

Main Technologies for CBM Exploration and Development in China

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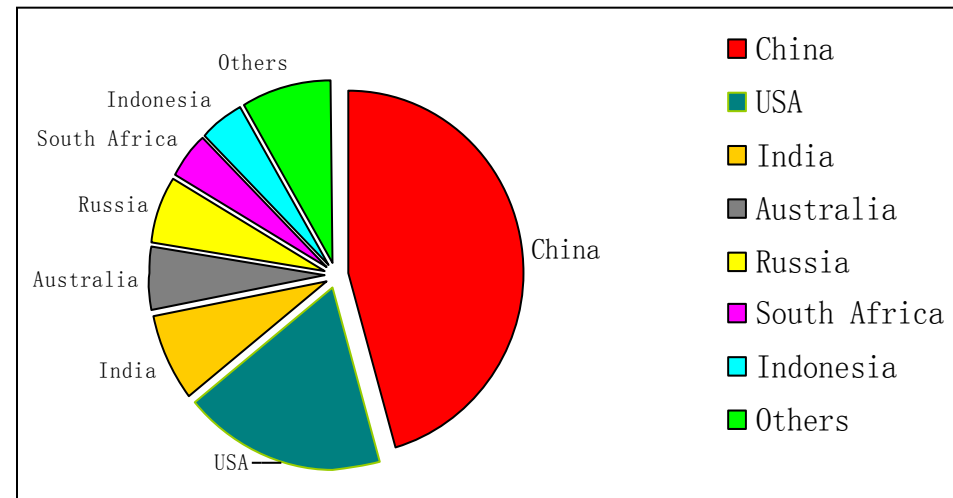
China is the biggest coal produce and consumption country, and discharges huge amount Coalmine methane per year.

- Coal resource which depth is less than 2000 meter is about 5.57 trillion tons, 3.24 billion tons coal was produced in 2010.
- High Gassy Mine account for about 48% in China, hundreds of people was killed by gas accidents per year (593 people died in gas explosion in 2010).
- Coalmine methane discharge amount exceed 10 BCM per year, affecting the environment seriously.

Distribution of China's Coal Resource



Coal output of world main country in 2008



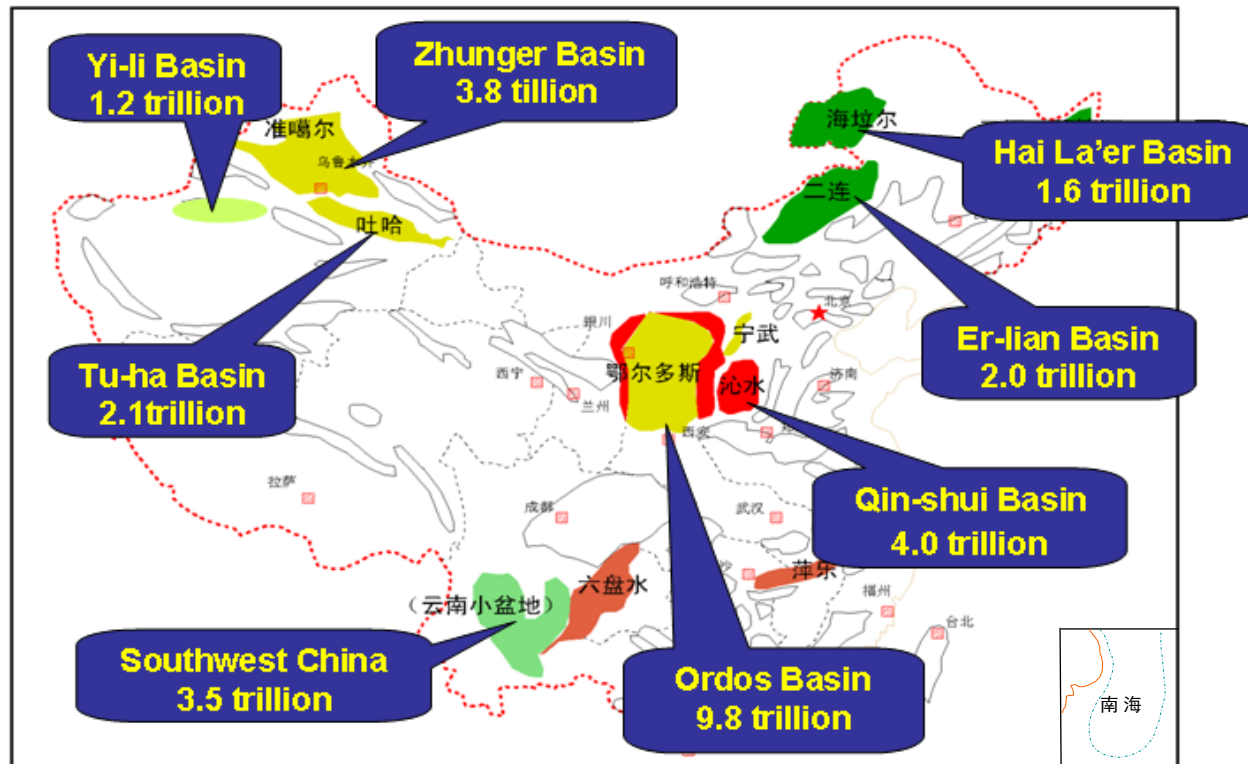
Yearly Coal output in China (billion ton)

year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
production	1.106	1.393	1.736	1.956	2.18	2.331	2.55	2.716	2.92	3.24

OUTLINE

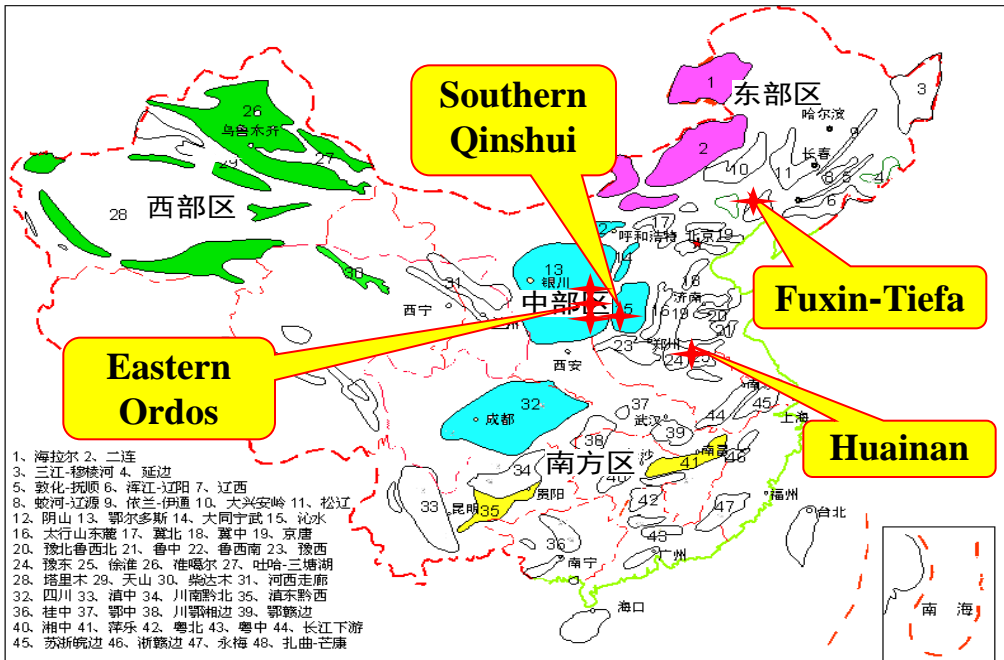
- ◆ **CBM Resources in China**
- ◆ **Geological character of CBM in China**
- ◆ **Specific technologies for CBM E&D in China**
- ◆ **Some Technical Challenges**

- ◆ The resources quantity which depth is less than 2000m come to more than 36.8TCM (TCM=trillion cubic meter).



