1st U.S.-China Clean Coal Industry Forum

Technology Process of China's CBM Exploration and Development

Wu Jianguang

China United Coalbed Methane Corporation., Ltd

August , 2015

Outline

1. CBM Exploration & Development Progress from CUCBM
2. Current Status on China's CBM Exploration & Development
3. Technology Trend of China's CBM Exploration & Development
4. Question and Suggestion

1.1 The nature of the company

- China United Coalbed Methane Co. ,Ltd.(CUCBM) was established on March 30, 1996 upon the approval of the Chinese State Council. CUCBM is specialized in CBM exploration, development ,production, transportation, sales and utilization, which was entitled the exclusive right to undertake exploitation, development and production in cooperation with foreign companies, in reference to management model of oil and natural gas.
- The Chinese State Council, NDRC, MOF, MOST separately approved and put CUCBM under auspices from Sept 7,1997 to July, 1999.
- CUCBM currently has been the holding company by CNOOC after equity transfers and changes many times from Mar.1999 to Dec.2013.
- CUCBM obtained “A” Qualification of Gas Exploration and passed the system of ISO9001.

1.2 Progress on CBM Exploration & Development

- CUCBM has 29 exploration right licenses and 2 mining right licenses with the total area of 20000 km^2, which was located in Shanxi, Shaanxi, Anhui and other 10 provinces.
- CUCBM found the first CBM field in Qinshui Basin of China—Qinnan CBM field in 2001, and submitted the first CBM proven reserve report.
- CUCBM has successively conducted more than 50 CBM exploration & development projects, 30 foreign cooperation projects in 31 areas of 15 provinces since the founding of CUCBM, all sorts of 3500 CBM wells were drilled.
- Up to 2014, CUCBM has obtained CBM proved reserves of 170 billion m^3, built production capacity of 2 billion m^3 per year with annual gas output of 1 billion m^3.

1.3 Science & Technology Led

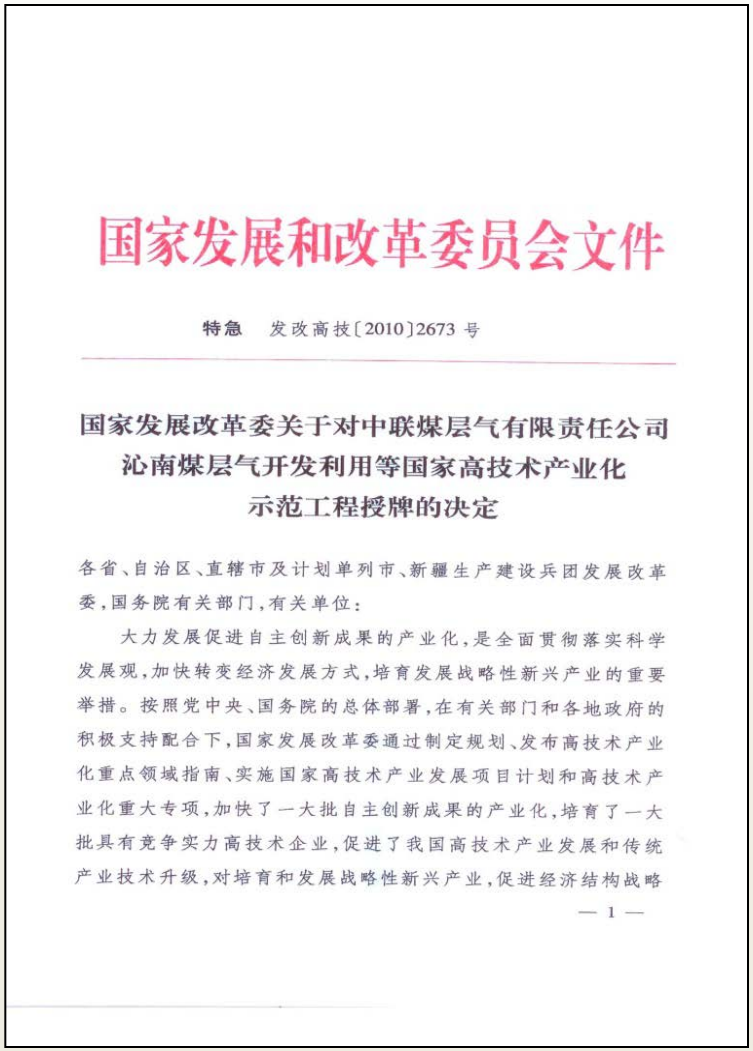
- CUCBM did a series of basic work in CBM industry planning, policy making and the comprehensive utilization of the resources for the relevant departments.
- Developed over 30 rules and specifications for CBM exploration and development.
- Organized and involved in the compiling of the National CBM program the 11th and 12th Five-Year Plan.
- Director unit of “Strategic Alliance of Technological Innovation for CBM Industry”.
- Affiliated unit of CBM Professional Committee to China Coal Society.

1.4 Technology Integration and Demonstration Project

"Qinnan Hi-tech Industrial Demonstration Project" was completed in 2009

- Forming 8 technical series in high rank CBM development in Qinnan.
- 210 CBM wells were drilled in the first phase of demonstration project and had been produced for 5 years, the daily average production for single well reached 4000m^3 , the most of the country.
- The successful completion of the demonstration project is of milestone significance in the development of China's CBM industry, marking the beginning of industrial production, which got the first prize of "National Energy Technology Progress".

1.4 Technology Integration and Demonstration Project



国家发展和改革委员会文件

特急　发改高技〔2010〕2673 号

国家发展改革委关于对中联煤层气有限责任公司沁南煤层气开发利用等国家高技术产业化示范工程授牌的决定

各省、自治区、直辖市及计划单列市、新疆生产建设兵团发展改革委，国务院有关部门，有关单位：

大力发展促进自主创新成果的产业化，是全面贯彻落实科学发展观，加快转变经济发展方式，培育发展战略性新兴产业的重要举措。按照党中央、国务院的总体部署，在有关部门和各地政府的积极支持配合下，国家发展改革委通过制定规划、发布高技术产业化重点领域指南、实施国家高技术产业发展项目计划和高技术产业化重大专项，加快了一大批自主创新成果的产业化，培育了一大批具有竞争实力高技术企业，促进了我国高技术产业发展和传统产业技术升级，对培育和发展战略性新兴产业，促进经济结构战略

— 1 —

Qinnan Hi-tech Project was granted by NDRC “the National Hi-tech Project for Industrial Demonstration the 12th China International Hi-tech Fair held on November 16,2010.

1.5 Actively exploring exploration & development technology in coal-bearing strata

The leading technology on CO_2 injection ,replacement of CH_4 and enhancing recovery of CBM

CO_2 -Enhanced CBM Pilot Test	2002-2006	China and Canada
Technology study on CO_2 injection and enhancing the recovery of CBM	2002-2003	MOST
Numerical simulation and economic evaluation of micro pilot test	2004-2005	MOST
Technology study on CO2 -injection/storage to enhance CBM production in deeper coal seam	2008-2010	China and Canada
Monitoring and verification of co_2 storage and ECBM	2006-2008	China and Netherlands
Towards institutionalised collaboration on knowledge development for sustainable integrated exploitation of coal	2009-2010	China and Netherlands
China-UK Near zero emissions coal project (NZEC)	2007-2008	China and UK
Enhanced –CBM project research collaboration	2010-2012	China and Australia
Technology study on CO_2 -injection in deeper coal seams	2010-2015	National Specific and Important Project

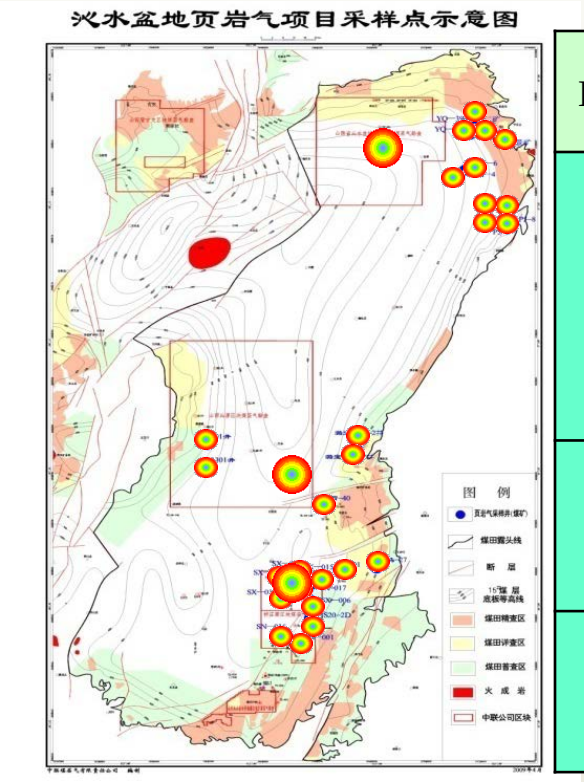
Demonstration project by American carbon sequestration leadership forum

