Prospect and technology of unconventional gas exploration and development in China

Wang Nan¹,², Zhao Qun¹,², Zang Huanrong¹,², Guo Wei¹,², Liu Dexun¹,²

¹Research Institute of Petroleum Exploration & Development-LangFang, Hebei 065007, China
²National Energy Research Institute of Petroleum Exploration and Development, PetroChina, 065007, China.

Abstract. The rapid development of natural gas lays the foundation for the unconventional gas development. In 2015, unconventional natural gas production is 44.9Bcm, accounting for 34.06% of total natural gas production. Increasing demand of natural gas provides a wide developing space for unconventional natural gas. China has deployed unconventional natural gas resource evaluation to different extent, which mainly includes tight gas, CBM and shale gas. Unconventional gas E&P in China is still in its initial stage. By 2015, 1.6 Tcm proved reserves and 36 Bcm production has made China tight gas entering a large scale and commercializing stage. CBM development is still in the initial stage of E&P, with less reserve and production, in the early stage for commercialized development. Shale gas has a significant breakthrough since its proved reserves reached to 544.1Bcm, and production reached to 4.5Bcm. At present, conventional gas develops rapidly in China. During the next 5-10 years, it will also take the dominant position in the natural gas development. Unconventional gas will play a more and more important role in the long-term development of natural gas.

1. Introduction

Natural gas resource is abundant in China, with great potential for reserve and production increase. The total gas resource in China is 56 Tcm. By the end of 2015, the proved reserve is 12.47 Tcm. The resource proved ratio is 22%, which shows great potential. The gas production in China increased from 22.3 Bcm in 1998 to 131.8 Bcm in 2015, with an annual average increase rate of 12%. The rapid development of natural gas lays the foundation for the unconventional gas. The top 14 large gas fields with more than 1 Bcm productive capability have established all over the country, such as Kela2, Sulige, Yulin, Jingbian, etc. Changingq, Tarim, and Xinan gas field are the three largest gas areas which secure the safe gas supply to West-East and Shanjing pipelines. The development of Unconventional gas is still in the early stage. By 2015, 1.6 Tcm of proved reserve and 36 Bcm Production have made tight gas entering large scale and commercializing stage. By 2015, Proved CBM reserves accounts for 418.5 Bcm and accumulative production accounts for 4.5 Bcm, which was showing CBM industry still in the initial stage of commercialization. Now, Shale gas has a significant breakthrough, as its production accounted for 4.5 Bcm. In the year of 2015, unconventional natural gas production is 44.9 Bcm, accounting for 34.1% of total natural gas production (fig 1). By 2020, it is expected that natural gas demand would reach 300 Bcm with shortage of 120 Bcm in China.
China Unconventional Gas Resource and its Distribution

China has deployed unconventional natural gas resource evaluation to different extent, which mainly includes tight gas, CBM and shale gas. Based on the analyses of RIPED-Langfang, PetroChina, tight gas resource accounts for 16 Tcm. CBM resource shallow than 2000m accounts for 36.8 Tcm. In 2015, resource survey and evaluation of shale gas is showing that shale gas in China is accounting for 30 Tcm, and recoverable resource accounted for 1.28 Tcm.

2.1 Tight Gas

The favorable exploration area of tight gas is about $13 \times 10^4 \text{km}^2$; total resource volume is about 16~25 Tcm (RIPE-D-Langfang, PetroChina, 2014). Tight gas is extensively distributed in more than 10 basins in China, such as Ordos basin, Sichuan basin, Songliao basin, Bohai bay and Tarim basin.

2.2 Coalbed Methane

The overall CBM resource is 36.8 Tcm (shallow than 2000m) which assessed by National Land & Resource Ministry. There are 8 basins with resource more than 1 Tcm which are mainly distributed in central and western China. The total resource in 8 large basins is 28 Tcm, accounting for 76% of the total resource. In north-eastern and north-western areas, small scale coal-bearing layers mainly occurred in continental facies, with low rank coal, lower gas content. In southern areas, limited scale and scatter-distributed coal layers are intensively transformed and severely damaged due to the late structural movement, and scattered distribution of resource. The total resource is 7 Tcm which regarded as the main exploring target.

2.3 Shale gas

Shale gas mainly occurred in the marine facies and China marine facie depositional area amounts to 2.8 million km². In Huabei area, shale gas mainly occurred in Cambrian, Ordovician, Carboniferous and Permian which has lower thickness and lower resource abundance. In South China, shale gas mainly occurred in Cambrian, Ordovician and Silurian system. Longmaxi formation of Silurian and Qiongzhusi formation of Cambrian are the favourable targets with single layer thickness ranging from 30 to 50 meters, high gamma ray and high TOC in bottom. Two sets of the marine shale have been developed in the Longmaxi formation of Silurian and Qiongzhusi formation of Cambrian in Chuangxiangqian, Qiannan-Guizhong, Qiandong-Qianxi, Suzhewan, Chuandongnan-Chuandongbei, which are the main exploration target for shale gas. To process the resource assessment, different organizations and experts have gotten different evaluation results (Tab.1).

| Area     | Resource Volume (Tcm) | Organizations | Year |
|----------|-----------------------|---------------|------|
| China    | 100                   | Rogner        | 1997 |
3. Current Status of Unconventional Gas E&P in China

Unconventional gas E&P in China is still in its initial stage. Tight gas has abundant reserve and relatively large scale production. CBM is still in the initial stage of E&P, with less reserve and production. Shale gas has significant production breakthrough with huge resource.