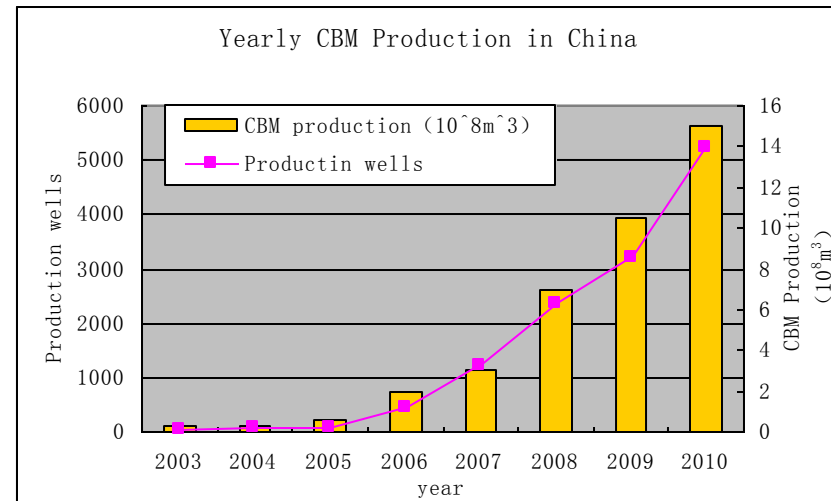
Resources distribution of CBM in China

Main CBM Development Areas in China



◆ At the end of 2010, the number of CBM production wells was about 5400. The CBM production ability has reached 2.5 BCM (Billion cubic meter)

About 1.5BCM CBM was sold last year in China.



Up to now, Qinshui CBM field' capacity is 2 BCMA.

CBM Development Areas in Qinshui Basin



There are 3750 CBM wells in Qinshui CBM field including 70 multi-lateral horizontal wells, and commercial gas will reach to 1.6 BCM this year.

Fanzhuang surface facilities:

- 7 Gas gathering stations
- 2 Power Stations
- 1 Central Processing facilities (CPF)

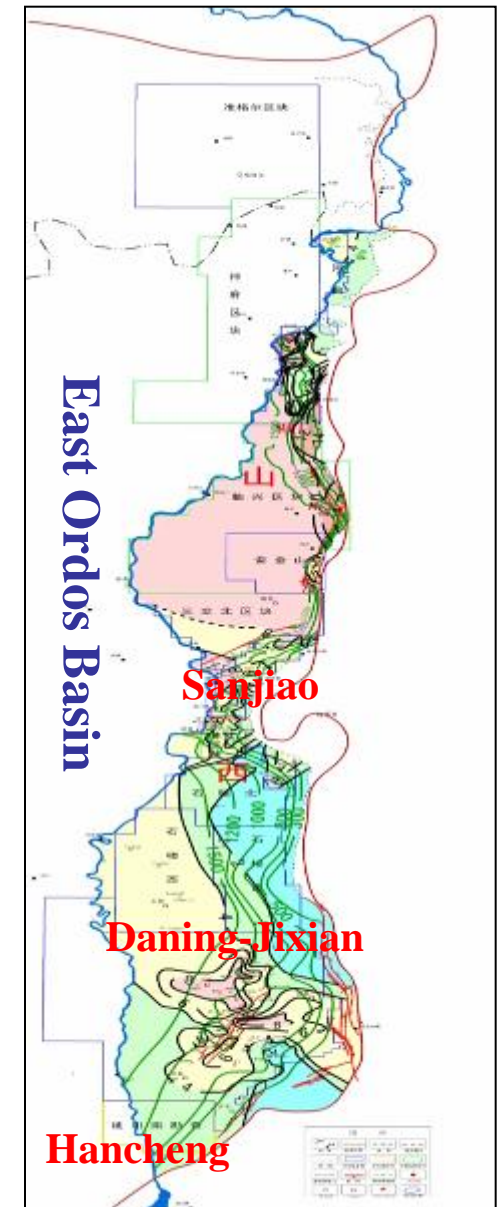
All wells and gas gathering stations are controlled by the Control room in the central processing factory.



This is the first numerical, automatic, remote controlled CBM field in China.

CBM field in Eastern Ordos Basin

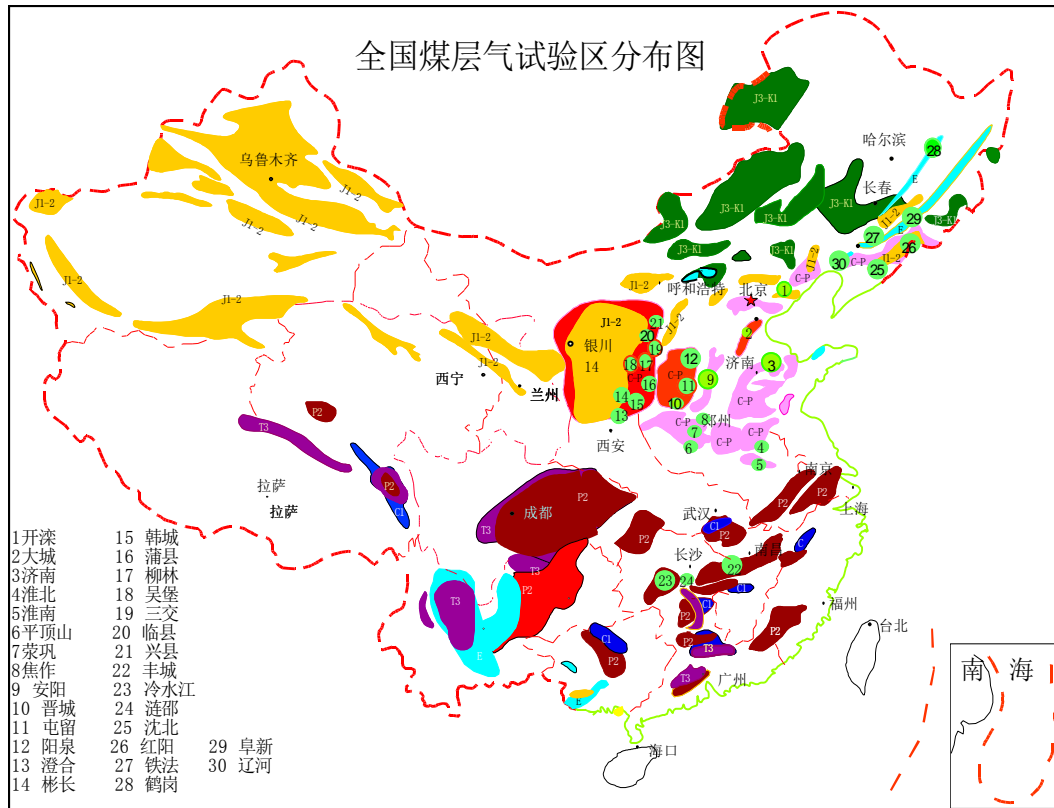
- Total 520 wells (11 multi-lateral horizontal wells) have been drilled in Hancheng, Daning-jixian, Sanjiao regions in eastern Ordos basin.
- The capacity will reach to 0.5 BCM/a at the end of this year.
- 100 wells produce 100,000m³/d now.