CO2-ECBMtest first in horizontal well

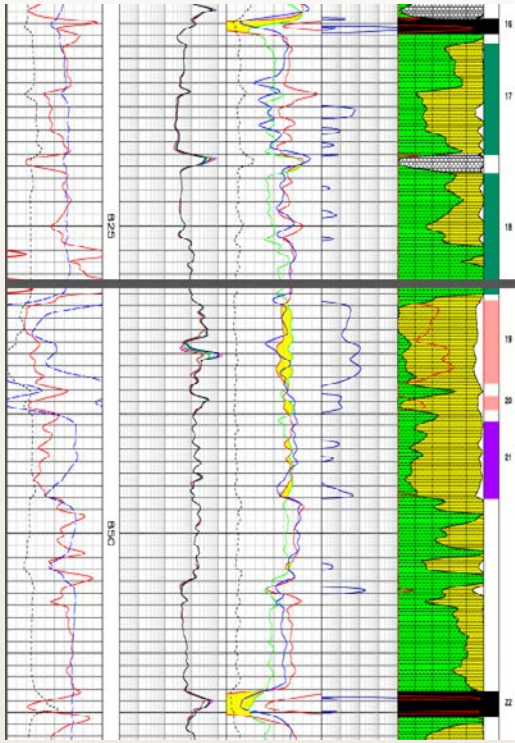
Well pattern injection

1.5 Actively exploring exploration & development technology in coal-bearing strata

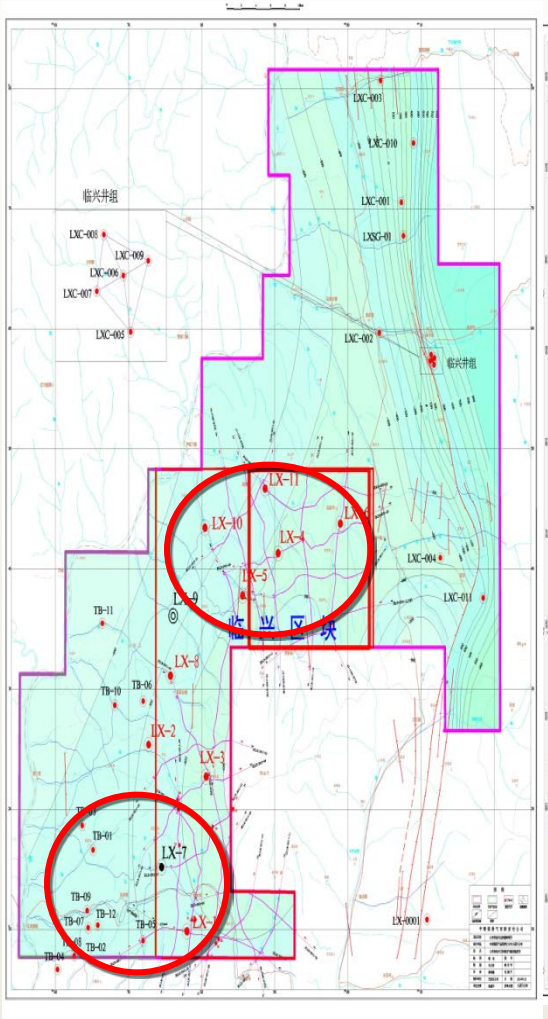
Finishing shale gas evaluation in Qinshui Basin, raising favorable area and 3 wells were fractured and tested.

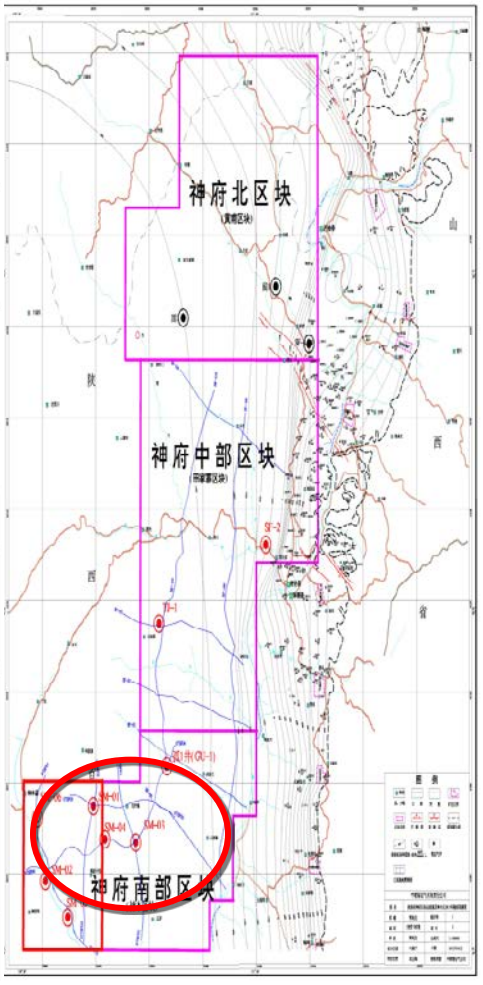


Location	Shizhuang North	Shouyang	Qinyuan
Well type	Parameter + production well	Parameter + production well	Parameter + production well
Target Seam	Lower shihezi formation、Shanxi formation、Taiyuan Formation		
Well depth	1207m	916 m	1977m



1.5Actively exploring exploration & development technology in coal-bearing strata





Linxing-Shenfu favorable play with tight sands gas，where industrial gas flow was found in several wells. The steady daily production of LX-4 reached 200 thousand m^3：

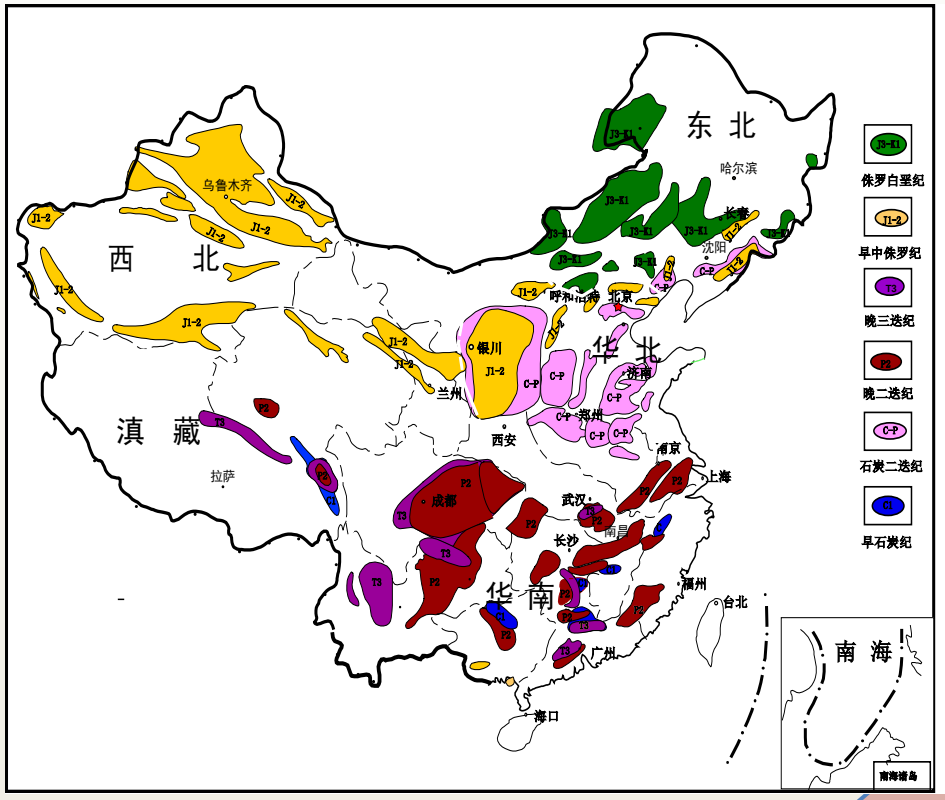
■Revealing high quality reservoir development mechanism of tight sands gas, raising the migration and accumulation model in Linxing-Shenfu Block.

■Forming technology series of sweet point recognition in gas-bearing of tight shale formation in sedimentary facies as core technology.

Outline

1. CBM Exploration & Development Progress from CUCBM
2. Current Status on China's CBM Exploration & Development
3. Technology Trend of China's CBM Exploration & Development
4. Question and suggestion

2.1 Current Status on China's CBM Exploration &Development



41 basins，114 gas plays，CBM area is 415 thousand km^2 shallow than 2000 m, prospective resource is 36.8 trillion m^3，14 basins with more than 0.5 trillion m^3 , which accounts for 93.4% of the total resources.

Characteristic of China's CBM resources：

- Variety of coal forming conditions
- Multi-period of coal forming periods
- Stacking of metamorphism
- Multi-period and complexity of tectonic movement

Don't copy American mature CBM technology

2.1 Current Status on China's CBM Exploration & Development

- By the end of 2014, 15000 CBM wells has been drilled in China with the proved reserves of 600 billion m^3 .
- Forming 2 large gas fields(Eastern Ordos Basin and Southern Qinshui Basin) with hundreds billion m^3 .
- Implementation of coal mining project mad production of coal mine more safe.