3.1 Tight gas

Tight gas manly distributed in Ordos and Sichuan basins. Since 2000, economic development has been realized in Sulige. In 2010, the annual tight gas production is 16Bcm, accounting for 17% of the total gas production nationwide, in which Ordos basin takes 84%. Ordos basin is about 380,000 km². The tight gas area of this basin is about 80,000 km²; resource volume is about 9Tcm and tight gas reserve is about 1.1Tcm, Layer mainly distribute in the Carboniferous and Permian. Sulige gas field is situated in Ordos City, the main part of the Ordos Basin. Upper Paleozoic strata of Sulige gas field is divided into Benxi Formation of Carboniferous; Taiyuan, Shanxi, Lower Shihezi, Upper Shihezi formation and Shiqianfeng formation ofPermian. Benxi No. 8 coal seam is widely distributed in the Sulige region, constituting a stable regional mark. The lenticular sand is controlled by the Upper Paleozoic braided river. The main layer of Permian Shanxi Formation include Shan No.1 and Shihezi No. 8 is delta deposit, the average depth is about 3295m; The sand thickness is 15 ~ 48m and normally thicker than 20m, porosity ranges from 5 to 12%, the pressure coefficient is 0.82 ~ 0.93, recoverable reserves of abundance varies from 27 million to 65 million cubic meter per square kilometres.

3.2 Coal bed methane

China CBM has entered the initial stage of commercialization. By 2011, the total national CBM wells accounts for 8765, which mainly distributed in the East of Ordos Basin and Qinshui Basin. The annual CBM productivity is 6 Bcm, Which includes 2.3 Bcm of PetroChina, 0.8 Bcm of CUCBM, 2.3 Bcm of Jinmei Mine and 0.6 Bcm from other companies. The annual total CBM production is 2.3 Bcm and it has commercialized in Qinshui, eastern Ordos, Fuxin and Tiefa area. There is rich CBM resource in Shanxi province with resource about 7 Tcm shallow than 2000m. E&P activities from China 3 major Petroleum companies and more than 15 domestic and overseas enterprises mainly focus on their CBM activities in Shanxi Province. Fanzhuang area of Qinshui coalbed methane field located in the south of Qinshui Basin in Shanxi Province, which has 182 km² areas and 40.2 Bcm proved reserve. The target coal is No.3 coal of Shanxi formation in Permian. The buried depth of coal ranges from 185 to 1300 meter. Reflectance ratio ranges from 2.0 to 4.0%; gas content varies from 10 to 26 m³/t; thickness ranges from 5 to 6 meter. Permeability of coal is smaller than 0.5 mD. Yearly production of 0.7Bcm has been achieved in Fanzhuang project. For Multi-lateral horizontal well, 2 trunks and 6 branches with open-hole completion are adopted, average single well gas rate is around 7000 m³ per day.

3.3 shale gas

Till the end of 2015, about 600 wells were drilled in total, including 400 horizontal wells, and more than 500 Bcm reserves were proved in Sichuan Basins. In 2015, the shale gas production was 4.5 Bcm. More than 10 companies had drilling activities in exploration, but only 2 major companies have real production, respectively 1.2 Bcm of CNPC and 3.2 Bcm of Sinopec. It is estimated that will exceed 7 Bcm in 2016.
Compare with U.S.A. (tab 2) China is characterized by marine shale which deposited in Cambrian and Silurian of early Paleozoic. Shale is mature and over-matures with Ro of 2.5-4.6%. Most shale reservoir is more than 5000 meters and few of them are shallow than 3000 meter. It has been proved that China shale gas is greatly influenced by the tectonic movement and induced fault and transformation will intensively influence the reservoir pressure and gas content quality. The tectonic activity should be considered as one of the important elements during the sweet spot screening.

| Area | Age | Deposition Facies | Geochemical Character | Fragile mineral content (%) | Depth (m) | Preserve condition | topography |
|------|-----|-------------------|-----------------------|----------------------------|-----------|------------------|------------|
| USA  | D,C | Deep water and continental shelf | TOC (%) | 2-14 | 1.1-3.5 | 40-70 | 1000 -3500 | Stable distribution structure Flat formation Well-development |
| China| ∈,S | Deep water and continental shelf | TOC (%) | 2-8 | 2.5-4.0 | 37-80 | 1500 -4000 | Faults due to multi-cycle structure movements |

4. Conclusions
In China natural gas is developing rapidly. Although the unconventional resource is abundant and has a bright prospect, it is still in early development stage and facing many challenges. It is good for all developer to cooperate with from energy industry to face these challenges. It will speed up unconventional gas E&P and meet natural gas demand in China, which will contribute to global gas industry as well.

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