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There are 5 coal epoch in china, C-P& J coal resources account for 98.22%.



Period	GIP (BCM)	Ratio (%)
N	15.26	0.04
K	331.86	0.90
J	18543.1	50.34
C、P	17947.96	48.72
Total	36838.1	100.00

CBM Exploration Program in China

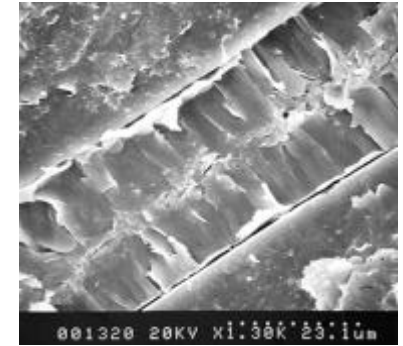
Carbonic-Permian CBM resources distribute in Qinshui Basin, ordos Basin in north China; and Sichuan, Guizhou province in south-west China;

Advantages: mudstone Capping rock, higher gas content, higher gas saturation

Disadvantages: Lower permeability ($<1 \times 10^{-3} \mu\text{m}^2$), more structural coal seams, hard to fracturing

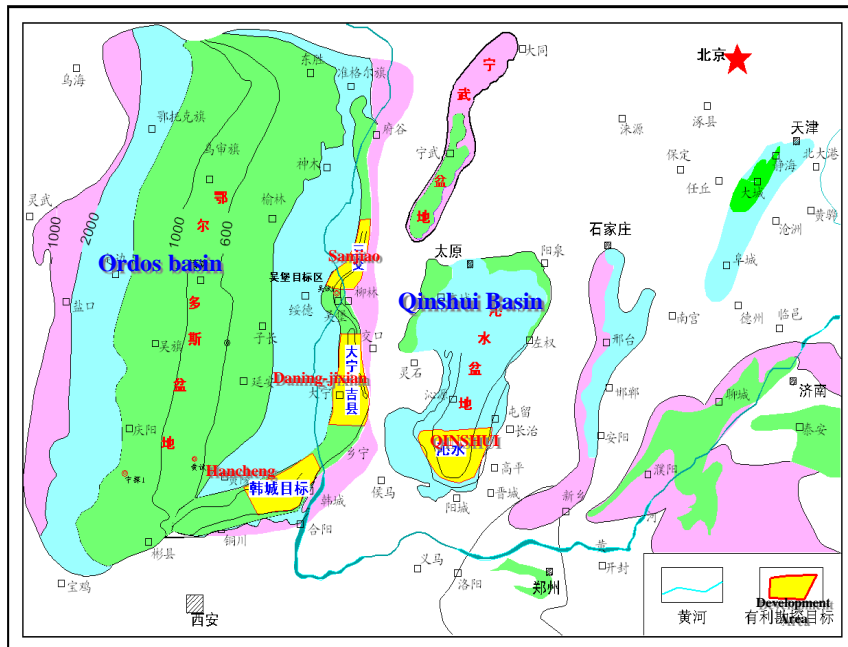


Wrinkled Coal (C_{30} , North China)

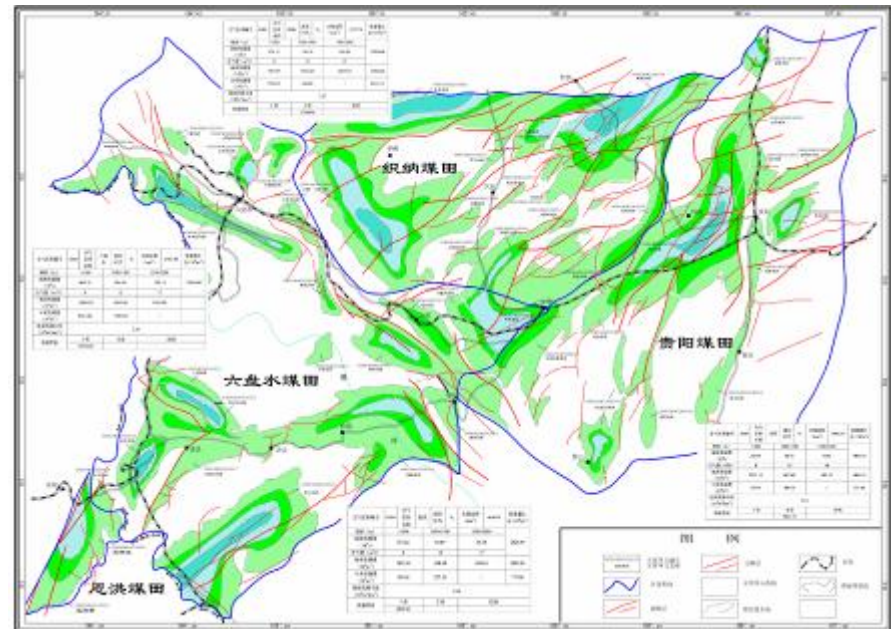


Filled Cleat (P_{2s} , Qinshui Basin)

