

# **A Review on Development of CBM Industry in China\***

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## **Abstract**

### **1. CBM Resources and Exploration and Development History of China**

Total CBM Resources of 38.61 trillion cubic meters, in which:

- 31%, 28% and 28% in the eastern, central and western, only 13% in the southern
- 85% occur in nine basins including Ordos, Jungar, Qinshui and so on

Three Stages of CBM Development:

- Geological constituency and production test from 1989 to 2002, in which hardly any CBM was commercially produced from ground wells.
  - Small scale of commercial production from 2003 to 2008 in the Qinshui and Tiefsa basins. Annual CBM output from the ground wells reached 5 billion cubic meters in 2008.
  - Substantial scale of production concentrated in the Qinshui and Ordos basins since 2009, reaching an annual CBM output of 155.3 billion cubic meters, in which the 36.9 billion cubic meters was produced from the ground wells.
- AAPG Datapages/Search and Discovery Article #90234 AAPG Asia Pacific Region, Geoscience Technology

Workshop, Opportunities and Advancements in Coal Bed Methane in the Asia Pacific, February 12-13, 2015, Brisbane Australia

CBM production of the Whole Country in 2014:

- Total CBM production is 155.3 billion cubic meters, including 36.9 billion cubic meters from the ground wells and 118.4 billion cubic meters from coal mines.
- By the end of 2014, China has about 14500 ground wells mainly located in the Qinshui and Ordos basins, in which about 9300 wells are operating with the average daily production per well of 1087 cubic meters per day.

## 2. Activities of CBM Research in China over the Past Ten Years

Three thousand two-hundred and sixty-seven CBM papers were published by 245 Chinese journals from 2003 to 2013.

Research Hotspots:

- In the field of geology and exploration, the interest was focused on the CBM resources and geologic controls, geophysical logging, the physical properties of coal reservoirs, CBM accumulation, and the paragenetic sequence and co-mining of coal measure gas (CMG) including CBM, shale gas and tight sandstone gas are concerned recently.
- In the field of CBM extraction and enhanced production technology, the focus were on the drilling fluid, well pattern optimization, hydraulic fracturing, fracturing fluid, foam fracturing, CO<sub>2</sub> injection, drainage system optimization etc.
- In the field of CBM utilization and environmental protection, the technologies of the CBM power generation, CBM purification and concentration, CBM transportation and storage are more discussed, and industrial policy and the clean development mechanism (CDM) are involved.

Interest Conversion:

- In the field of geology and exploration, the research findings of the CBM recoverability were concentrated in 2006, and paragenetic sequence and co-mining technology of CMG has come into the study view since 2008.
- Researches on CBM development technology growth significantly in the past ten years, and research hotspots are most concentrated. Concern for CBM well type is expanded from multi-branch horizontal wells (2005), cluster wells (2008)

into U-pattern well (2010), and the interest for the technology of CBM reservoir stimulation develops from hydraulic fracturing (2003), CO<sub>2</sub>-ECBM (2006), VES fracturing fluid (2009) into HRS fracturing and nitrogen foam fracturing (2012). Recently, the research results on the pulse shock wave technology for increasing the coal reservoir permeability have been reported.

- In the field of comprehensive CBM utilization, concern only focus on fuel before 2004, on concentration, purification, liquefaction, hydrate of CBM during 2005 to 2006, on the clean CBM conversion since 2007, on the synthesis gas since 2010, and on the pressurized gathering, network and storage since 2012.
- The evolution of research hotspots shows clearly the fronting trends of the CBM research in China, and indicates the major problems of science and technology for the development of CBM industry in China.

#### Interested Areas:

- Research was carried out mainly in the Qinshui, Ordos, western Henan, western Guizhou, eastern Yunnanp and Liaohe, accounting for the 18% of published papers over the past ten years. Then, the Turpan-Hami, Junggar, Liang Huai and Sichuan also obtained attention, and the Ningwu, Hailar, Erlan and Santanghu were involved.
- For the literature on the Ordos and Qinshui basins, those of geological research, exploration and drainage test is accounted for more than 96%, indicating that the main concern of CBM research in China is paid on these two basins in recent years. In fact, the more than 90% of the ground-well CBM production in China was derived from the two major basins over the past ten years.

Since 2008, Chinese government has launched major CBM National Science and technology Projects, and the investment funded by the government and related CBM enterprises has exceeded 100 billion US dollars so far. The project is divided into two categories. CBM research and development includes the 10 projects, covering each technical link of the whole process from the CBM resource evaluation to the development. Technical demonstration is composed of the six projects, including the CBM drainage technology with the surface wells and coal mine, and four of them are implemented in the Qinshui and Ordos basins.

### 3. Progress of CBM Exploration and Development Technology in China

China is the biggest coal producing country in the world, so that the CBM development had to be taken to the strategy of the ground wells jointly with coal mine drainage. The purpose is to make full use of CBM resources, reduce the disaster risk from coal mine gas and coal mine methane emissions to the atmosphere. Six series of Technology have been formed:

- Development technology of the CBM from high-rank coal reservoir in Qinshui basin with ground wells.
- Development technology of the CBM from middle-rank coal reservoir in Qinshui and other basins with ground wells.
- Drilling and CBM development technology of directional wells, including the horizontal multi-branch, horizontal comb-pattern, horizontal multi-seam, U-type and cluster wells.
- CBM development supporting tools and equipment such as the long needle threading tool, electromagnetic wave geosteering tool, complete sets of continuous tube equipment, rotary abrasive jet equipment for deep penetration, and micro seismic equipment of well jointly with surface for monitoring the fracturing.
- CBM drainage technology suitable to China's coal reservoirs, such as the area step-down method with double control step by step, drainage control with five stage and three pressure points and recovery with fine stability control.
- Efficient extraction technology of coal mine gas represented by the Huainan model and Jincheng model.

These technologies are supporting the development CBM and coal industry of China:

- Has built up the surface CBM development bases with the production capacity of 110 billion cubic meters, bring about the gas production of 120 billion cubic meters in underground coal mines, and the CBM industry of China has been initially formed.
- Continuously to improve the coal mine safety in China. Since 2006, the coal output of China grew at an average annual rate of 2.3 tons, and the mortality per million tons coal decreased from 2.81 in 2005 to 0.293 in 2013, significantly reducing gas accidents.
- Total proven CBM reserves of 8454 billion cubic meters, find the two CBM field respectively with the reserves of more than one hundred billion cubic meters, and provides the basis for the sustainable development of national CBM industry.

#### 4. Problems and development trends of China's CBM industry

After more than 30 years of unremitting efforts, China's CBM industry has made significant progress on the background of complex coal reservoirs, but still faces many problems to be solved. The government will continue to support the industry in

the R&D investment and policy and the related large CBM enterprises are looking for ways to solve the key technical problems in constant.

Major problems:

- The lower single well production on the whole affects the CBM development benefit and investor confidence.
- Exploration and geological evaluation technology of the "sweet spot" within a block still under development.
- Development technology suitable to various coal reservoirs needs to be improved.
- Drainage production needs more support of the technology, such as coal power suppression.
- Industry strategic alternative bases are still to be formed.

Measures that have been taken or will be taken:

- The Chinese government promulgated the "Coalbed Methane Industry Policy" in 2013 March, has been clear about the industrial development objectives, market access, industrial layout, technology policy, safeguard measures and so on.
- The government will continue to carry out Major CBM National Science and Technology Project, support the CBM research and technical demonstration projects.
- More attention will be paid to the R&D of enhanced production technology for single well of two existing industrial base, including the new technology principle.
- More attention will be paid to the R&D of integrated exploration and development technology for the CBM, shale gas and tight sandstone gas in coal measure.
- More attention will be paid to the technology and demonstration of low-rank CBM resources, accounting for total CBM resources of 47% in China.

The latest progress in CBM exploration and development:

- Low-rank CBM production of single well has realized industrial gas flow breakthrough in some areas such as Fukang, Yilan, Hui Chun, Huolinhe etc.. Among them, one wells Fukang, Xinjiang, yields the stable gas flow of 12,000 cubic meters per day.
- Production of single well in some blocks of the existing two bases is significantly increasing overall, such as nearly 3,000 wells in Hancheng block, Ordos basin.

- Co-drainage tests of coal measure gas have achieved a major breakthrough. For example, gas productions of the single wells in Lin Xing block, Ordos bas and in western Shilou block, have reached several ten thousands of cubic meters.
- CBM exploration in some other areas has produced industrial gas flow of single wells, such as the western Guizhou, southern Sichuan and eastern Heilongjiang.

