).
- Chen, G.D., et al., 1997. DIWA(Geodepression) structure and gold metallization[M]. Beijing: Geological Publishing House, 126-159 p (in Chinese).
- Zhengxiang Li, Xianhua Li, 2007. Formation of the 1300-km-wide intracontinental orogen and postorogenic magmatic province in Mesozoic South China: A flat-slab subduction model [ J]. Geology, 135(2 ):179-182.
- Yu Dagan, Guan Taiyang, Huang Guofu, 2000. Southern China (East) late Proterozoic rift system characteristics and the formation and evolution of Jinning-Caledonian sea basin[M]. Beijing: Atomic Energy Press, 1-36p(in Chinese).
- Wang Qingchen, Cai Ligu, 2007. Phanerozoic Tectonic Evolution of South China [ J]. Acta Geologica Sinica, 81(8): 1025-1040 (in Chinese with English abstract).