C-P CBM resources distribution in north China



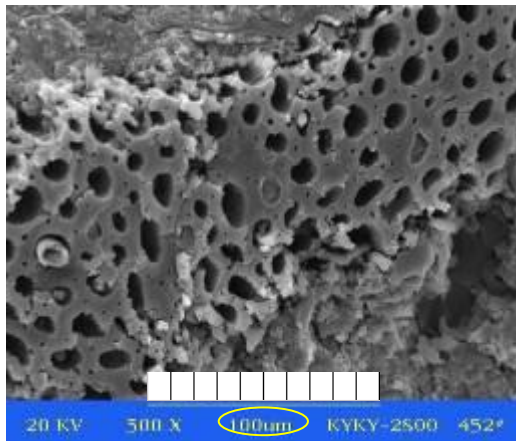
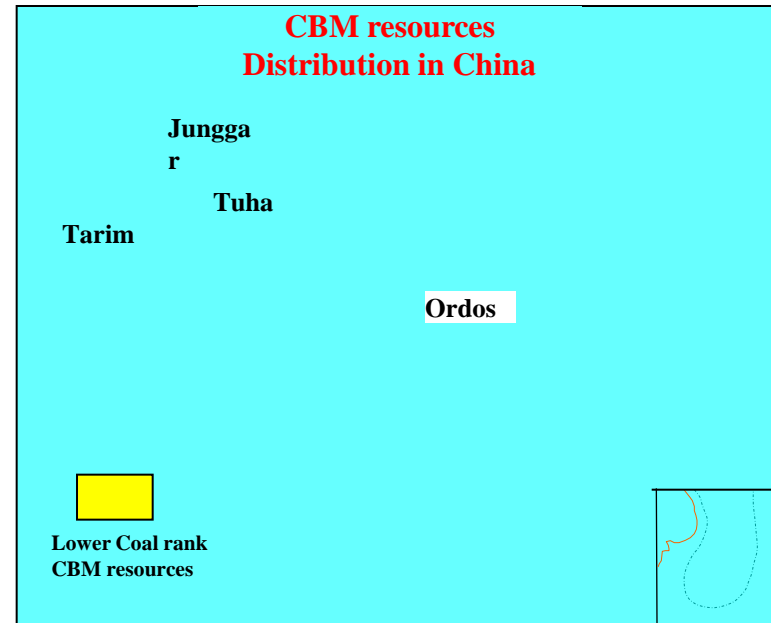
C-P CBM resources distribution in south-west China



Jurassic CBM resources distribute in Ordos basin in north China; Junggar, Tuha basin, Yili basin in north-west China. Most of them are intermountain compressional Basins with complicated structure and too many faults, lack of efficient capping rock;

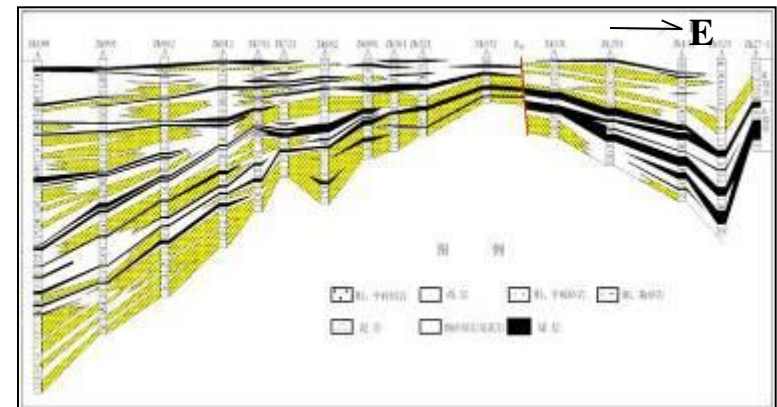
Advantages: Lower coal rank, higher porosity, high permeability

Disadvantages: Lower gas content, Lower gas saturation



High porosity (J₃, Tuha Basin)

Southern zhungaer Basin Jurassic coalseam section



lack of efficient capping rock

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- ◆ **CBM Resources in China**
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- ◆ **Some Technical Challenges**

1. **CBM laboratory technologies**
2. **2D Shallow Seismic**
3. **Well Logging**
4. **Mud logging**
5. **Coal-layer wireline coring technique and tools**
6. **Simulation technique for CBM production history**
7. **Injection/Pressure drawdown test**
8. **Well Drilling technologies**
9. **Hydraulic Fracturing technique for CBM wells**
10. **Diagnosis of artificial fracture**
11. **CBM Well Drainage**
12. **HSE management**

1. CBM laboratory technologies

RIPED- Langfang has built the earliest, most integrate CBM laboratory in China.

● **Experimental program include :**

➤ **Gas Content**

➤ **Adsorption Isotherm Measure**

➤ **Gas Composition**

➤ **Proximate Analysis of coal**

➤ **Ro, Porosity/Permeability test, etc.**

● **All experimental processes strictly follow national standard and trade standard**

● **providing service not only for CNPC, but also for more than 20 domestic and external companies. such as CUCBM, PHILLIPS, BHPB, BP, Arrow (China) ,**



中国石油天然气股份有限公司
PetroChina Company Limited



中联煤层气有限责任公司
China United Coalbed Methane Co., Ltd.



Phillips Petroleum Company
(Before 2000)



BHP BILLITON



BP

1. CBM laboratory technologies



CTDCA-1000 gas content test instrument



FY—VI coalbed gas content fast desorption instrument



IS-100 isotherm adsorption instrument



DC-100 moisture, ash, volatile, fixed carbon analyzer

1. CBM laboratory technologies



elemental Analyzer for the determination of carbon and hydrogen



Sulfur analyzer



electronic scan microscope

(reflectivity test, microscopic components ration)

1. CBM laboratory technologies



**Specific surface-pore
distribution determinator**



mercury porosimeter



HP gas phase chromatograph



rock mechanics testing system

1. CBM laboratory technologies



automatic core flowing instrument

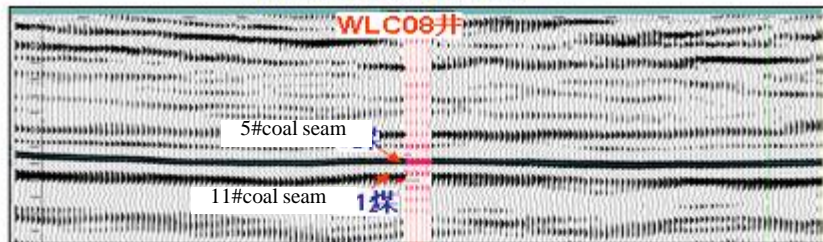


Breakthrough pressure test instrument

2. 2D Shallow Seismic Technologies

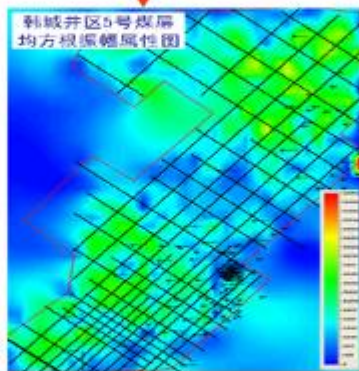
Shallow Seismic used in coal exploration, the costs is only 2/3 of petroleum seismic.

