



Original article

Technical status and challenges of shale gas development in Sichuan Basin, China

Pingli Liu^{*}, Yinsheng Feng, Liqiang Zhao, Nanyin Li, Zhifeng Luo

State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation in Southwest Petroleum University, Chengdu, Sichuan 610500, China

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ABSTRACT

During the past decade, shale gas developments have changed the energy structure in the US natural gas industry, and the exploration activities for shale gas are also increasing worldwide. According to the papers published in recent years, shale gas resources are quite abundant in China. With the successful experience obtained from North America, many state-of-the-art technologies are brought in and refined for field application. State-owned enterprise, private enterprises and foreign enterprises have all actively participated in the exploitation of shale gas. Compared with US, China faces many more challenges, both geological and above-ground, in the development of shale gas resources.

This paper begins with the introduction of shale gas reserve distribution in China and the identified shale gas formation in Sichuan Basin. The following paper reviews the methodology employed in the geophysical prospecting, drilling and completion, and hydraulic fracturing process. Since China is in the early stage of shale gas development, there is a great technical gap between China and North America. Based on literature review, the major challenges faced in the exploration and production process are identified. What presented in this paper should be of particular interest to the personnels involved in shale gas production in China and countries that are about to set foot in shale gas business. It will also be of interest to researchers who are dedicated to developing these technologies to unlock unconventional gas resources in China.

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Shale gas is the natural gas that trapped within shale formations in the condition of adsorption or ionization. In shales, natural gas exists in the form of absorbed gas, free gas and dissolved gas. Among them, absorbed gas on the organic material and free gas within the rock pores or natural fracture systems are the dominant forms. Last year, only three countries, America, Canada, and China, produced shale gas in commercial quantities according to the study released by U.S. Energy Information Administration (EIA) and Advanced Resources International (ARI). In 2012, shale gas took 39% of the total natural gas

production in the United States and 15% in Canada, while in China the volumes contributed less than 1% of the total natural gas production [1].

Compared with US, China faces many more challenges in the development of shale gas resources, both geologically and topographically. The burial depth of shale formations in China varies commonly from 3000 to 5000 m, deeper than that in US and the formations are much more complex. Reserves are often in mountainous terrain where the infrastructure facilities are incomplete, making it difficult for the access of equipment. Lack of water resources and immature expertise also impede the development of shale gas. Even though, the government is still optimistic about the future shale gas production. The ministry of Land Resources has set aggressive targets of 6.5 Bcm/yr by 2015 and at least 60 Bcm/yr by 2020. Commercial success in North American shale gas has benefited a lot from sustained and rapid development of expertise and technologies in horizontal well drilling and hydraulic fracturing [2], while in China, the technical

^{*} Corresponding author.

E-mail address: liupingli@vip.163.com (P. Liu).

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status is far behind North American, as summarized in this paper. Introducing advanced technology is important for the efficient development of shale gas, but what's more important for Chinese is to develop these technologies of their own.

1. Shale gas resources

China has abundant organic-rich source rock shales, according to the EIA, the recoverable shale gas at present in China reaches to 31.57 Tcm, ranking the first in the countries evaluated in the assessment (Fig. 1). This means shale gas reserves are 10 times more than its current proven conventional gas reserves [3]. Although the data presented in Fig. 1 is likely to change over time with the availability of additional information, it is reasonable to predict that shale resources will take a substantial share of hydrocarbon resources.

In 2013, up to 200 Mcm shale gas were produced in China, although it only took less than 0.2% of the total natural gas production, it increased from 30 Mcm the year before [4]. Sichuan, Tarim and Ordos basins and some other continental sedimentary basins with shale gas formations are the main distribution areas of shale reserves, depicted in Fig. 2. The estimated potential shale gas resources in China amount to about 30.69–99.58 Tcm [5]. Table 1 gives the reserve status of the majority basins in China. With the largest technically recoverable reserves, Sichuan Basin becomes the pilot target for exploitation. Some basic information about the identified shale gas formation in Sichuan Basin is listed in Table 2. Shale plays here are featured as deep buried depth and high thermal maturity [6], as shown in Table 3.