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# A Review on Development of CBM Industry in China

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# Outline

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1

**CBM Resources and Exploration & Development History of China**

2

**Activities of CBM Research in China over the Past Ten Years**

3

**Progress of CBM Exploration and Development Technology in China**

4

**Challenges and responses of China's CBM industry**



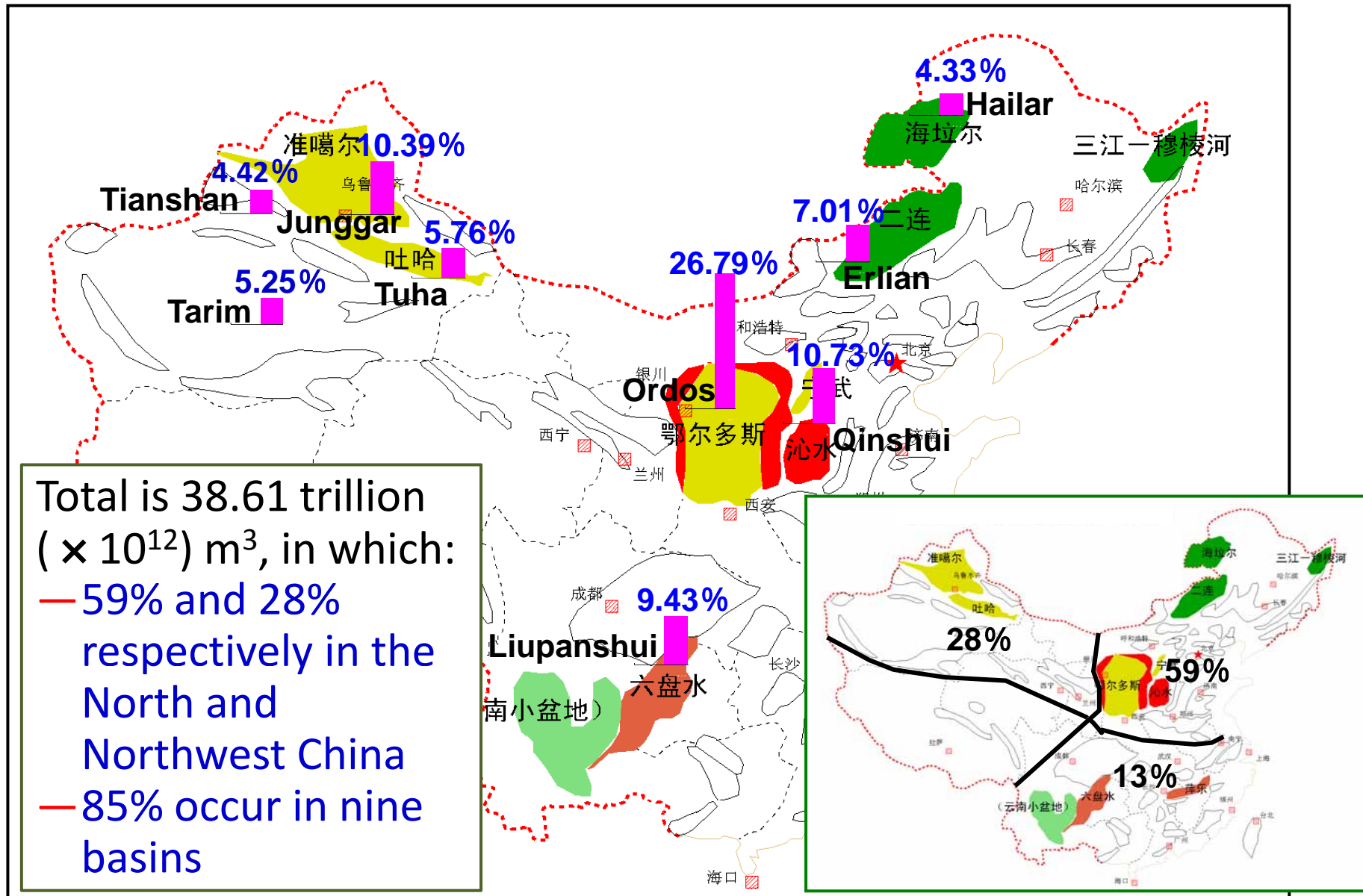
# 1

## CBM Resources and Exploration & Development History of China

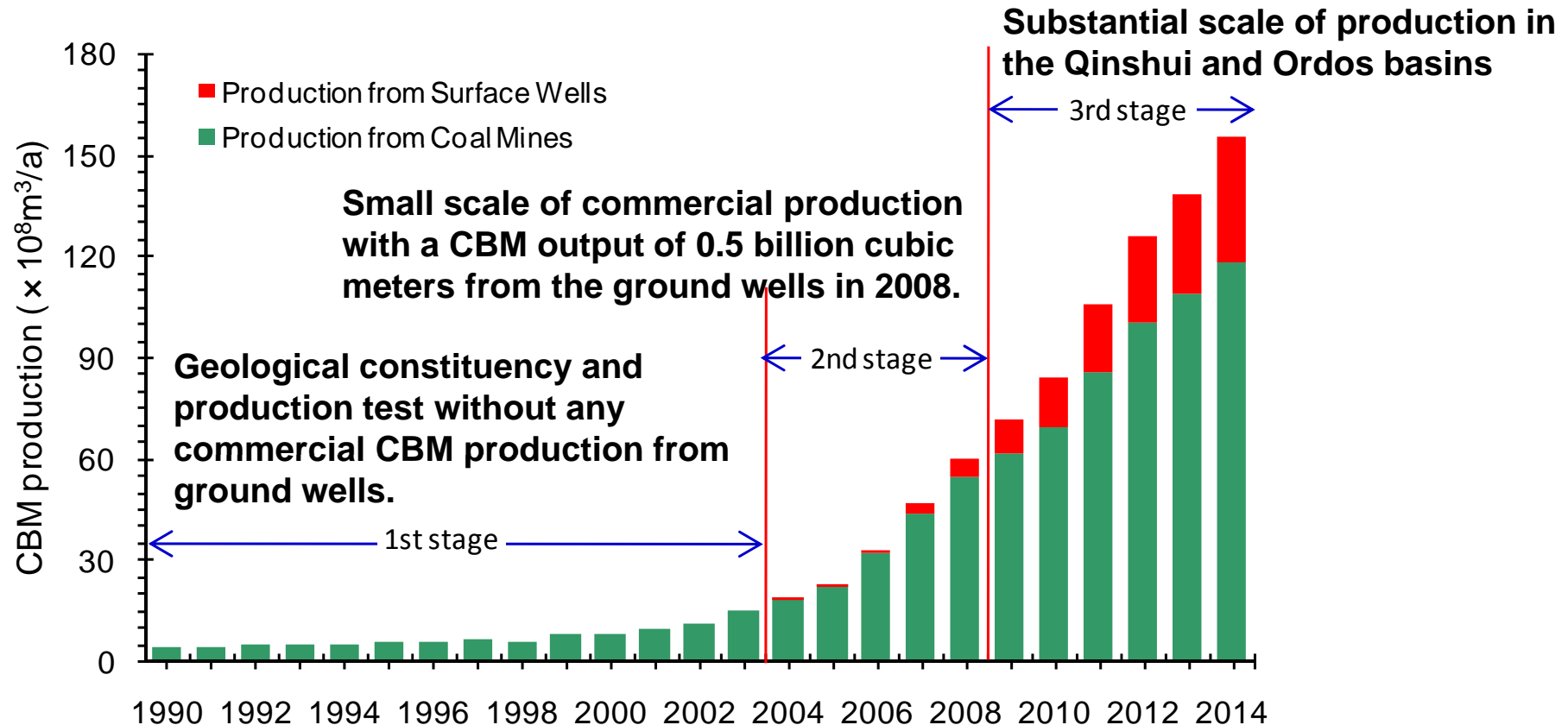
CBM exploration play in China began in 1989, and it is 25 years old.



# CBM Resources of China



# CBM Development Stages of China



## In 2014:

- Total CBM production was 15.53 billion cubic meters, including 3.69 billion cubic meters from the ground wells and 11.84 billion cubic meters from coal mines.
- By the end of 2014, China has about 14700 ground wells mainly located in the Qinshui and Ordos basins, in which about 9300 wells are operating with the average single well production of about 1050 cubic meters per day.