储层井震精细标

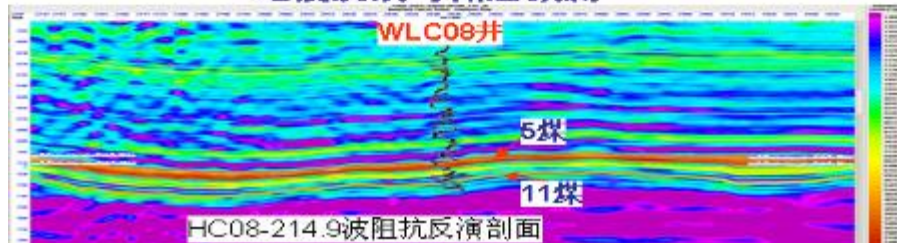


property extraction

地震属性处理与解释



地震反演与储层预测



- Forecasts Favorable Reservoir
- Forecasts high permeability zones
- Optimize well patterns and design wellbore track

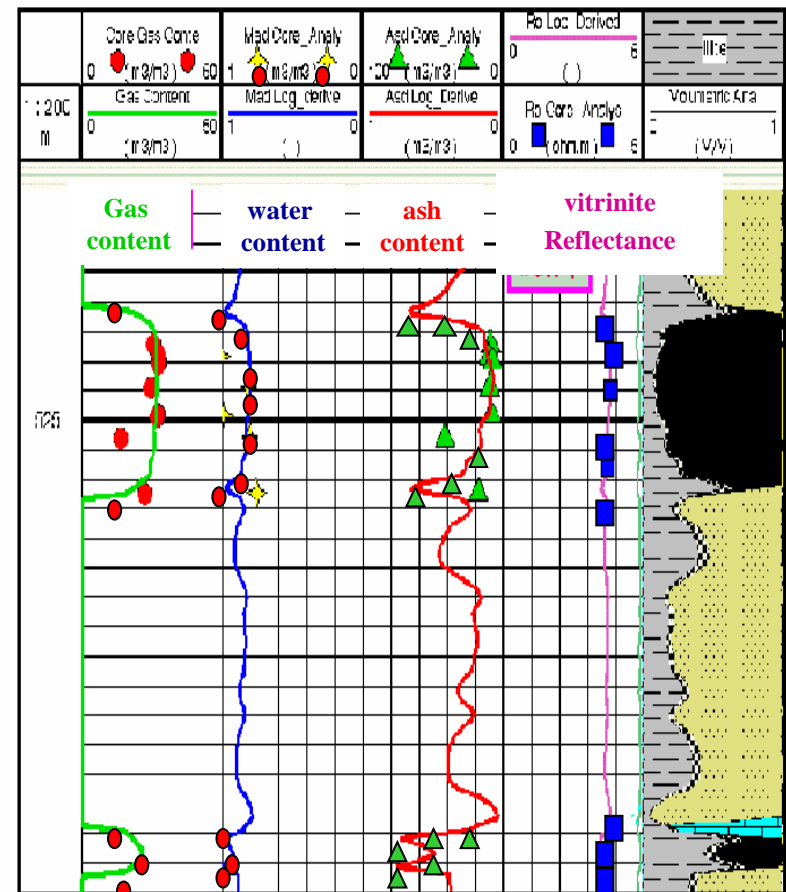
3. CBM Well logging

used for:

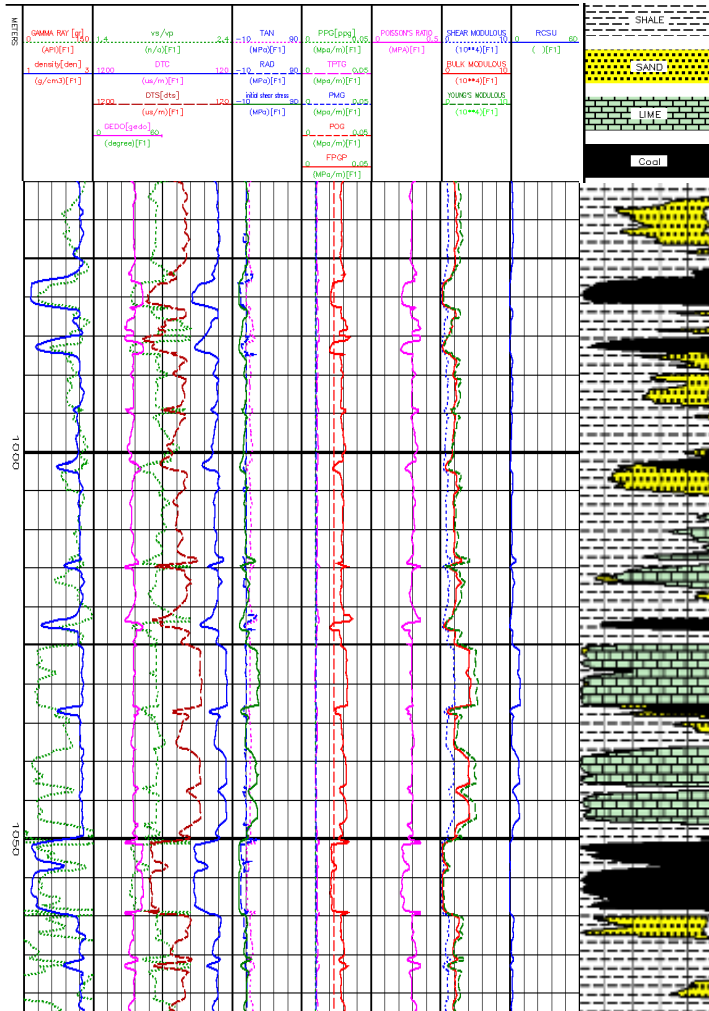
- Identifying the lithology
- Classifying the thickness
- Evaluating the reservoirs property (coal composition, core/fracture)
- Expounding the mechanical property



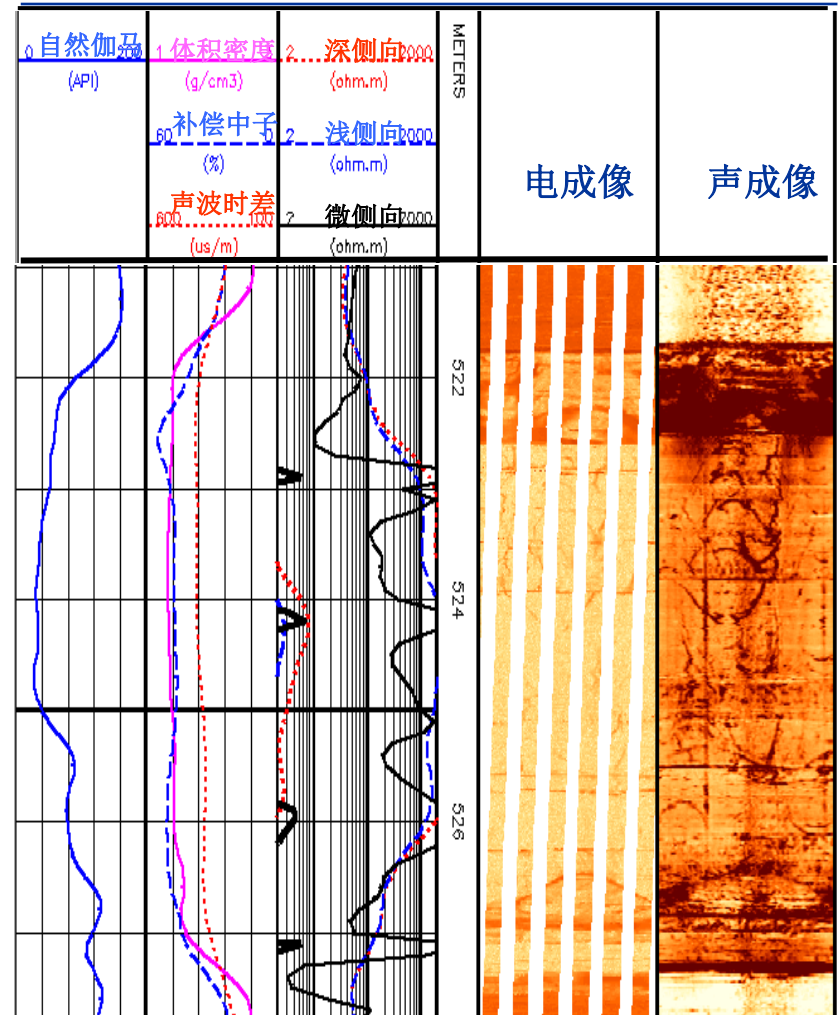
Well Jinshi1 :Results of well logging comparing to the core analysis