2.1 Current Status on China's CBM Exploration & Development

- **CBM transportation pipeline was completed and taken shape, transportation capacity increased greatly.**
  - **Completing five CBM pipelines with the annual transportation capacity 10 billion m^3, the length of pipeline is about 2000 km.**
  - **Planning and constructing "three vertical and eleven horizontal pipelines" in Shanxi province, which will exceed 3000km.**
- **Wide application of CBM**
  - **City gas, fuel for car and industry .**

2.1 Current Status on China's CBM Exploration & Development

CBM Exploration from shallow area to the deeper area

- **Deeper area designated：800-1000m**
- **Characteristic of geologic reservoir in the deeper coal seams：stress is higher，permeability is greatly reduced，which led to fragile coal structure. The complicated drilling and fracturing and long-period production made CBM exploration in the deeper coal seams more challenging.**
- **Obtained good gas production for single well in some of deeper areas:**
  - **Qinshui Basin: coal seam depth is 900~1400 m, daily production reached 2500 m^3**
  - **Ordos Basin: coal seam depth is 1500~2000 m, daily production reached 3600 m^3**

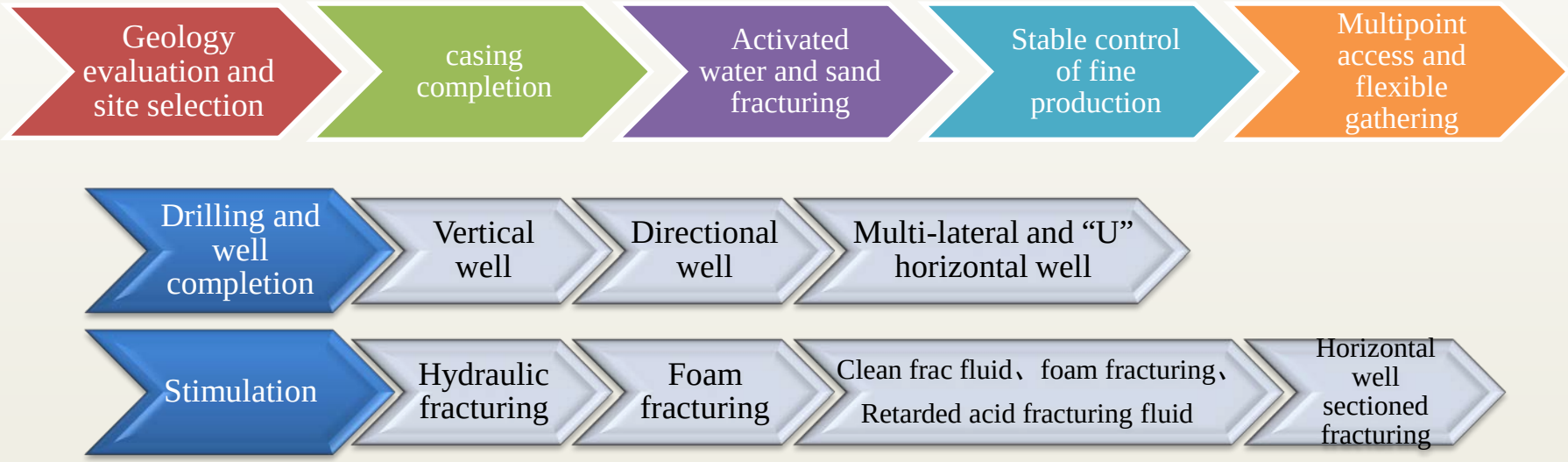
2.1 Current Status on China's CBM Exploration &Development

Achievements in new areas、new fields、new series of strata

- In Southern Zhungeer Basin in northwest of China，daily production of horizontal well for pilot test reached 17 thousand m^3 .
- In Fuxin block in northeast of China, 26 wells were drilled, daily production was about 60 thousand m^3；four wells in Hunchun, steady production for single well is 1500-2200 m^3；six wells in Yilan, produced three years and steady production was 1000-1200m^3 .
- Zhijin and Junlian area, in southwest of China, gas production for single well reached1000m^3 .

2.2 Technology Progress of China's CBM Exploration & Developmen

A relatively mature CBM exploration and development technology has been formed which is suitable for high-rank coal in Southern Qinshui Basin, this technology provides strong technical support for China's CBM development.



~ 17 ~

2.2 Technology Progress of China's CBM Exploration &Development

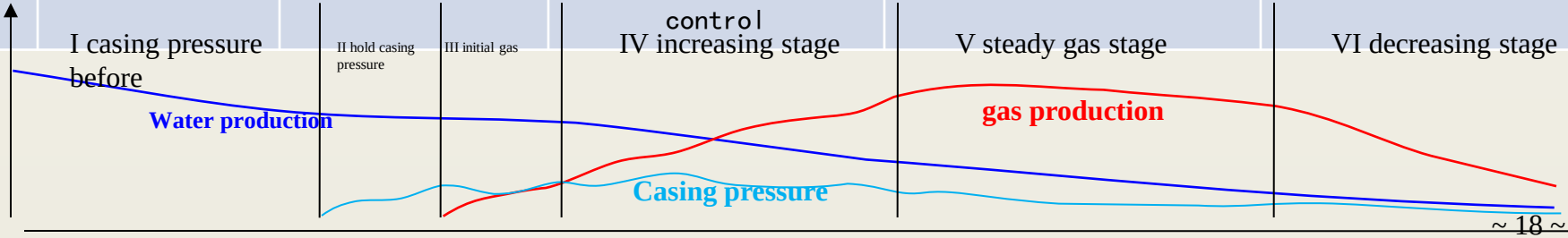
Summarizing production technology series suitable for China's CBM

- double control, regional depression gradually
- "five stages, three pressures" production control
- Stable control of fine production

purpose

- To protect reservoir
- To furthest expand depression area
- To furthest release production capacity

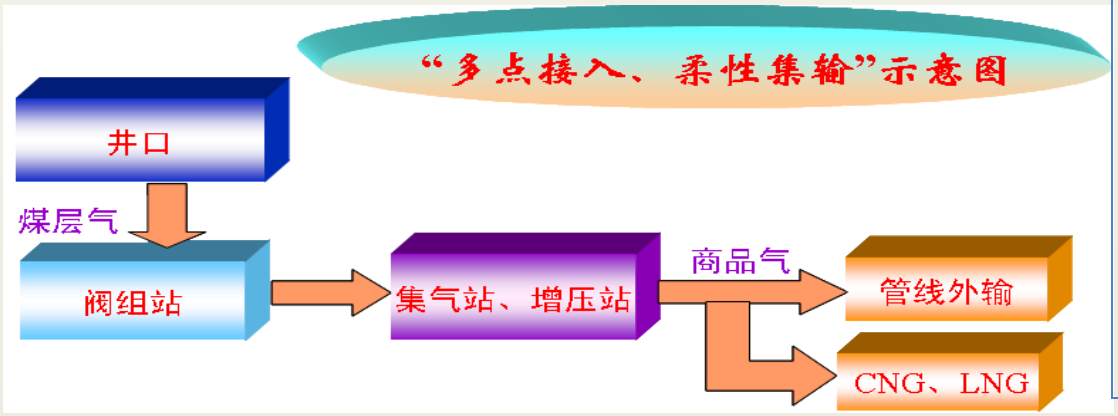
status	casing pressure before	Initial gas	Gas increasing	Steady production	Gas decreasing
target	**Set fluid capacity,** pressure funnel is gentle, expand pressure and drop area	**Hold casing pressure,** Control gas velocity, more powders stuck pump, keep formation energy	**Production phase by phase,** avoid gas and fluid increase rapidly, and then strata stress changes greatly. Keep steady gas supply through pressure and powder control	**Sustainably steady gas production**	**Gas decreased gradually**