## 2

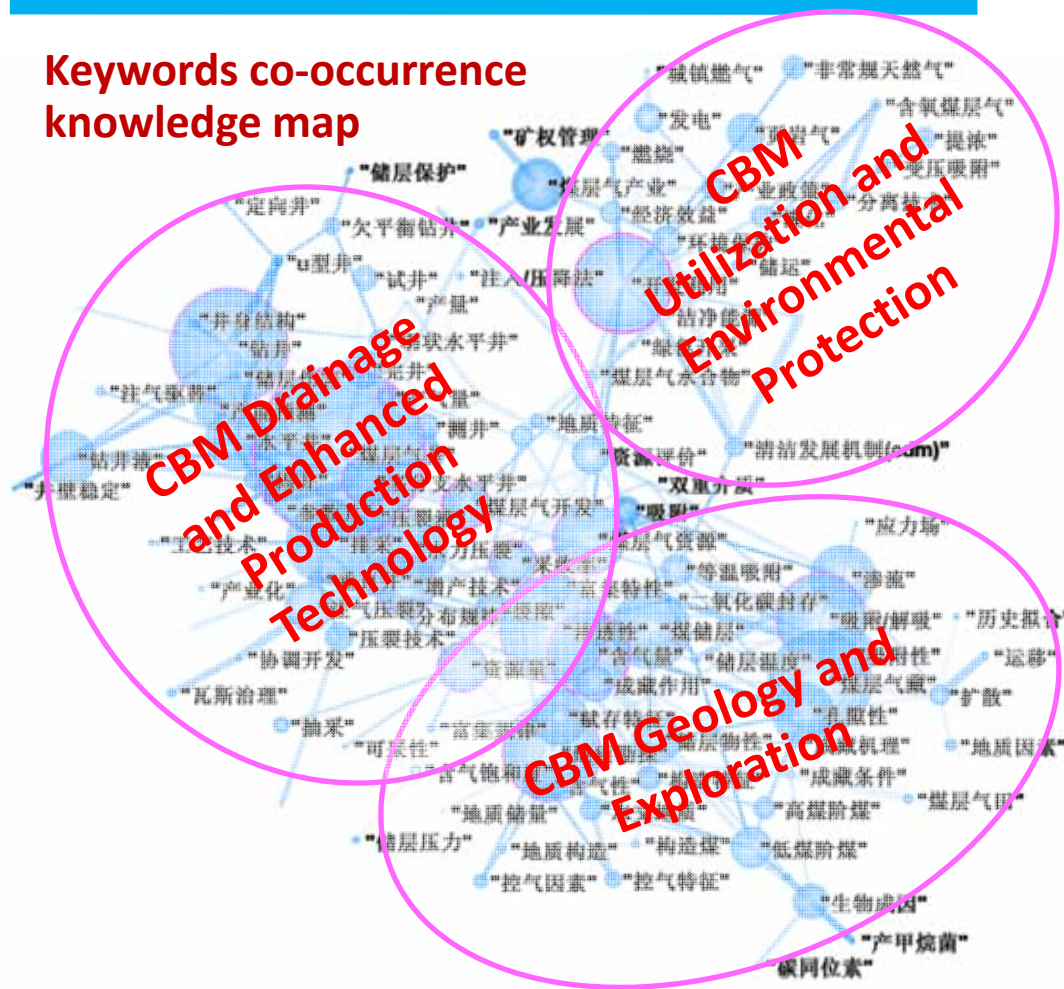
## CBM Research Activities in China over the Past Ten Years

After searching from CNKI database, it was known that the 3267 CBM papers were published by 245 Chinese journals from 2003 to 2013.





## Keywords co-occurrence knowledge map

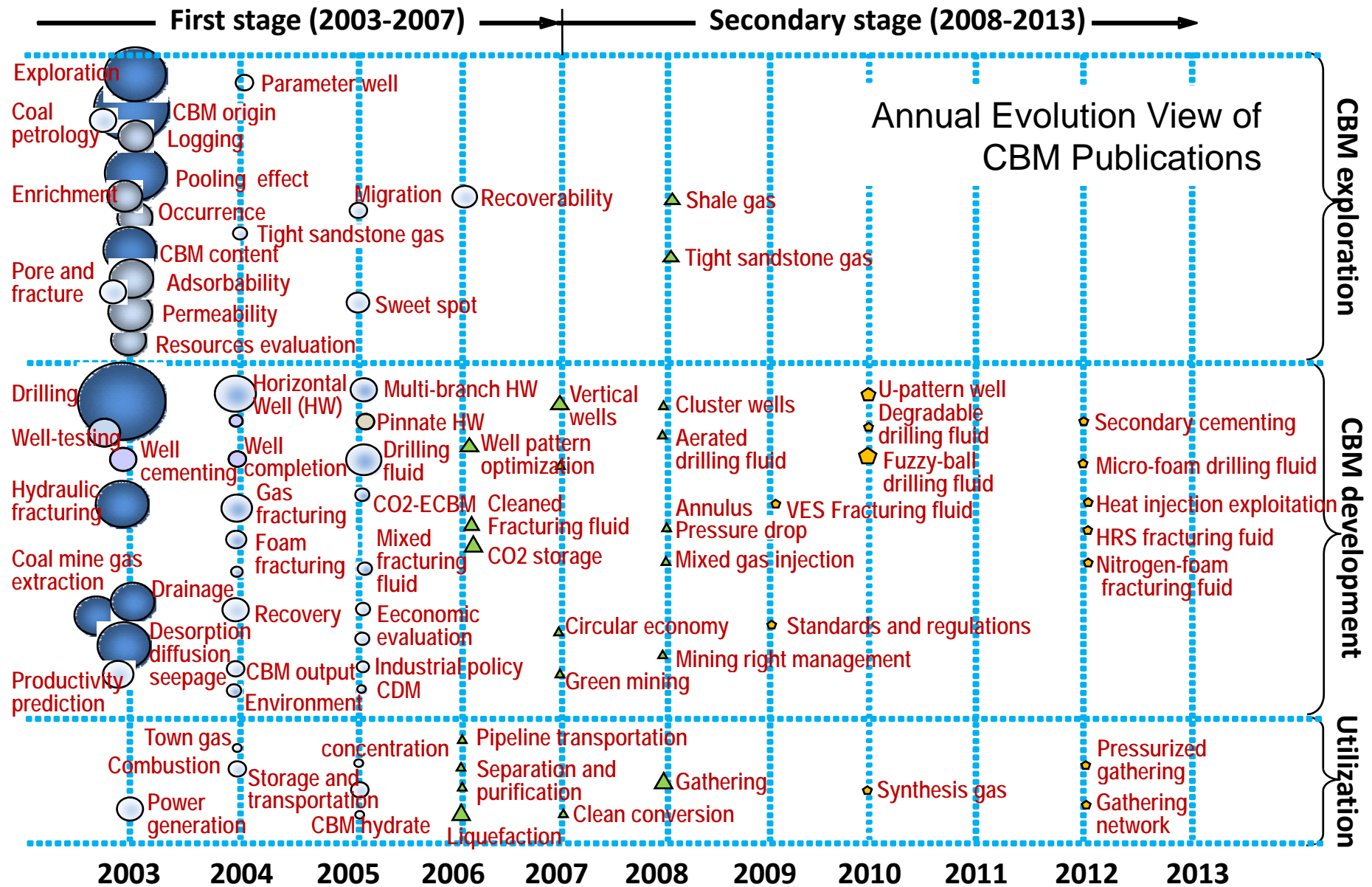


- CBM power generation, purification, transportation and storage are more discussed.
- Industrial policy and the CDM are involved also.

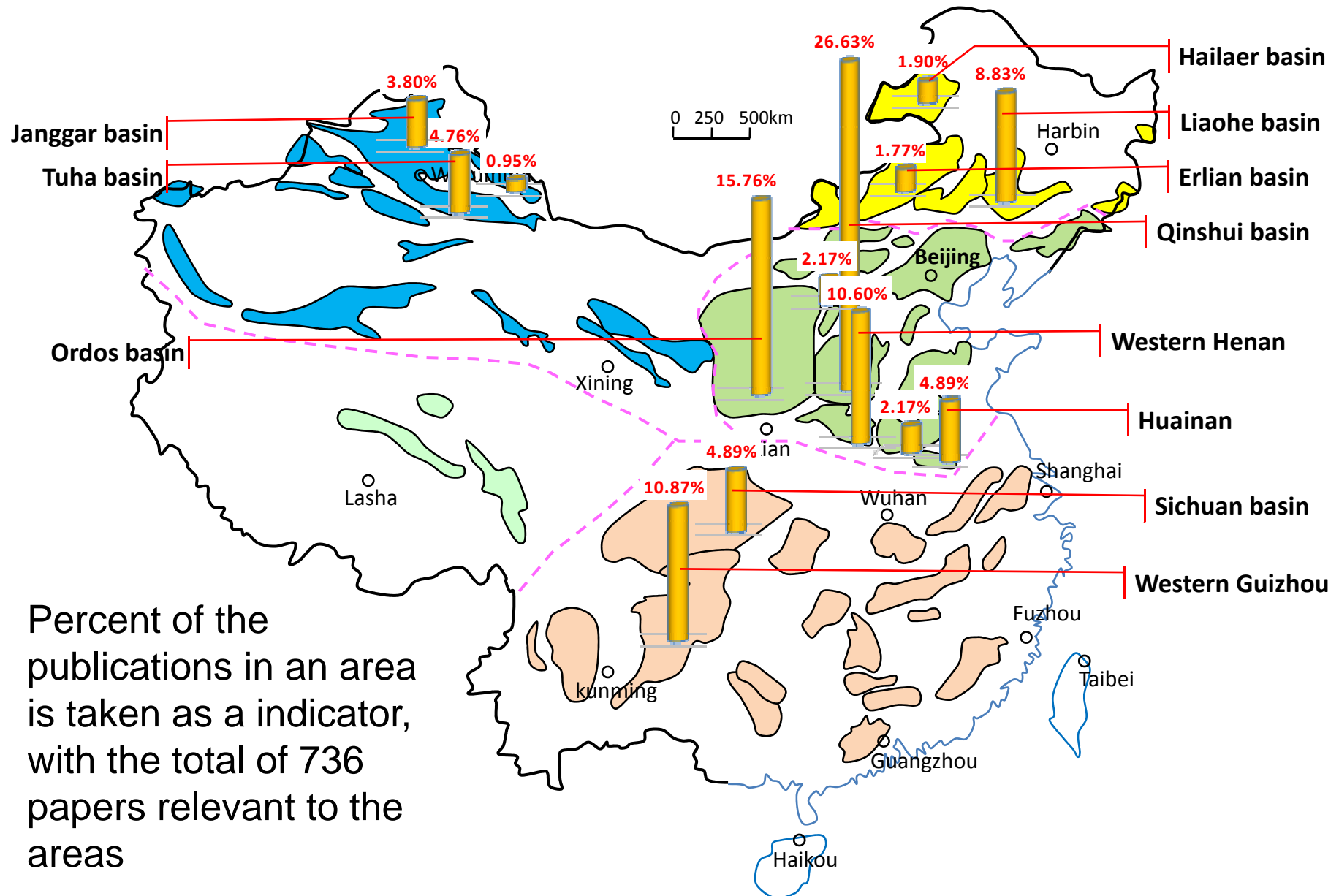
- The interest is focused on the CBM resources and geological controls, geophysical logging, coal reservoir properties and CBM accumulation.
- Coal measure gas (CMG) including CBM, shale gas and tight sandstone gas are also concerned recently.