Expounding the mechanical property



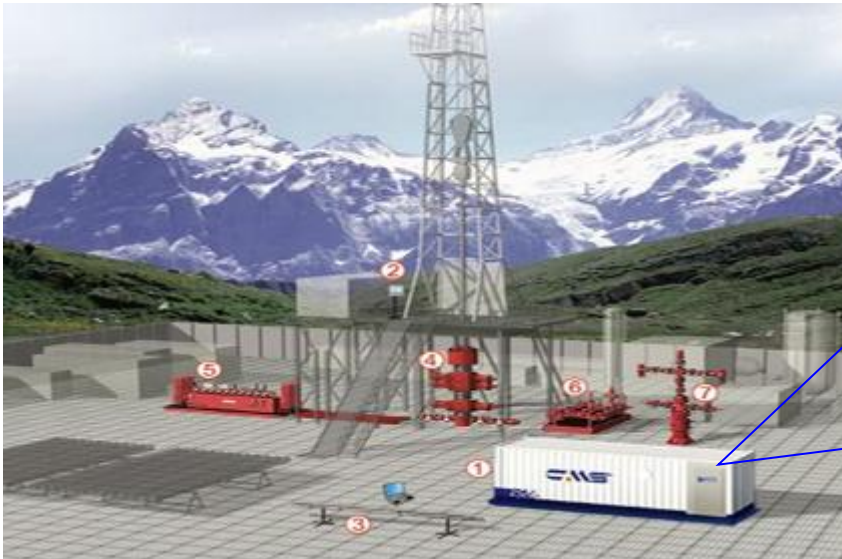
Judging fracture characteristic



4. Mud logging Technologies

Exploration well and horizontal well adopt the compound mud logging.

Comprehensive mud logging devices



- To detect hydrocarbon or non-hydrocarbon rate real-time from drilling fluid
- Discriminate lithology and judge gas-bearing reservoir
- Provide the formation & engineering parameter

4. Mud logging Technologies

Simplified mud logging equipments are often used in production wells.



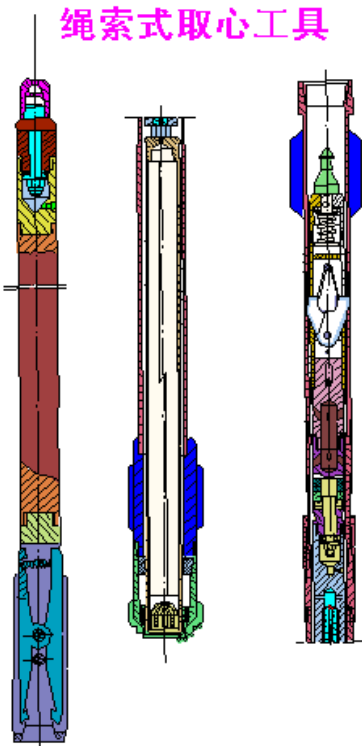
—To collect, monitor and process the drilling data, include the well depth, drilling time, total hydrocarbon, heavy hydrocarbon, etc.

wireline coring tools

绳索取心技术

绳索式取心工具

1. 中扶正器
2. 打捞矛头
3. 弹卡室
4. 弹卡
5. 收卡管
6. 悬挂环
7. 分水接头
8. 单动机构
9. 内外八方套
10. 内管上接头



11. 外管
12. 内管
13. 下扶正器
14. 扶正环
15. 钻头
16. 全封闭式拦卡簧
17. 钢丝绳
18. 绳卡销套接头
19. 加重杆
20. 打捞钩

Comparison of CBM wireline coring indices

Coring time	
min/1000m	8-10
Core recovery	
(%)	80-100

Compared with conventional coring technology, its advantage:

- fast coring, high core recovery and slight gas leak out
- calculating gas content & saturation accurately

We have COMET-3D, F.A.S.T-CBM, ECLIPS and another simulation software developed by ourselves.