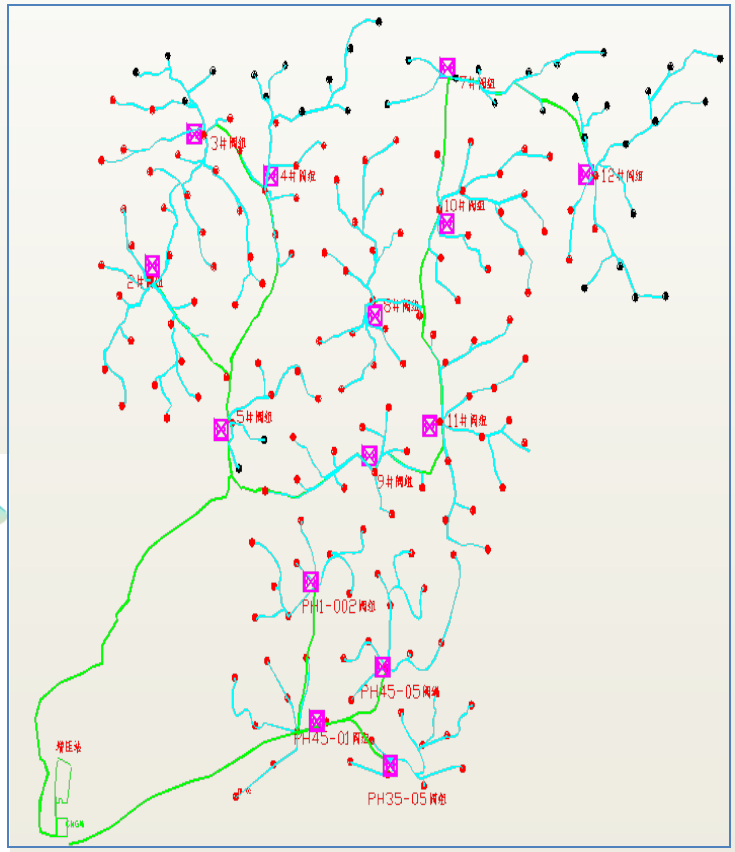


2.2 Technology Progress of China's CBM Exploration &Development

Forming gathering & transportation technical series of "multipoint access、flexible gathering" as core technology, suitable for complicated topographical condition of low production and more wells

"multipoint access、flexible gathering" realized technical breakthrough from three- staged arrangement traditionally to one-stage arrangement which greatly increases gathering radius, effectively reduces stages and then greatly reduces investment and easier to be managed.

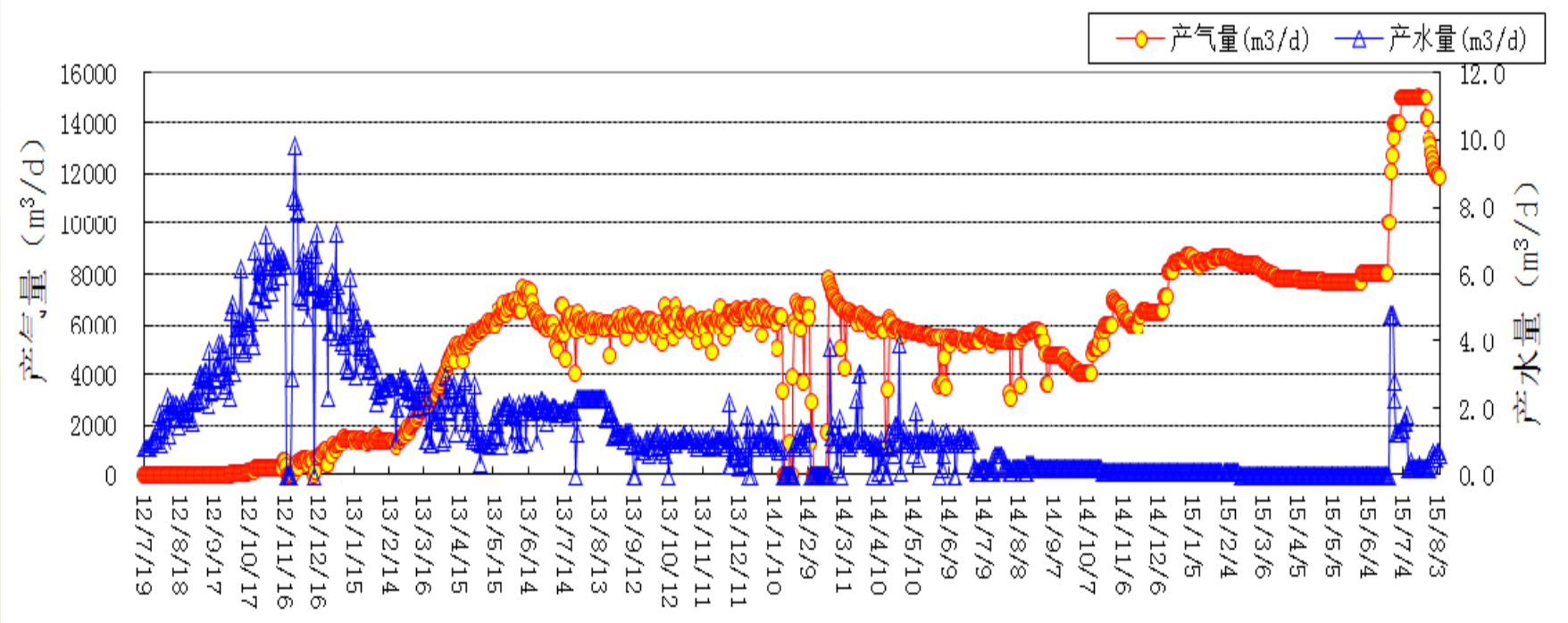




2.2 Technology Progress of China's CBM Exploration &Development

New technologies were tested successfully

Staged fracturing in "U" horizontal well



Well depth is 590 m，well thickness is 6.5 m，drilling footage is 617 m，fracture 7 sections

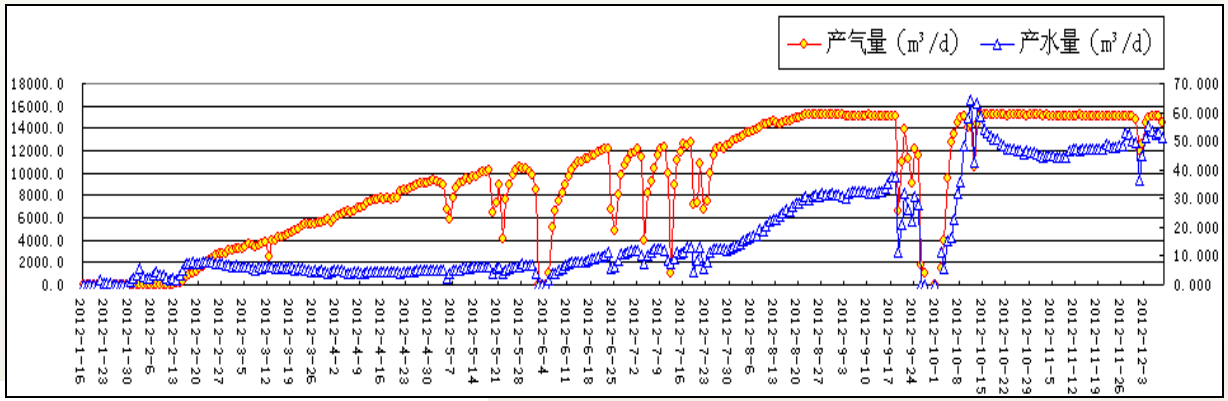
Daily steady gas production is 15000 m^3/d，casing pressure is still kept in 0.23MPa

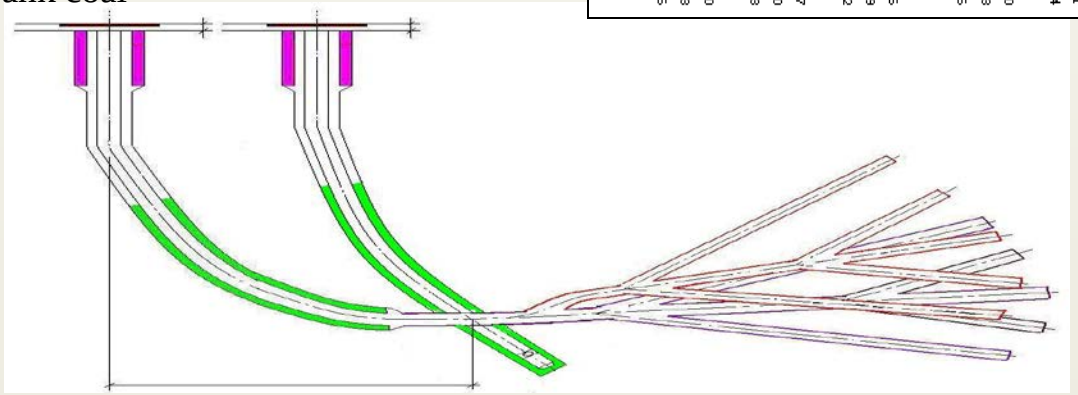
2.2 Technology Progress of China's CBM Exploration &Development

New technologies were tested successfully

Double-bench horizontal well was successfully for commingled production of thin seam and multi-seams

- First case in the world: multilateral horizontal well with inclined well connected to multi seams
- Design on production well of inclined to inclined and multi seams and equipment design
- Set up a new national record in gas production for single well in middle-rank coal



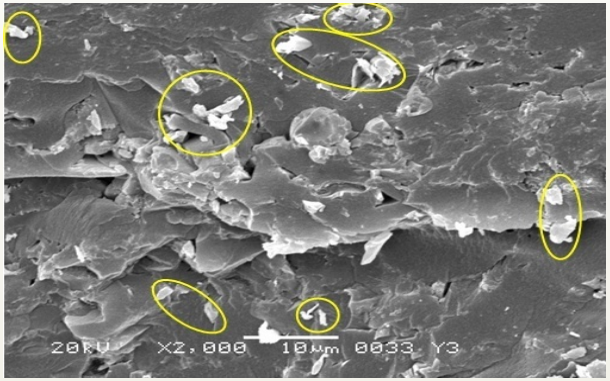


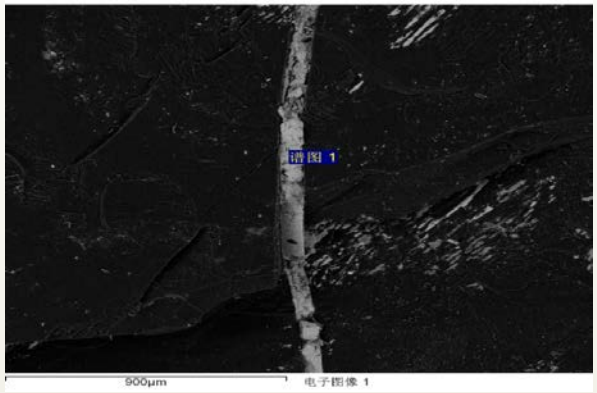
Daily gas production was kept in 15000m^3 or so.