- the focuses are on the drilling fluid, well pattern optimization, hydraulic fracturing, fracturing fluid, foam fracturing, CO2 injection, drainage system optimization etc.

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# Hotspot Areas



# Major National CBM Sci.&Tech. Plan



Since 2008, a major CBM National Science and Technology Projects has launched , and funded by the government and related CBM enterprises has exceeded about 10 billion US dollars so far.

**The plan includes two categories,**

- Ten CBM R&D projects, covering each technical link of the whole process from the CBM resources evaluation to the drainage.
- Six technical demonstration projects, including the CBM drainage from the ground wells and coal mines, and 4 of them are being implemented in the Qinshui and Ordos basins.



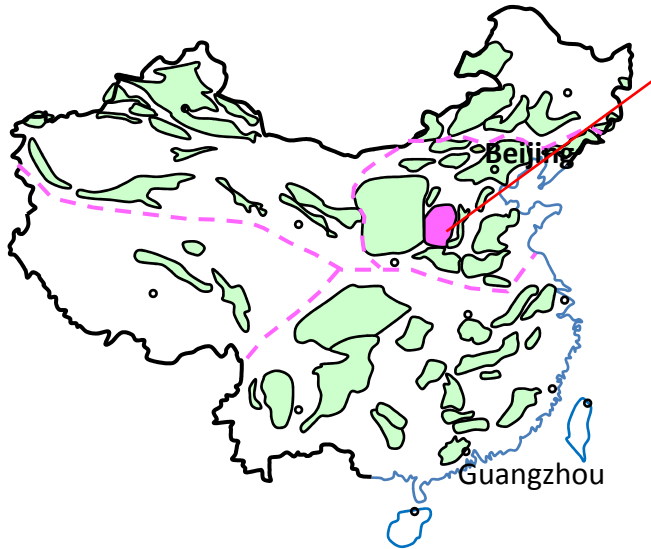
## 3

## Progress of CBM Exploration and Development Technology in China

China had to be taken to the CBM strategy of the ground well drainage jointly with coal mine extraction.



# Five Series of Technology Formed



**Firstly** to form the ground-well technology of the CBM production suitable to high-rank coal reservoirs in the Qinshui basin where is the largest CBM base in China now.

- 6300 operating wells including about 110 horizontal wells
- CBM output of about  $26.5 \times 10^8 \text{ m}^3$  in 2014

**Sweet spot assessment**

**Vertical well with casing completion**

**Hydraulic carrying sand fracturing**

**fine drainage with stable control**

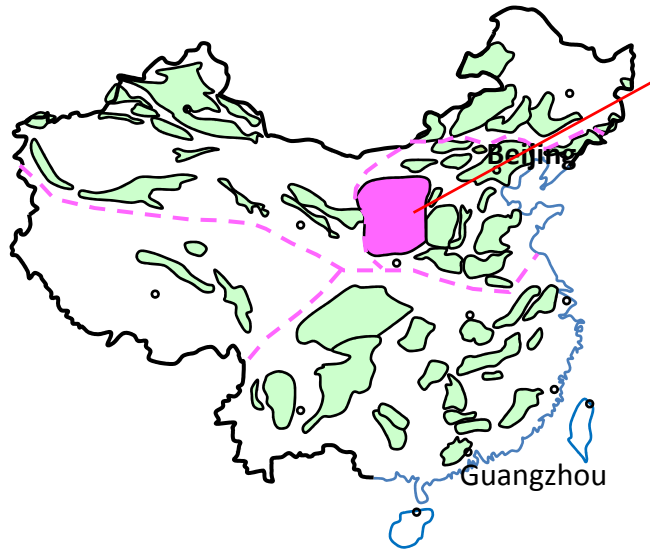
**flexible transmission with multiple access**

Well patterns,

- vertical well
- cluster well
- horizontal well with multi-branches or segmentation fracturing
- U-type horizontal well

Reservoir stimulation tech.,

- hydraulic fracturing
- foam fracturing
- CO<sub>2</sub>-ECBM
- clean fracturing fluid
- .....

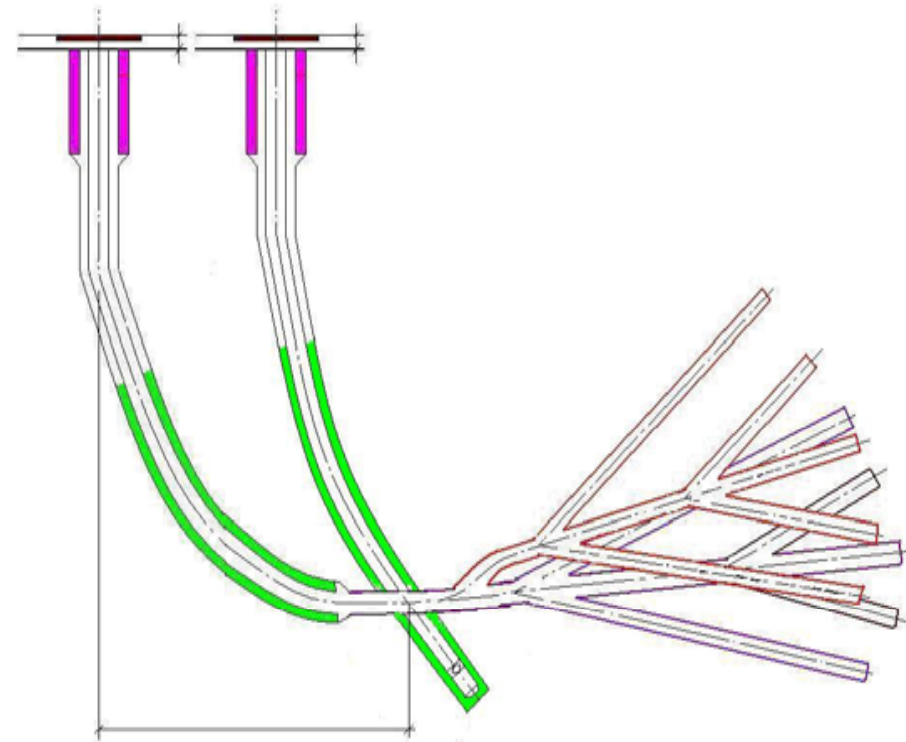


**Secondly** to form the ground-well tech of the CBM production suitable to the middle-rank coal reservoirs in eastern Ordos basin where is another CBM base in China now.