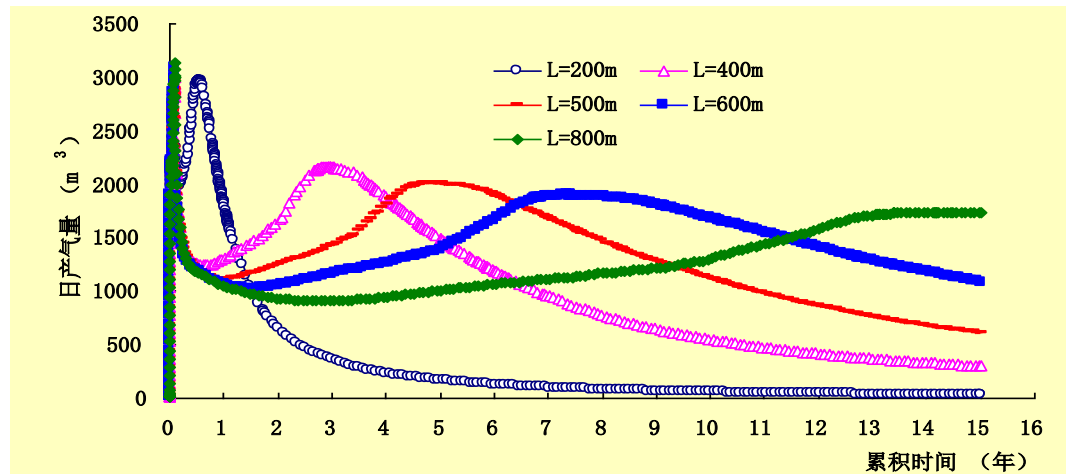
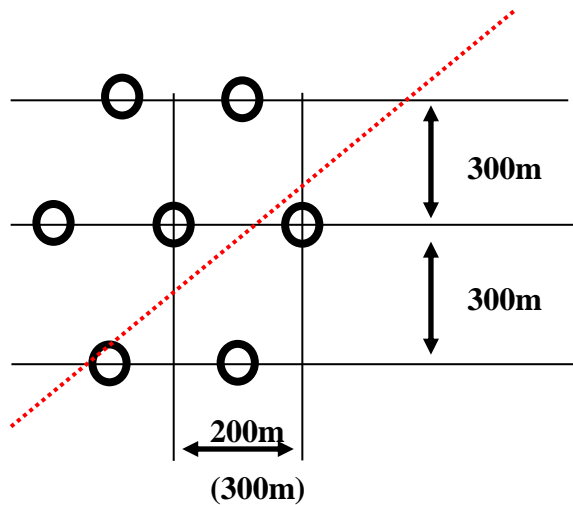
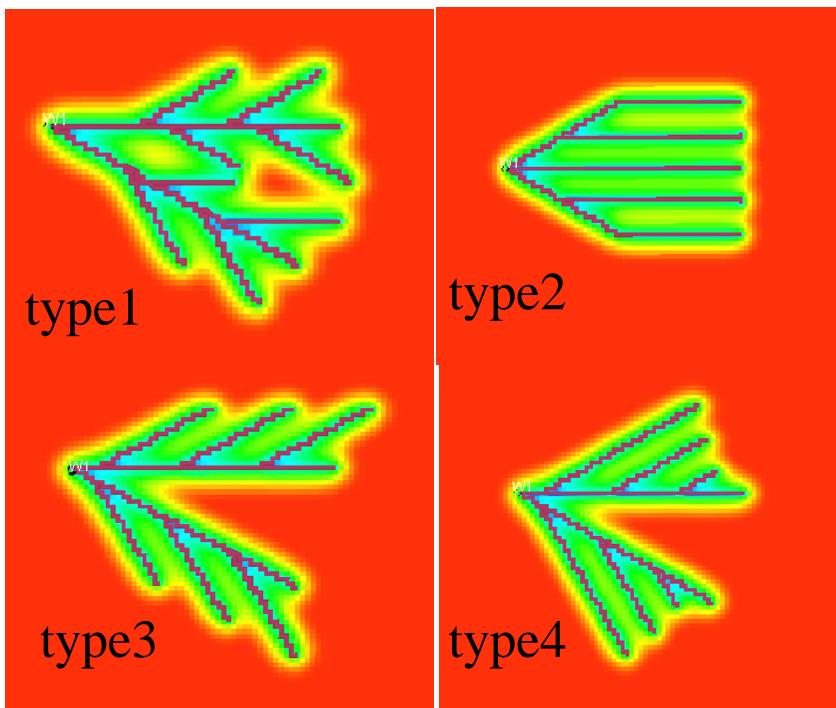


图3-15 晋试1井不同单井控制面积日产气量对比曲线
($k=7 \times 10^{-3} \mu\text{m}^2$ $L_f=25\text{m}$)

Production history can be simulated, so as to determine reasonable well spacing and geometric configuration of well pattern, and to evaluate the development index of individual well, or a CBM reservoir, further to provide basic data for economic evaluation of development plans.

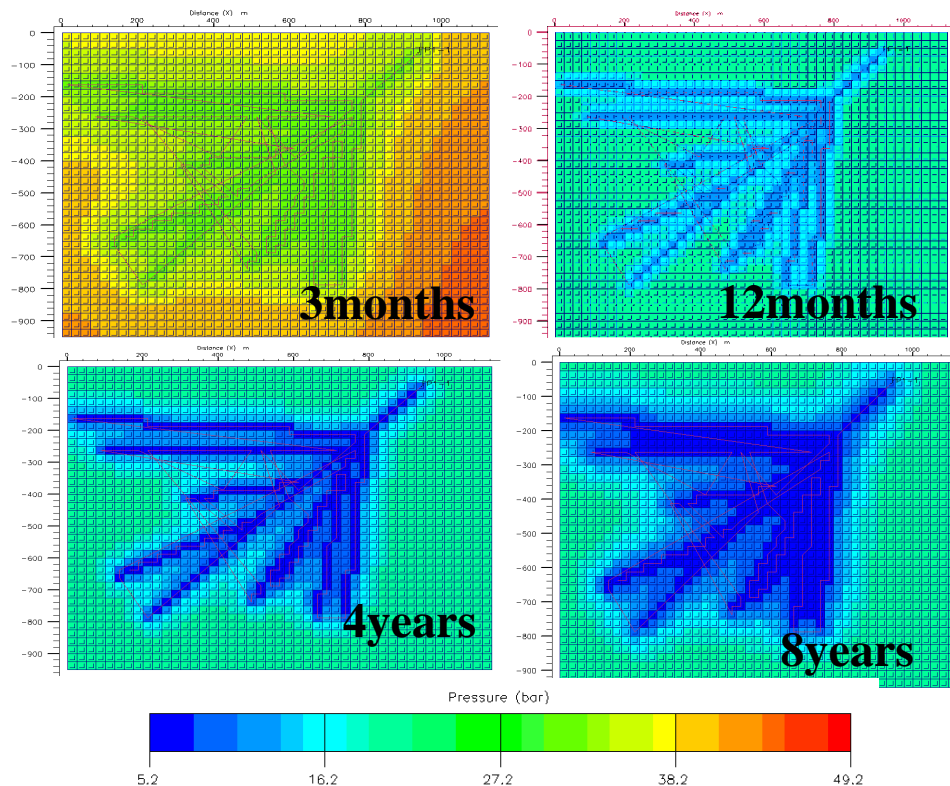
6. Simulation technique for CBM production history

水平井不同井眼轨迹压力变化预测
Reservoir pressure forecast under different track of horizontal well



Optimizing Horizontal Well Track

FP1-1井含气量变化
Well FP1-1: gas content change during production



Calculating Reserves and Recovery factor

7. Drilling technologies

Characteristics of different coal-rank CBM reservoirs and suitable well-type in China

Coal Rank	Characteristics of CBM reservoirs	Suitable Wells	Typical Areas
High-	Hard coal seams; Low permeability (0.5-1md); strong adsorption; High gas content (15-25m ³ /t)	Multilateral Horizontal wells; Fractured Vertical wells	Qin-shui Basin
Mid-	Hard coal seams; ample cleats; moderate permeability (1-5md); Higher gas content (8-16m ³ /t)	Fractured Vertical wells	Eastern Ordos Basin Ning-wu Basin
Low-	Soft coal seams; ample pores; good permeability (>15md); Low gas content (<5m ³ /t)	Cavity vertical wells	Junger Basin Tu-ha Basin

7. *Drilling technologies*

- ◆ Small rigs are used for CBM development due to its lower drilling cost.