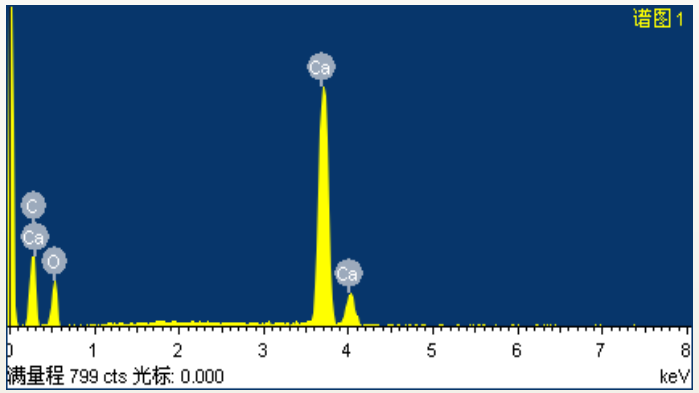
2.2 Technology Progress on China's CBM Exploration& Developmen

New technologies were tested successfully

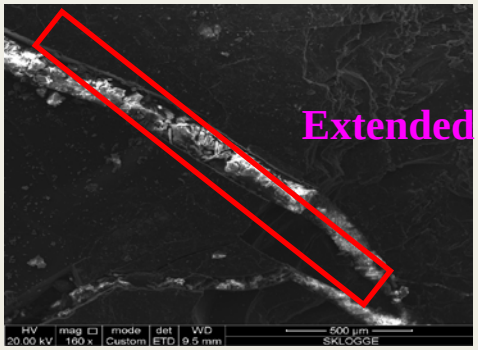
Latent acid（retarded acid）was applied in CBM fracturing，which improved matrix condition

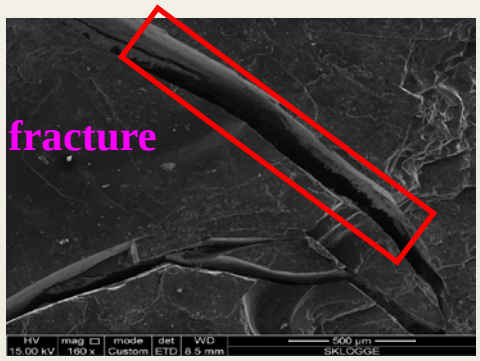


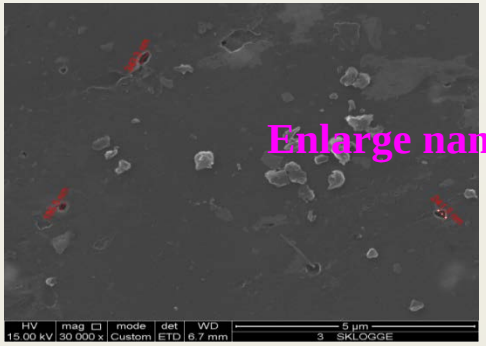


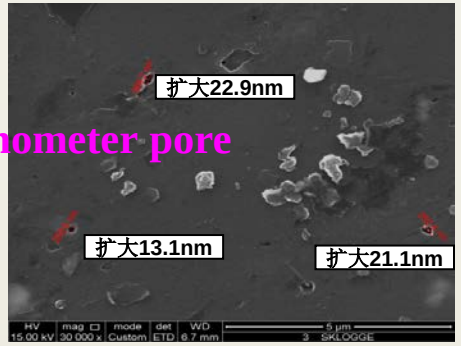


A lot of calcites in coal fracture in Qinnan area，a few of calcites and plasters in pores









矿物溶蚀前后扫描电镜对比

2.2 Technology Progress on China's CBM Exploration &Developmen

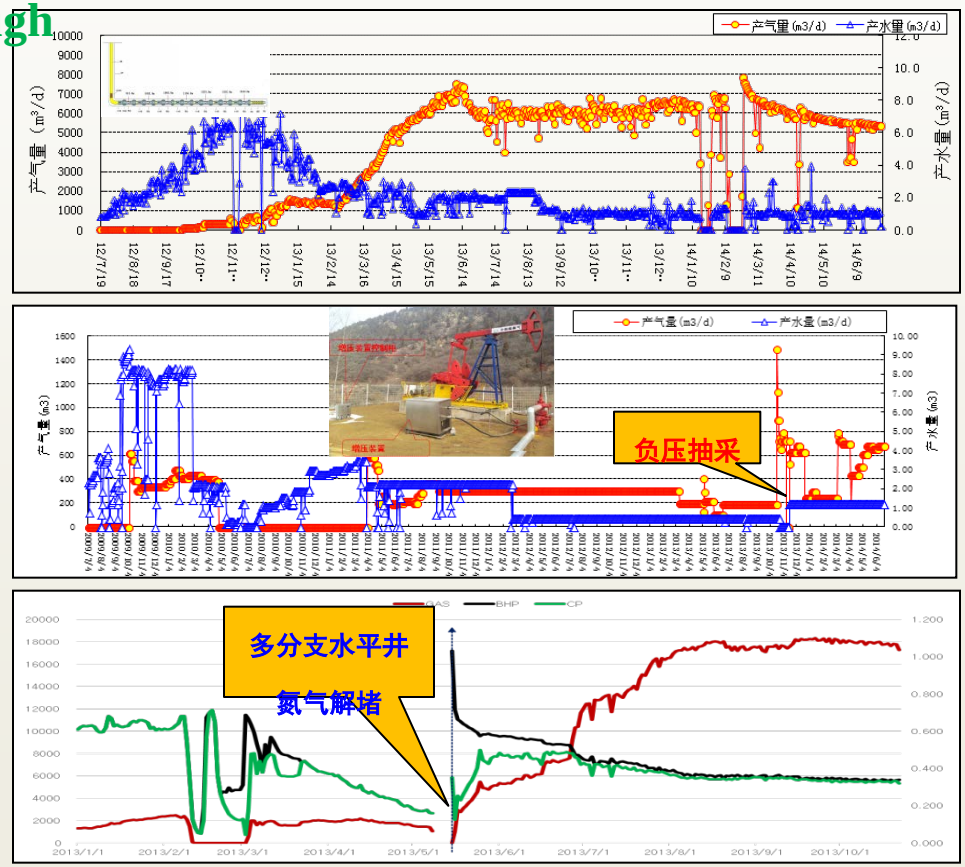
New Technologies were tested successfully

CBM stimulation technology got breakthrough

1、research and test on increasing flow area：

- **Optimizing Horizontal well completion and fracturing section by section**
- **Horizontal well flushing with N_2**
- **Redrilling, recycling and carrying out coal powder**

2、extracting under-pressure：improving single well production through pressure increase or pipeline boost and then reduce flow pressure of well bottom.