- 2959 operating wells including 106 horizontal wells
- CBM output of  $8.5 \times 10^8 \text{ m}^3$  in 2014

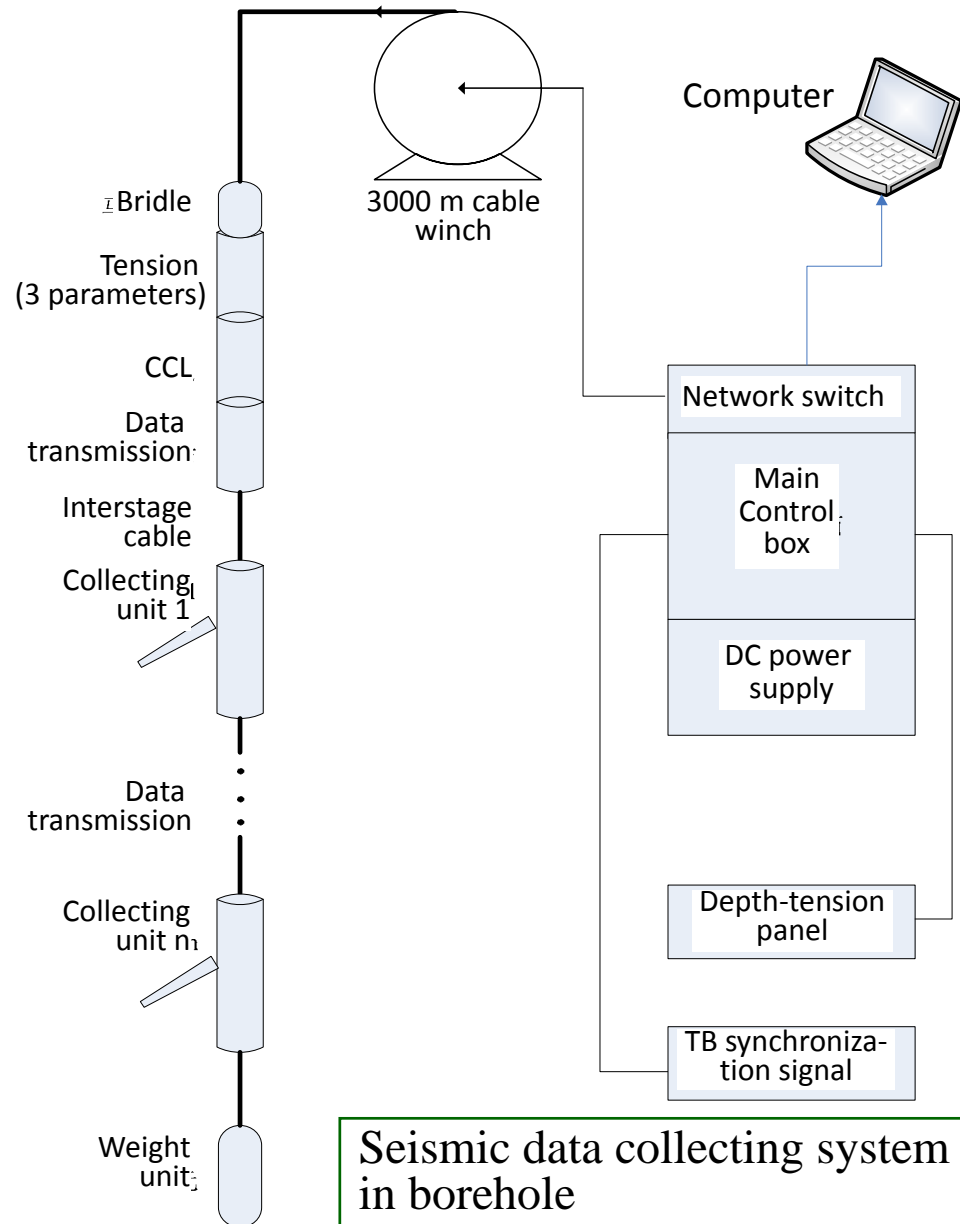
Major technologies,

- evaluation of CBM sweet spots
- underbalanced drilling with anti-deviation and leakage reducing
- fracturing fluid with nano-fiber complex
- multi-branch horizontal well of multi coal seams connected by Inclined shaft



**Thirdly** to develop the supporting tools and equipments,

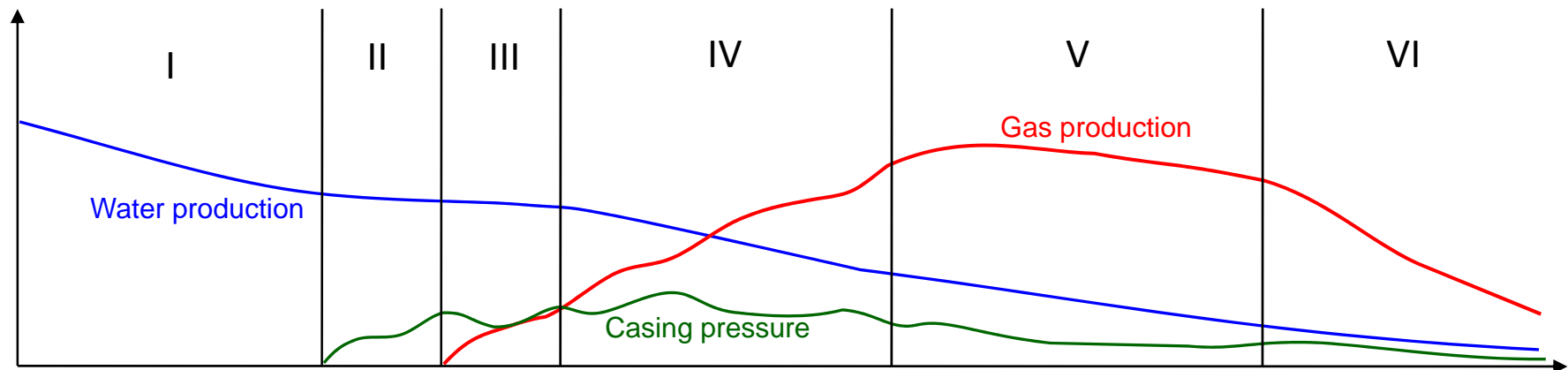
- long needle threading tool
- electromagnetic wave geosteering tool
- sets of continuous tube equipment for well completion
- rotary abrasive jet equipment for deep penetration
- micro-seismic equipment of well jointly with ground for monitoring the fracturing process



