

Research Article

# Shale gas exploitation: Status, problems and prospect

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## Abstract

Over the past five years, great progress has been made in shale gas exploitation, which has become the most driving force for global gas output growth. Hydrocarbon extraction from shale helps drive the USA on the road to energy independence. Besides, shale oil & gas production has been kept in a sustained growth by continuous improvement in drilling efficiency and well productivity in the case of tumbling oil prices and rig counts. Shale gas reserves and production have been in a rapid growth in China owing to the Lower Paleozoic Wufeng and Longmaxi shale gas exploitation in the Sichuan Basin, which has become an important sector for the future increment of gas reserves and output in China. However, substantial progress has been made neither in non-marine shale gas exploitation as previously expected nor in the broad complicated tectonic areas in South China for which a considerable investment was made. Analysis of the basic situation and issues in domestic shale gas development shows that shale gas exploitation prospects are constrained by many problems in terms of resources endowment, horizontal well fracturing technology, etc. especially in non-marine shale deposits and complicated tectonic areas in South China where hot shales are widely distributed but geological structures are found severely deformed and over matured. Discussion on the prospects shows that the sustained and steady growth in shale gas reserves and production capacity in the coming years lies in the discovery and supersession of new shale plays in addition to Wufeng and Longmaxi shale plays, and that a technological breakthrough in ultra-high-pressure and ultra-deep (over 3500 m buried in the Sichuan Basin) marine shale gas exploitation is the key and hope.

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**Keywords:** Shale gas; Exploitation; Marine facies; Hot shale; Resource endowment; Sichuan Basin; South China; Complicated tectonic area; Gas play

## 1. Introduction

During the “12th Five-Year Plan” period, China learned successful experiences in “shale gas revolution” of North America and made great progress in the shale gas exploitation through sustained endeavor and field tests on the technologies to recover the Lower Paleozoic marine shale gas in the Sichuan Basin. Along with the successive discovery and confirmation of the Upper Oligocene Wufeng–Lower Silurian Longmaxi shale gas in the blocks such as Fuling, Weiyuan, Changning, and Fushun–Yongchuan in the Sichuan Basin, China's shale gas reserves and production have grown vigorously from zero. Up to the end of “12th Five-Year Plan”

period, the cumulative proved marine shale gas reserves in China amounted to  $5441 \times 10^8 \text{ m}^3$ , and the production of marine shale gas in 2015 was  $45 \times 10^8 \text{ m}^3$  [1]. Shale gas has gradually become an important sector for the future increment of gas reserves and output in China, and made China one of the only four countries that have realized commercial development of shale gas around the world (Fig. 1) [1–4]. However, continental and marine–continental transitional shale gas, which was believed to have a great potential in the shale gas investigation in the early “12th Five-Year Plan” period, was not satisfactorily explored and was deemed to be limited in potential. The continental and marine–continental transitional shale gas resources predicted in 2015 were much less than that in the early “12th Five-Year Plan” period, suggesting an uncertain prospect [5,6].

During the “12th Five-Year Plan” period, marine shale gas exploitation in the Sichuan Basin gained a significant

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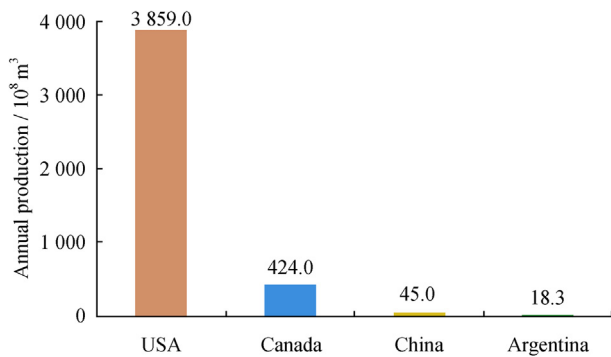


Fig. 1. Shale gas production of four shale gas producing countries in 2015. Note: The data are sourced from Refs. [1–4], and the data of USA refer to dry gas production.