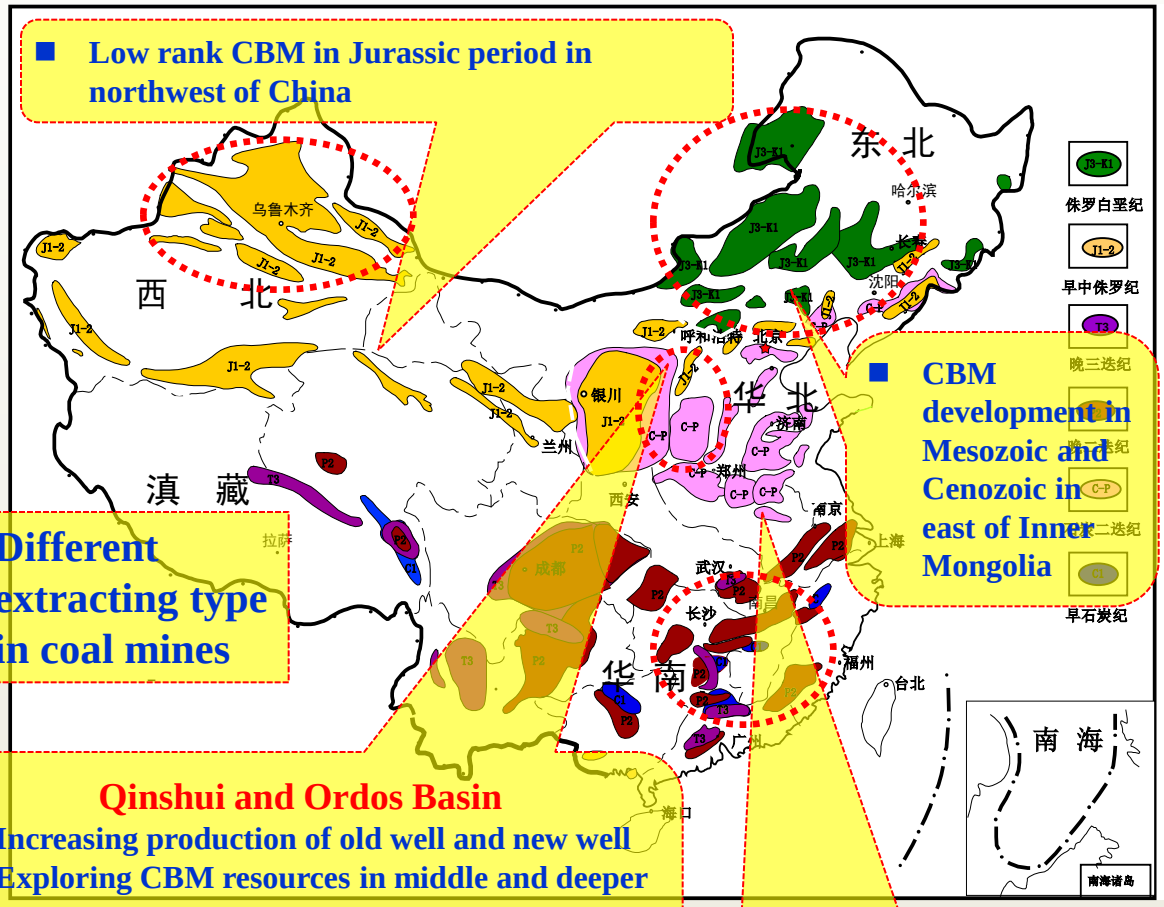


Technology bottleneck still exists

Outline

1. CBM Exploration & Development Progress from CUCBM
2. Current Status on China's CBM Exploration & Development
3. Technology Trend of China's CBM Exploration & Development
4. Question and suggestion

3. Technology Trend of China's CBM Exploration &Development



- Low rank CBM in Jurassic period in northwest of China
- CBM development in Mesozoic and Cenozoic in east of Inner Mongolia
- Different extracting type in coal mines

Qinshui and Ordos Basin

- Increasing production of old well and new well
- Exploring CBM resources in middle and deeper areas
- Comprehensive development of multi gas in coal bearing series

- Multi-seams, high stress in east of Yunnan and

◆ **The key breakthrough：**

Increasing gas production and reserves in Qinshui Basin and Ordos Basin

◆ **Multi-point blossom：**

Extend and explore resources in new areas or new coal-bearing basinsloe

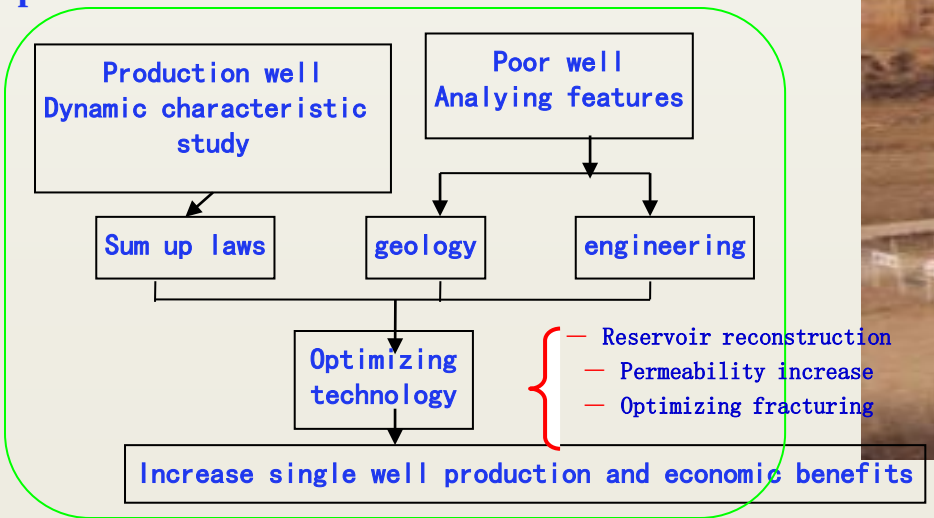
◆ **Development concept：**

- Combination of demonstration in different phases
- Combination of surface development and extracting underground
- both of main resources and replacement resources

3.1 Stimulation technology in Qinshui Basin and Ordos Basin

CBM industrialized bases of Qinshui basin and Ordos basin

- Big gap between the proved reserves and annual gas production
- Gas yield is different in different blocks
- More wells with poor production，slow production increasing
- Basic research is not further
- Development is more complicated with the deeper coal seam



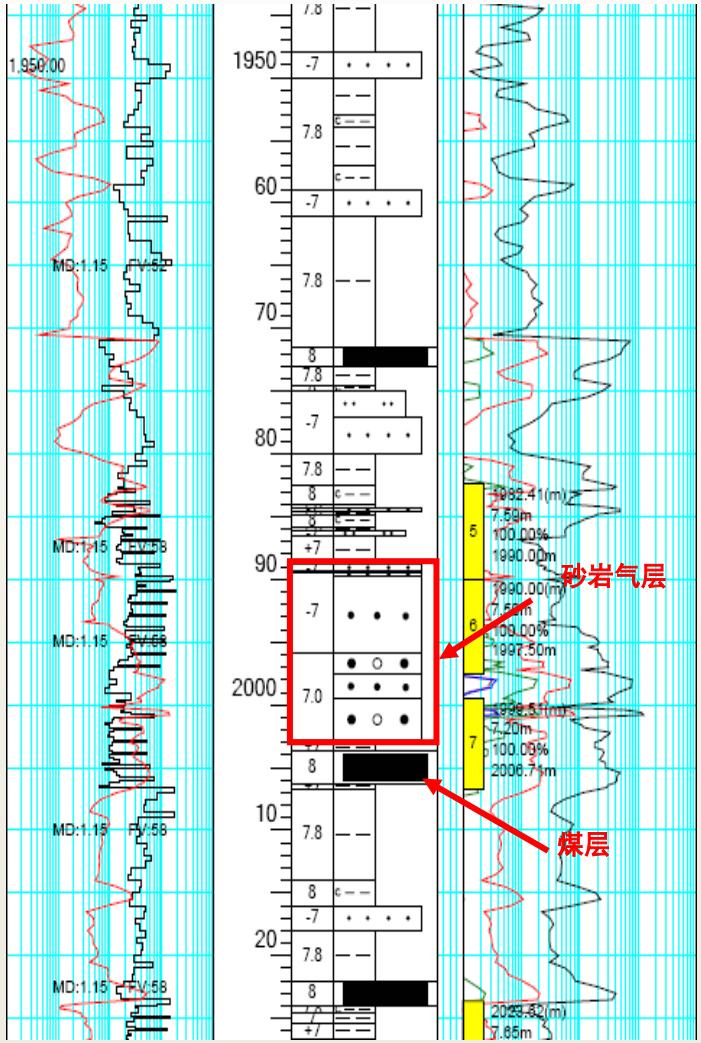
3.2 Comprehensive Exploration & Development Technology on Commingled production of CBM and Tight Sands Gas in Coal-bearing Series

- Abundant resources of CBM and Tight sands gas in coal-bearing series and huge potentiality.
- Longitudinal seam overlays with layers of tight sandstone and continuous accumulation , suitable for commingle.
- Technology core： promote CBM desorption through disturbing underground pressure system by high pressure to adjacent tight gas, reducing development difficulty and cost , extending time of steady production and improving benefits.

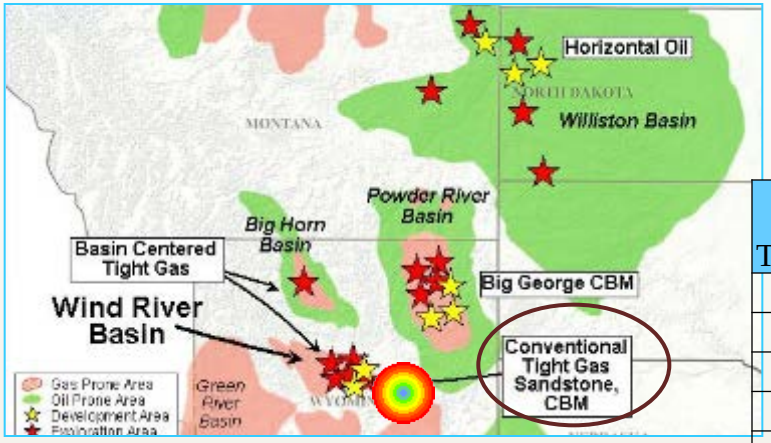
a) Reservoir composition type of CBM/TGS and fluid mechanism between layers

b) Destroying each other by engineering

c) Reservoir stimulation control and production technique.