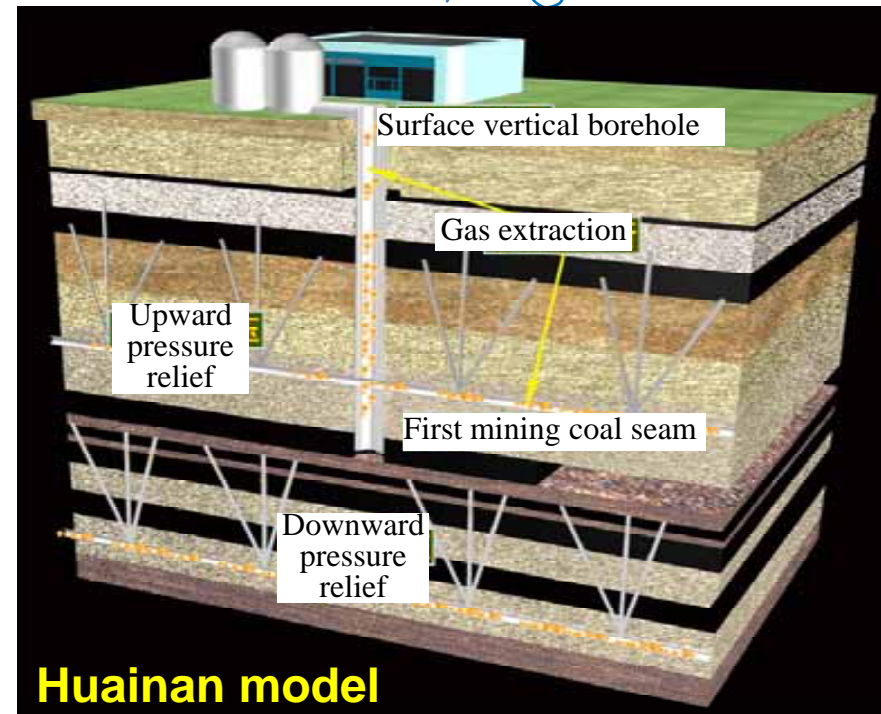
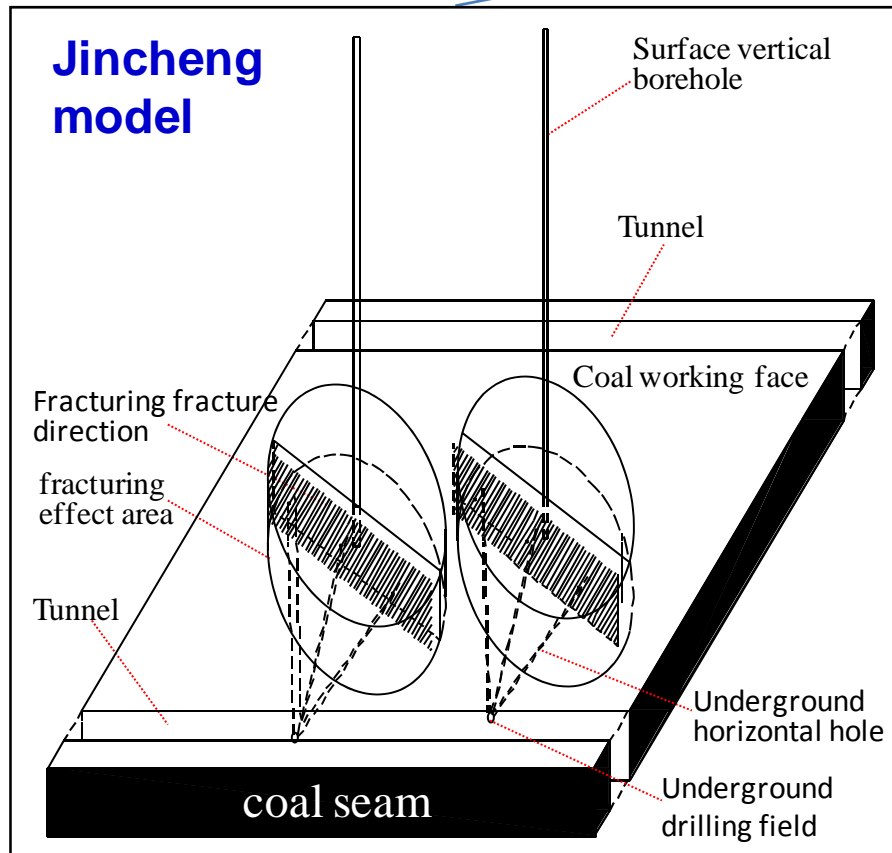
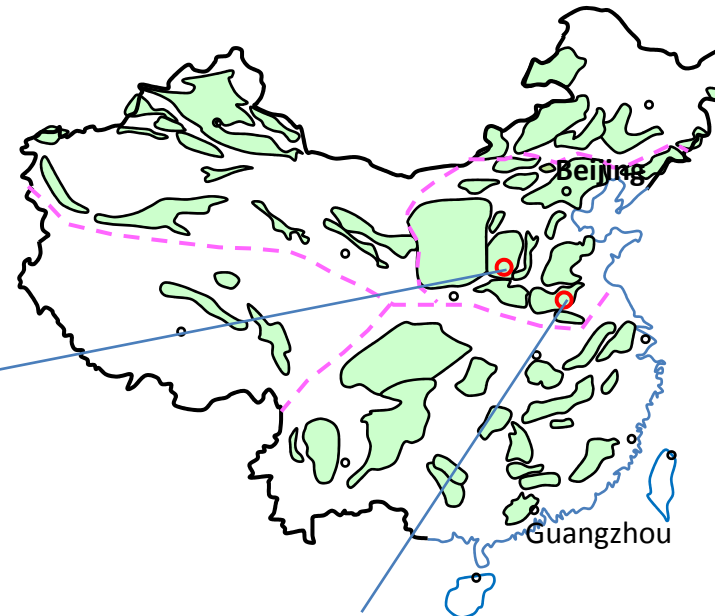
**Fourthly** to develop the CBM drainage technology suitable to China's coal reservoirs,

- an area step-down method with double control step by step
- drainage control with five stage and three pressure points and recovery with fine stability control

Stage	After appearance of casing pressure	Early gas production	Gas production increased	Stable gas production	Fading gas production
Objective	Judging the capacity of fluid supply to expand the pressure drop area	Holding the casing pressure to maintain the formation energy	Releasing the production capacity to keep continuous and stable gas supply by controlling the pressure and powders	keeping the general stability of gas production	Gas production slowly decaying

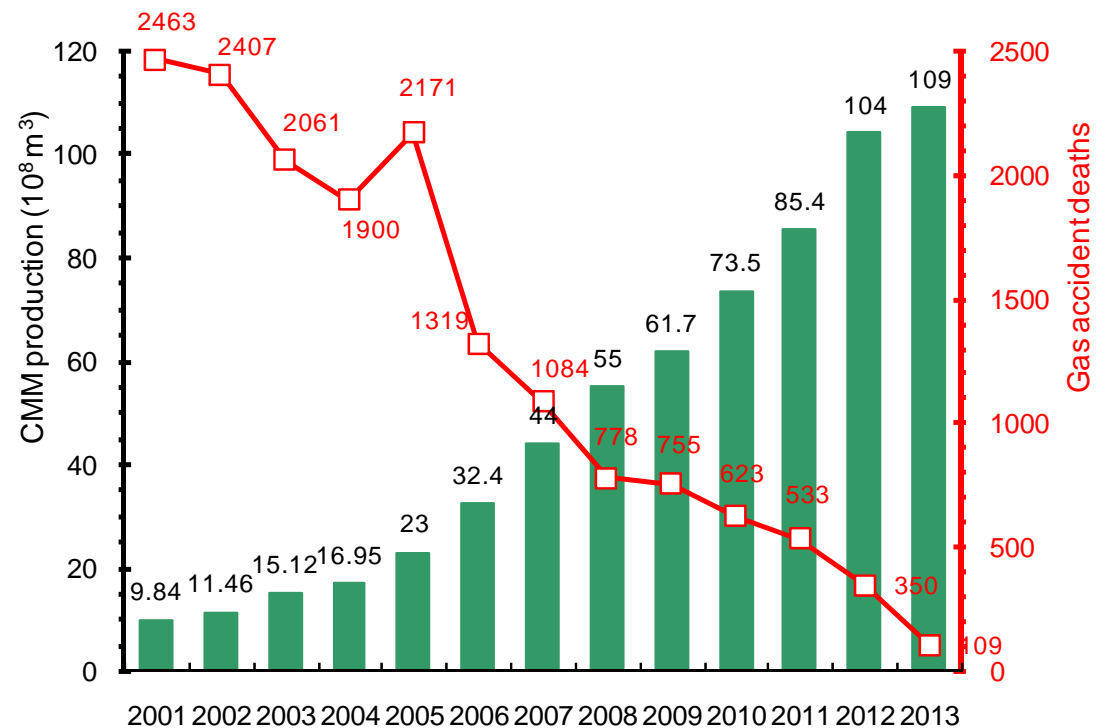


**Fifthly** to set up the efficient extraction technologies of coal mine methane (CMM) represented by the Huainan model and Jincheng model



# Supporting CBM and coal industries of China

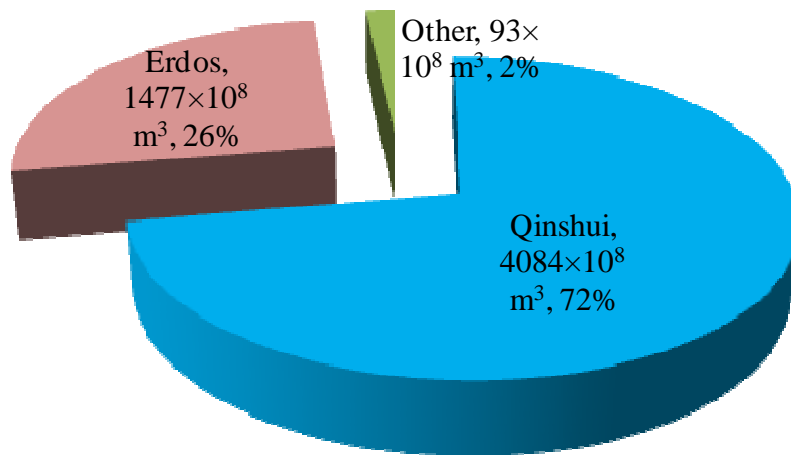
- The ground CBM bases with the capacity of 11 billion cubic meters have been built up, and bring about the gas production of 3.69 billion cubic meters from ground wells in 2014. The CBM industry of China is emerging.
- Coal mine safety in China has been continuously improved. Countrywide coal output grew at an average annual rate of 0.23 billion tons, but the mortality per million tons coal decreased from 2.81 in 2005 to 0.29 in 2013, reducing significantly mine gas accidents.