At present, coal consumption takes a large portion of the total energy consumption in China (see Fig. 3), which is poor in efficiency and causes substantial CO₂ emissions. Natural gas, however, contributes less than 5% of the total, far behind the world's average 24%. Increasing pressure from energy supply and environmental protection has become a prominent social issue. An effective way to deal with these pressures is to optimize the composition of primary energy consumption. The Action Plan for the Control of Air Pollution released by the State Council on September 12, 2013 strictly demands that coal consumption should be reduced to 65% in 2017. In order to reform the energy consumption, domestic natural gas production must be

increased dramatically due to the fact that about 27% of the gas consumption is still dependent on the imported gas resources.

The 12th Five-year Plan for Energy Development highlights that China would vigorously develop unconventional gas resources, and shale gas is undoubtedly included. So far, two rounds of shale gas exploration competitive bidding have been conducted to reinvigorate the domestic gas program [7]. The bidding winners in the second round, without any experience in upstream natural gas development, are eager to cooperate with experienced service companies. Shale gas market has been opened to Chinese-foreign equity or contractual joint ventures, and exploration of shale gas is encouraged by the government. The central government also provides subsidies for the exploration and production of shale gas. Starting in January 2010, Shell and PetroChina have been evaluating an area of Joint Cooperation in the Sichuan Basin with the goal to explore, appraise, and ultimately develop a Shale Gas opportunity [8]. Houston-based New Exploration Co also signed a deal with PetroChina to evaluate shale gas resources at Weiyuan field in Sichuan Basin.

2. Technical status and challenges

Since the gas flow resistance of shale gas is considerably higher than conventional gas, stimulation strategies have to be carried out for economic production. Therefore, successful development of this unconventional resource depends highly on the advanced technologies. So far, China has built a certain foundation in the equipment manufacturing, some of the equipment such as drilling rigs, fracturing trucks and downhole tools have been exported for the development of shale gas. However, core technologies such as long interval horizontal drilling, subsection hydraulic fracturing and micro seismic monitoring techniques have not been fully mastered yet.

2.1. Geophysical prospecting

The volume of gas likely accumulated in shale can be inferred from the total organic content and thermal maturity. The evaluation indexes of shale gas have shifted from conventional reservoir parameters such as porosity, permeability and gas saturation to total organic content, thermal maturity, development degree of fractures and rock brittleness. Good shale gas reservoirs feature with high GR values, low oil and water

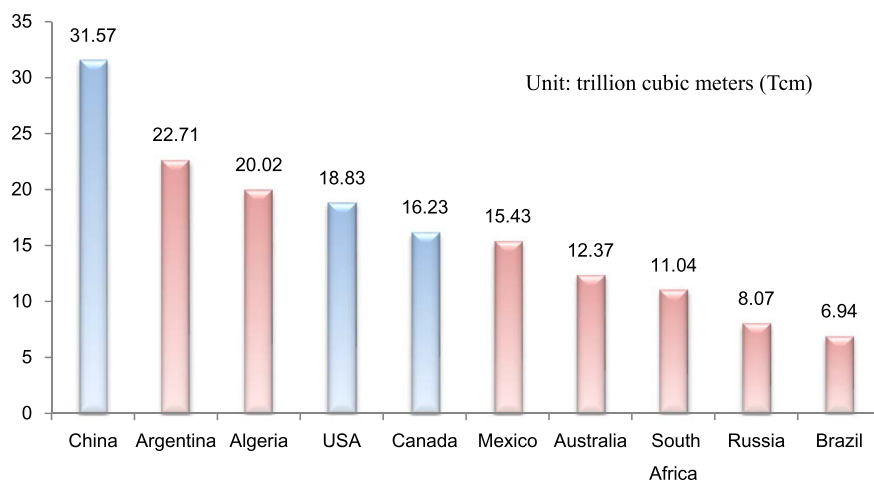


Fig. 1. Top 10 countries with technically recoverable shale gas resources, Note: Countries with commercial shale gas production were illustrated in color blue; Data Source: EIA, June, 2013, Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries outside the United States.

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