3.2 Comprehensive Exploration & Development Technology on Commingled production of CBM and Tight Sands Gas in Coal-bearing Series



3 formations between 1000 and 2000 m in Powder River Basin of America，formation interval is 100 m，separately fracturing and commingled production on CBM layer and sandstone layer. Daily gas production for single well in 20 vertical wells reached tens of thousands m^3，the peak is

Top hole depth（m）	Bottom hole depth（m）	Perforating density（hole/m）	Perforation diameter（cm）
879.04	879.95	3.28	0.96
884.83	885.14	3.28	0.96
890.01	890.32	3.28	0.96
903.12	903.42	3.28	0.96
934.21	937.87	3.28	0.96
939.69	940	3.28	0.96

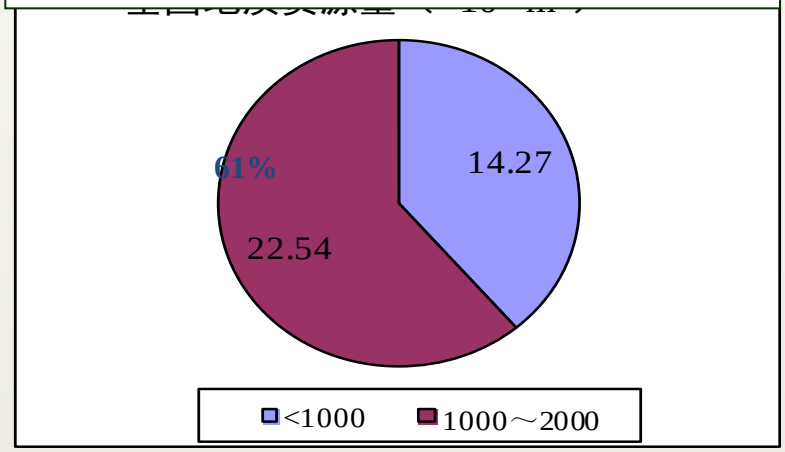
Commingled production on CBM and low permeability sandstone gas in White River Uplift of Piceance Basin. Target seam depth is 1560~2560m，daily production of single well in 65 wells was steadily kept in 10890m^3 or so，the peak is 14375m^3，production formation is Cameo and sandstone layer.

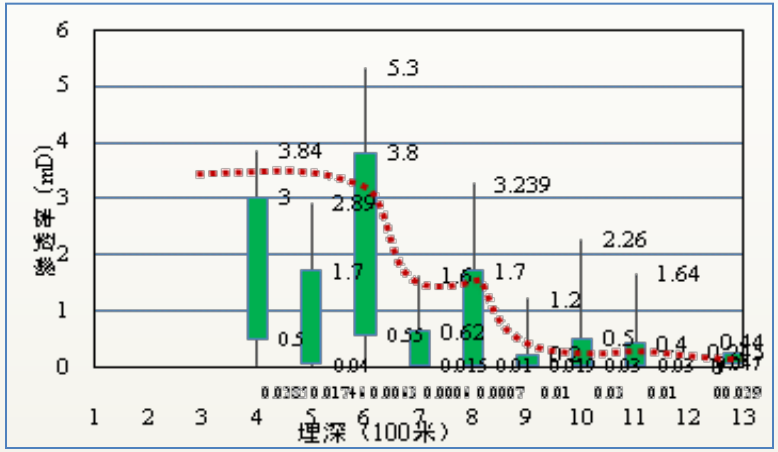
26 CBM wells has been put into production in Fuxin coal mine of Liaoning since 2006, among of which 11 wells for commingled production. High production , stable production. Intermittent blow happened in some of wells

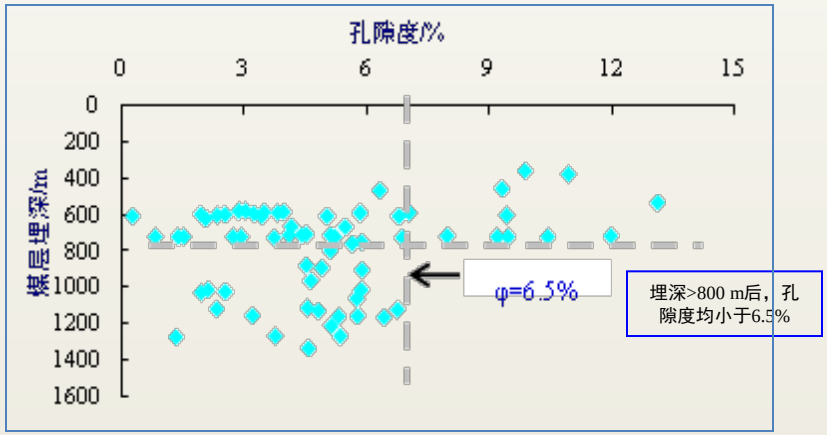
产层类型	投产井数口	开井口	生产层位	射孔平均厚度 m 煤层	射孔平均厚度 m 砂层	起压时间 d 最短	起压时间 d 最长	起压时间 d 平均	平均单井日产气量 m^3
煤层	17	16	阜新组	42.79	0	1	121	31	1335
煤层与相邻砂层	11	10	阜新组	39.33	15.45	0	44	10	2051

3.3 CBM Reservoir Physical Property in the Deeper area and Key Development Technology

- Rich resources in the deeper area with huge potentiality
- In the recent two years, exploration and development is from shallow than 800 m to deeper than 1000 m





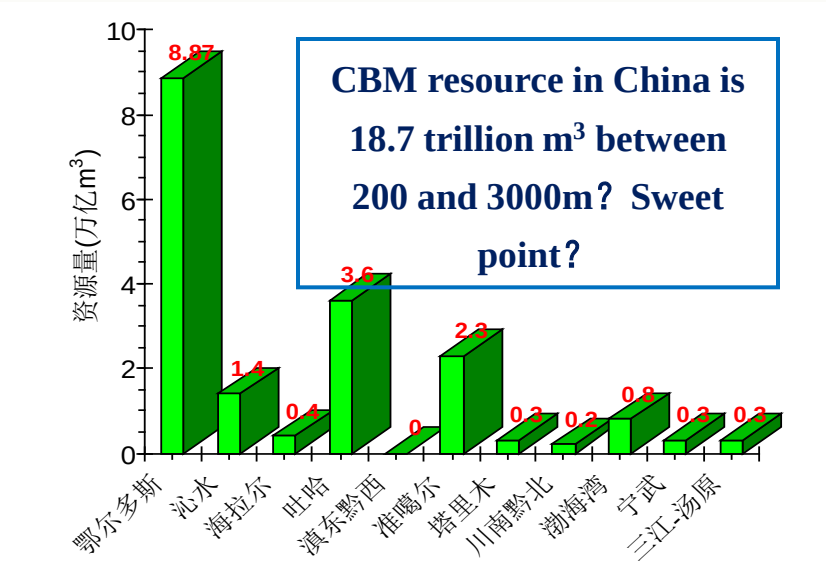


CBM reservoir physical property changes by index with the increase of buried depth, and then development is more difficult.

3.3 CBM Reservoir Physical Property in the Deeper area and Key Development Technology

The adaptive traditional technology

- The effectiveness of fracturing technology
- The effectiveness of displacement technology
- The effectiveness of depressure technology
- The effectiveness of damage reduction on reservoir



Feasibility of new technology in the deeper area

- Permeability increase：fracture created、connection、block remover
- Desorption promotion：reaction of chemistry and physics（gas-water-organic matter-mineral）
- Depressure technology：vertical stress
- Damage reduction on reservoir：formation fluid-coal-artificial fluid