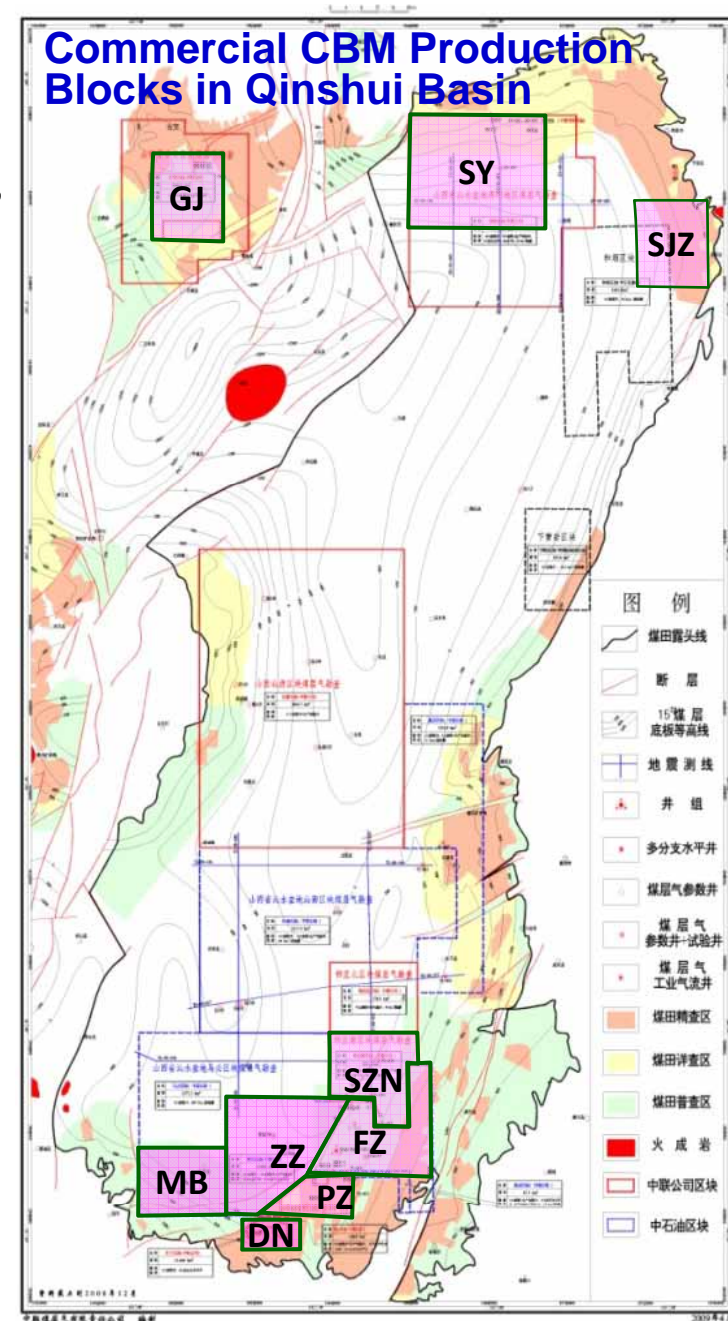
CMM production and coal mine gas accident deaths of China since 2001



- By the end of 2014, China has total proven CBM reserves of 845.4 billion cubic meters, including two CBM fields with the reserves of more than one hundred billion cubic meters, which provides the basis for the sustainable CBM industry in China.



Project	Number	Production capacity (10 <sup>8</sup> m <sup>3</sup> )	Output in 2014 (10 <sup>8</sup> m <sup>3</sup> )
Production capacity formd	9	40	36.9
Production capacity under construction	12	60	
Total	21	100	36.9





# 4

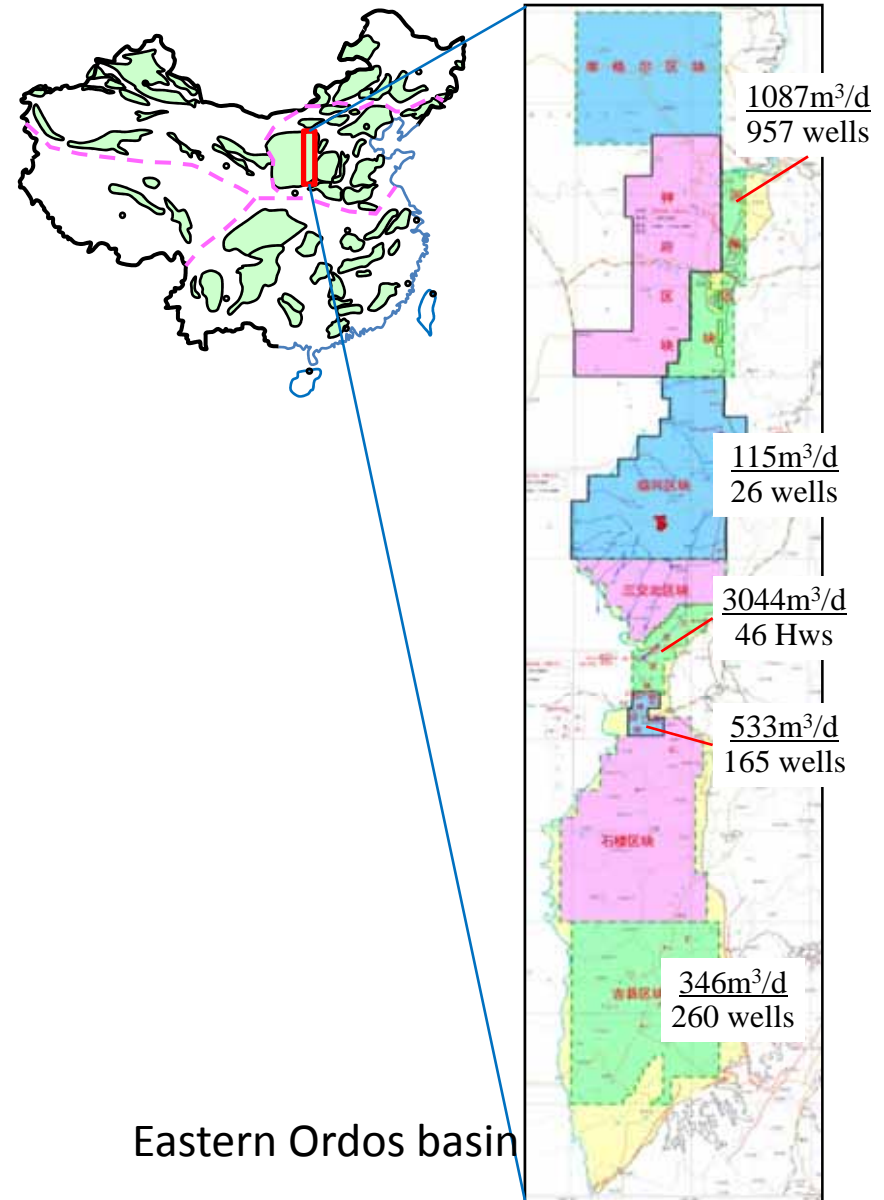
## Challenges and responses of China's CBM industry

Through more than 20 years of efforts, China's CBM industry has made significant progress, but still many challenges need to be faced.



# Major Challenges

- The lower single well production on the whole affects the CBM development benefit and investor's confidence.
- Technology of the "sweet spot" evaluation within a block is still under development.
- Simulation technology suitable to various coal reservoirs needs to be improved.
- Drainage production needs more technological support, such as coal power suppression and casing pressure control.
- Strategic alternative bases of CBM industry are still to be formed.