breakthrough and the commercial productivity was realized soon after commissioning. Accordingly, the future shale gas exploitation in the periphery of the Sichuan Basin and even in the whole South China is highly expected. On one hand, the National Energy Administration (NEA) adjusts shale gas production in China at the end of “13th Five-Year Plan” period from  $(300\text{--}600) \times 10^8 \text{ m}^3$  to  $300 \times 10^8 \text{ m}^3$ , while some scholars propose that a target of  $200 \times 10^8 \text{ m}^3$  by 2020 is more rational [5,7]. On the other hand, an optimistic opinion considers a production of  $300 \times 10^8 \text{ m}^3$  a little conservative and suggests defining the  $45 \times 10^4 \text{ km}^2$  range covering Sichuan, Chongqing, Yunnan, Guizhou, Hunan and Hubei, including the Sichuan Basin, as a “Special Shale Gas Zone”. If so, China's shale gas production by 2020 is expected to reach  $1000 \times 10^8 \text{ m}^3$  [8]. Anyway, all of these viewpoints are based on an optimistic prediction on shale gas in the whole South China, although exploration practices and research achievements in shale gas licenses during the “12th Five-Year Plan” period have revealed that shale gas exploitation in many complex structural areas in the South China, other than the Sichuan Basin, is susceptible to huge geologic risks and engineering challenges, and the economy of commercial shale gas development is also uncertain [5,6,9,10]. However, it seems that some departments are too optimistic about marine shale gas exploitation in South China, especially in complex structural areas, when they make shale gas development planning, being less aware of the problems therein. Under this background, for the sake of orderly development of shale gas in the future, it is necessary to comprehensively review the current status of shale gas exploitation in China and abroad and identify the problems therein.

## 2. Basic situation and characteristics of shale gas development abroad

### 2.1. Shale gas exploitation has become the main driving force of global natural gas production growth

According to the EIA evaluation in 2013, globally, shale gas was extremely rich, and technically recoverable shale gas resources were up to  $206.56 \times 10^{12} \text{ m}^3$  [11]. Thus abundant shale gas resources laid a solid material foundation for the “shale gas

revolution” in the North America. Although only four countries have realized the commercial shale gas exploitation (Fig. 1), it is believed that more and more countries will join the sector along with the technical progress and the constant improvement of policies, markets and infrastructures.

EIA's prediction in 2016 [2] showed that the global daily natural gas production would increase from  $97 \times 10^8 \text{ m}^3$  in 2015 to nearly  $157 \times 10^8 \text{ m}^3$  in 2040, among which shale gas would make the greatest contribution – being tripled from 2015 to 2040, when shale gas production would account for 30% of global natural gas production, and China would rank as the second largest shale gas producer only after the USA. Besides the four countries producing shale gas, Algeria and Mexico will cooperate with IOCs to produce shale gas commercially around 2020 and 2030 respectively. By 2040, these six countries will totally contribute 70% to global shale gas production. Clearly, future natural gas production growth mainly relies on shale gas, and global shale gas production growth mainly depends on China and the USA. In China, key shale gas production and breakthrough are expected in the marine shale areas in the southern part of the country [1].

### 2.2. Shale oil/gas exploitation has led the USA towards energy independence

In the USA, since the discovery of Barnett shale gas play in the early 1980s, 13 shale oil/gas plays have been put into commercial development [12], and shale gas development has grown swiftly especially from the beginning of the 21st century. The substantial growth of natural gas production in the country is mainly contributed by shale oil/gas. The annual production of shale gas (only dry gas) increased quickly from nearly  $100 \times 10^8 \text{ m}^3$  in 2000 to nearly  $4000 \times 10^8 \text{ m}^3$  in 2015, accounting for 50% of the total annual natural gas production in the USA [13]. The Annual Energy Outlook 2016 of EIA [3] shows that the imported natural gas of USA was  $283 \times 10^8 \text{ m}^3$  in 2015, and the supply and demand were basically in balance, with a difference of only 3%; it is anticipated that in 2018 the USA will become a net exporter of natural gas for the first time since the 1950s, and in 2040 the gap between the oil production and consumption in the USA is only 7%, and the daily import only is 1.5 million barrels. Therefore, the USA is now realizing energy independence by virtue of scale exploitation of shale oil/gas. In the past years, under the circumstance of tumbling oil prices, some new characteristics are observed in shale gas exploitation in the USA.

- 1) Shale gas production in the USA can still increase stably year by year under the circumstance of tumbling oil price, and will keep the trend of stable growth in the following years (2016–2040) [3]. This is benefited from the unique and unduplicated resource and market conditions in the USA as well as the constant progress of the low-cost high-efficient shale oil/gas development technologies [13], rather than the so-called industrial policy guidance, support or stimulation highlighted by the domestic opinions.

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