3.3 CBM Reservoir Physical Property in the Deeper area and Key Development Technology

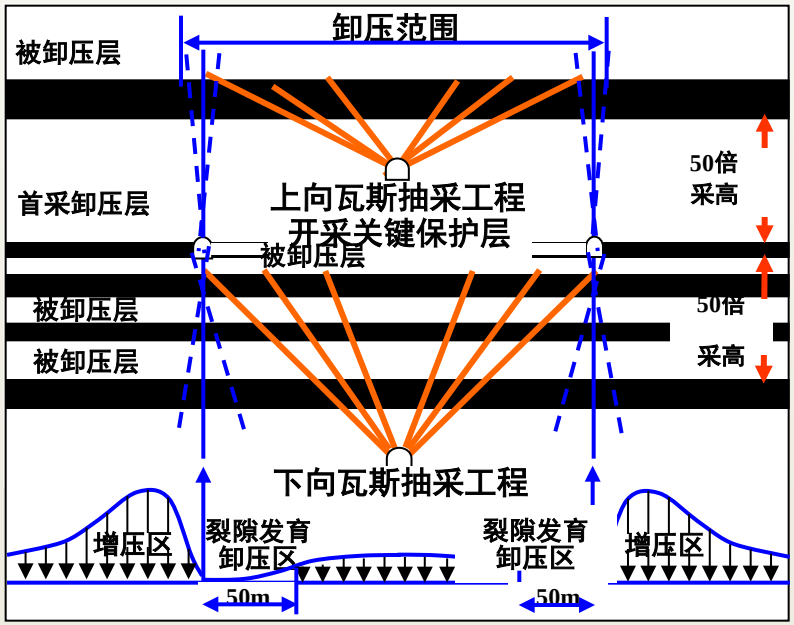
Advantages：

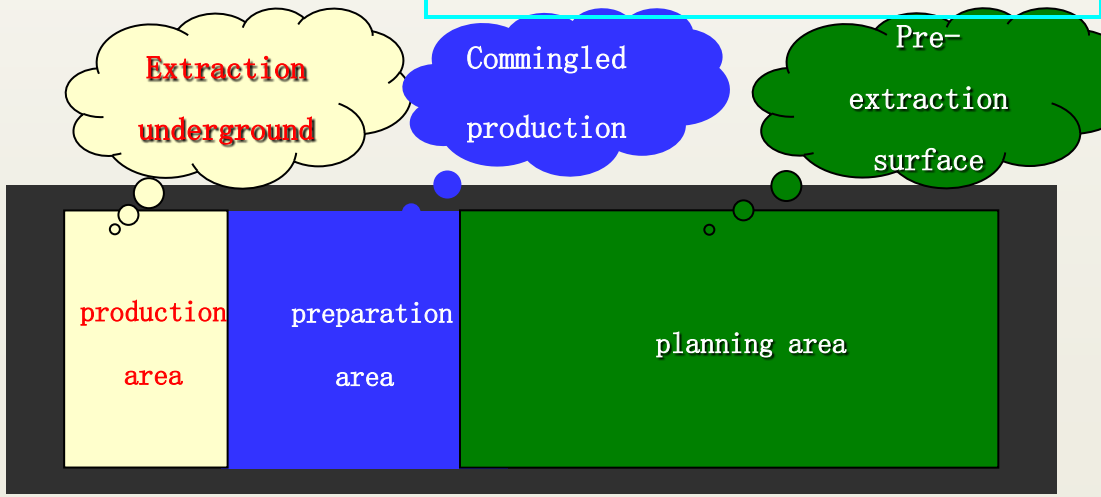
- Stress release in coal mines is helpful to desorption and migration of CBM，declining the difficulty of development
- Coal mining area is about 0.2 million km²

Disadvantages：

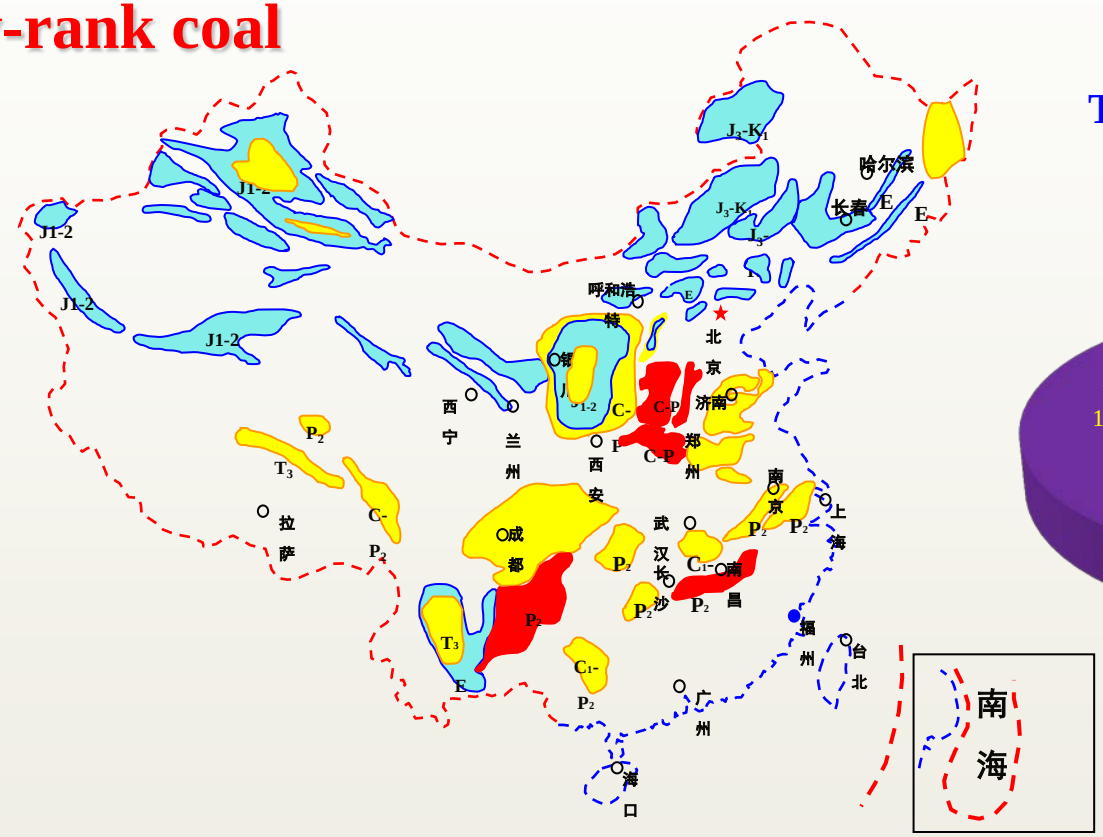
- Coordination of CBM development and coal exploitation

- Prediction technology on stress of depressure area
  Pore-forming of horizontal well and reservoir protection
- Coal powder prevented

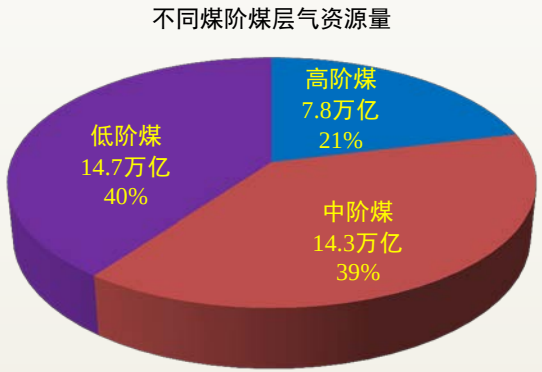




3.4 CBM Exploration & Development Technology Suitable for low-rank coal



Three ranks of coal



- Gas production in America mainly from low-rank coal
- Low-rank coal in China has development potentiality from achievement of recent years

Outline

1. CBM Exploration & Development Progress from CUCBM
2. Current Status on China's CBM Exploration & Development
3. Technology Trend of China's CBM Exploration & Development
4. Question and suggestion

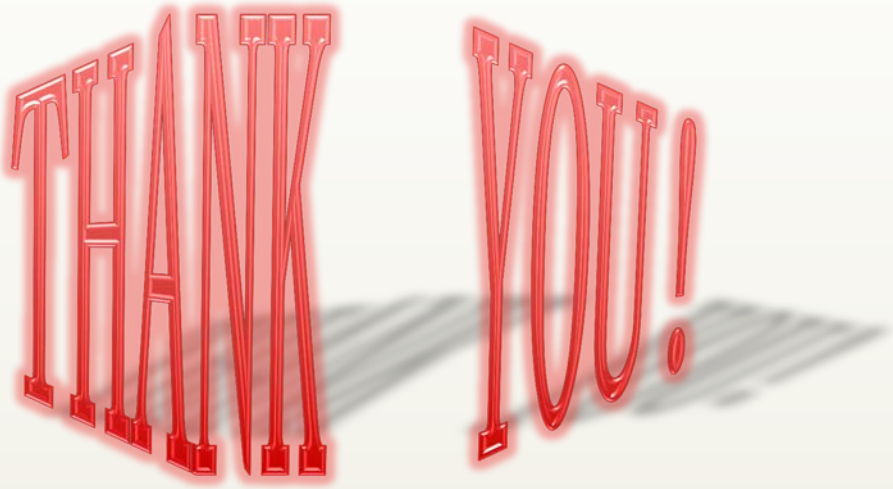
4. Question and Suggestion

Question

- China's CBM development is still in the initial stage of scaled development， the complicated geologic condition decides the variety of CBM technology, which makes us not follow the American mature technology.
- The proven reserves rate OF China is too low, 1.5%
- CBM investment in the first stage is too great ,long recovery period , which needs more support from Chinese government

Suggestion

- Chinese government should increase exploration and provide more support for test, and to improve proved resources rate.
- Set up different demonstration projects for leading R&D of new technology and production and promote the rapid progress of CBM industry.


THANK YOU!