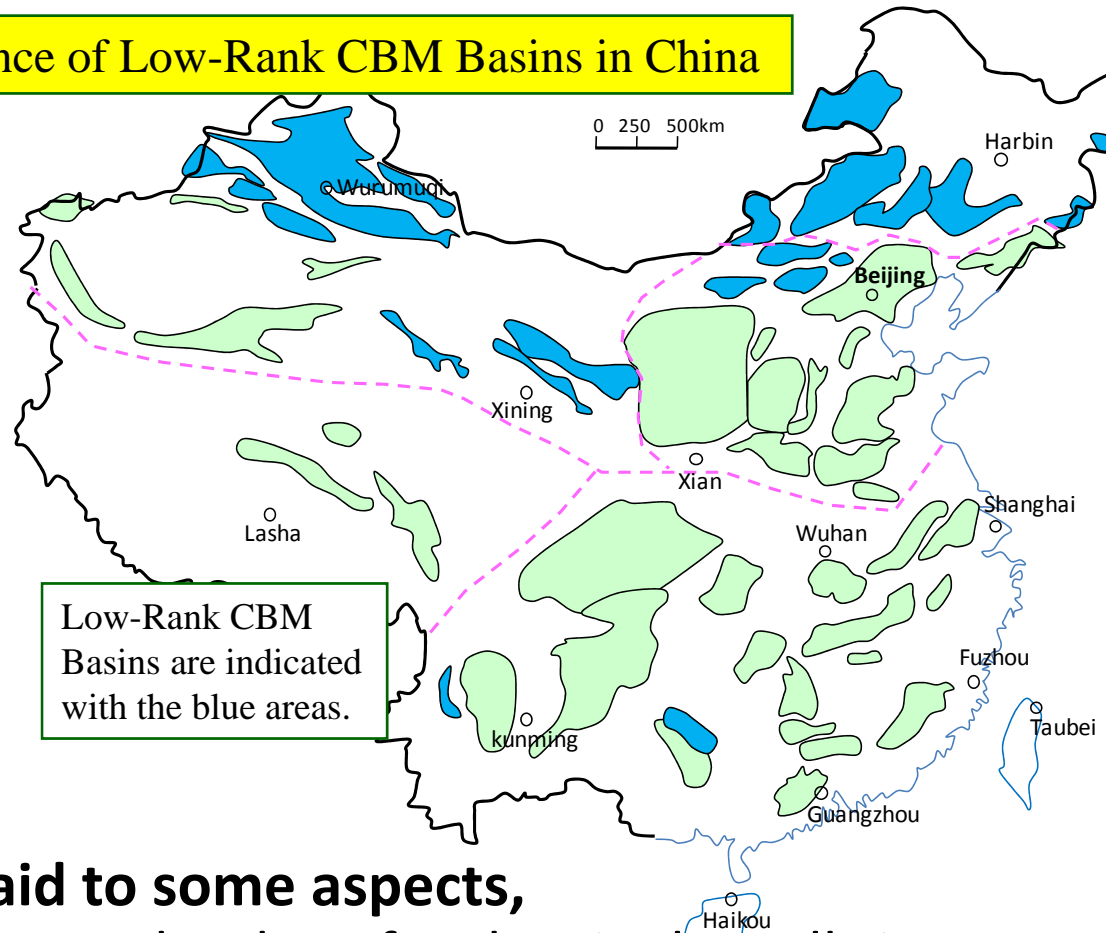


# Efforts taken or to be taken

- The China's government promulgated the "**Coalbed Methane Industry Policy**" in February 2013, has been clear about the industrial development objectives, market access, industrial layout, technology policy, and safeguard measures.
- The government will continue to carry out the **Major National CBM Science and Technology Plan** for supporting the CBM research and technical demonstration projects.



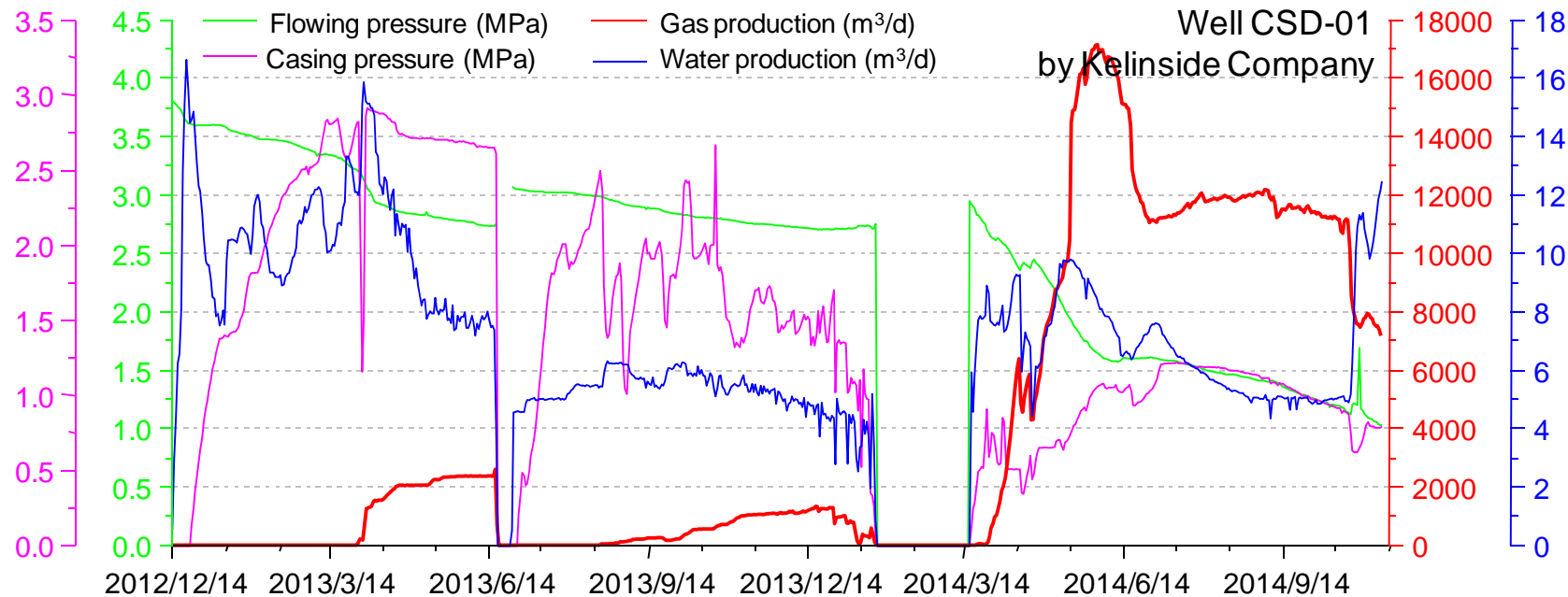
## Occurrence of Low-Rank CBM Basins in China



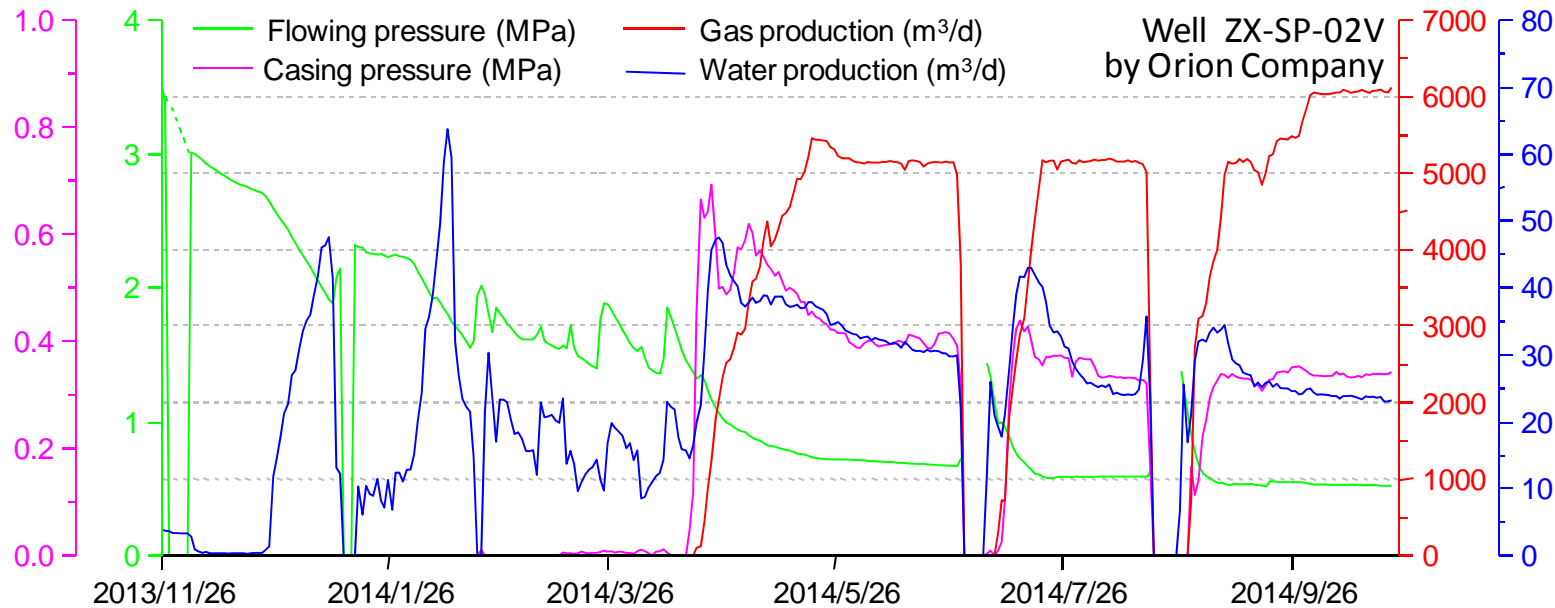
**More attention will be paid to some aspects,**

- the enhanced production technology for the single wells in two existing bases, including the new technology principle.
- the integrated exploration and development technology for the CBM, shale gas and tight sandstone gas in coal measure.
- the demonstration of low-rank CBM resources drainage, accounting for total CBM resources of 47% in China.

# The Latest Progress



- Single wells in some low-rank coal reservoirs has produced the high CBM flow. For example, one well in the Fukang, Junggar basin, has the stable gas flow of more than 8000 m³/d since June 2013.
- Production of single well in some blocks of the existing two bases is enhanced significantly on the whole, such as nearly 1300 wells in the Hancheng block, Erdos basin.
- CBM exploration in some other areas with complex geological conditions has produced industrial gas flow of single wells.



- Using the ground well (specially segment-fracturing horizontal well), the stable and high CBM flow has been obtained from soft coal reservoir for the first time in Hebi, with the technologies such as the long-distance directional drilling, remote needle connection, casing completion without cementing, sand-blasting perforation and coiled tubing fracturing.
- Co-drainage tests of coal measure gases have achieved a major breakthrough. For example, gas productions of the single wells in the Linxing and Silouxi blocks, Ordos, have reached tens of thousands cubic meters per day.

# Thanks for your attention

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