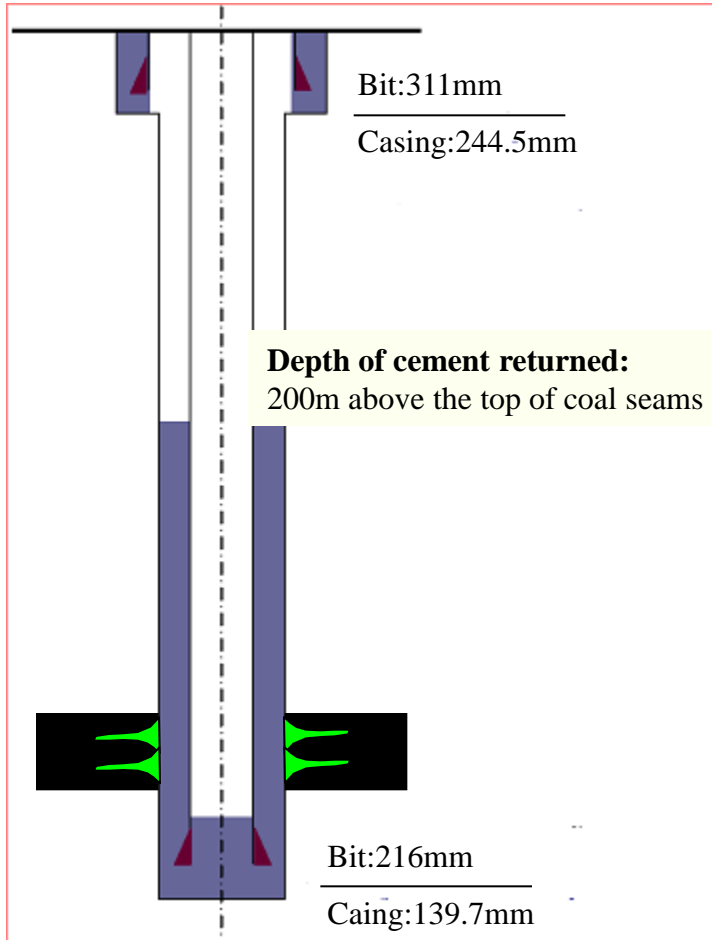
Light rig and its well site



Mobile drilling rig

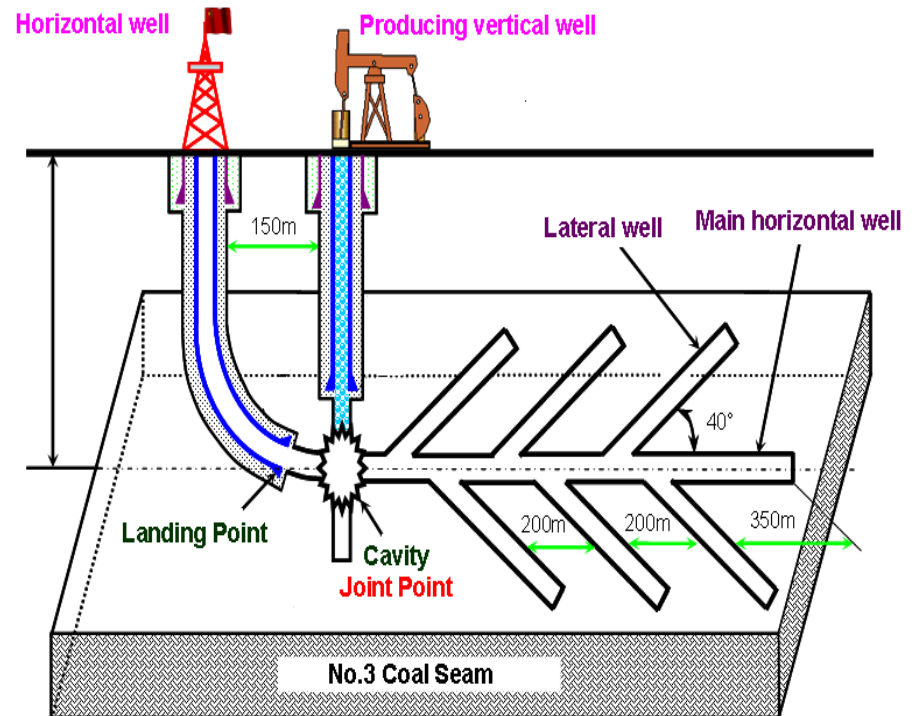
8. Drilling technologies

◆ Vertical wells



◆ Multilateral horizontal wells

Normally, multilateral horizontal wells consist of two wells (horizontal well and cavity vertical well).



➤ Aerated UBD (under-balance drilling)

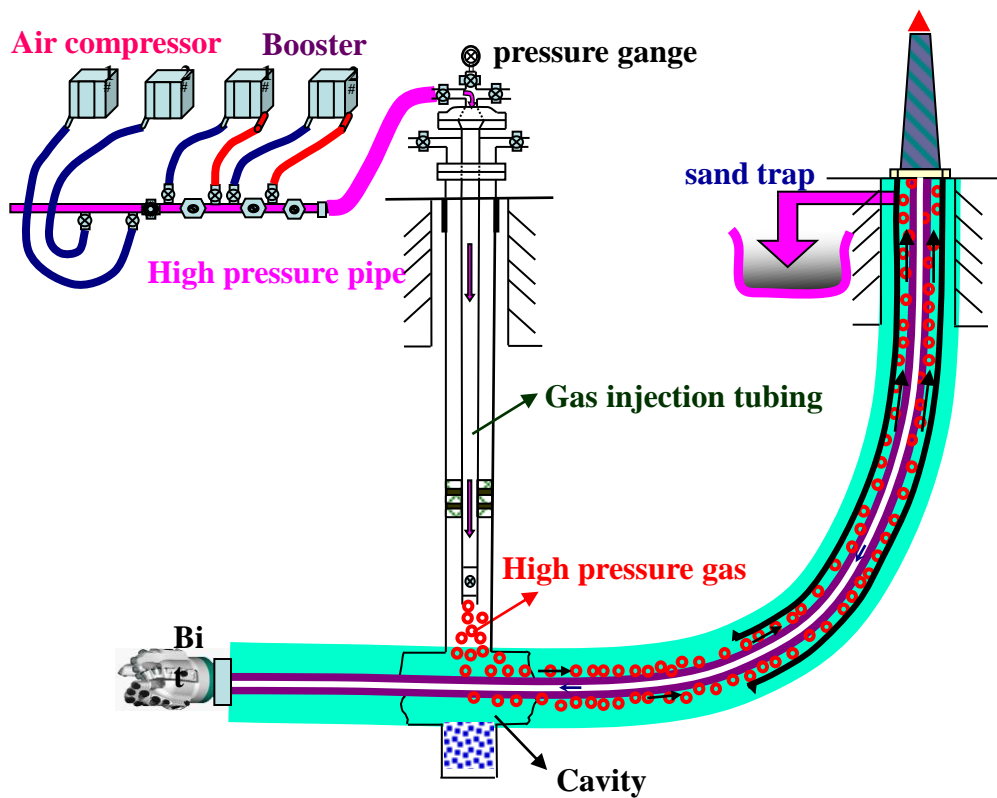


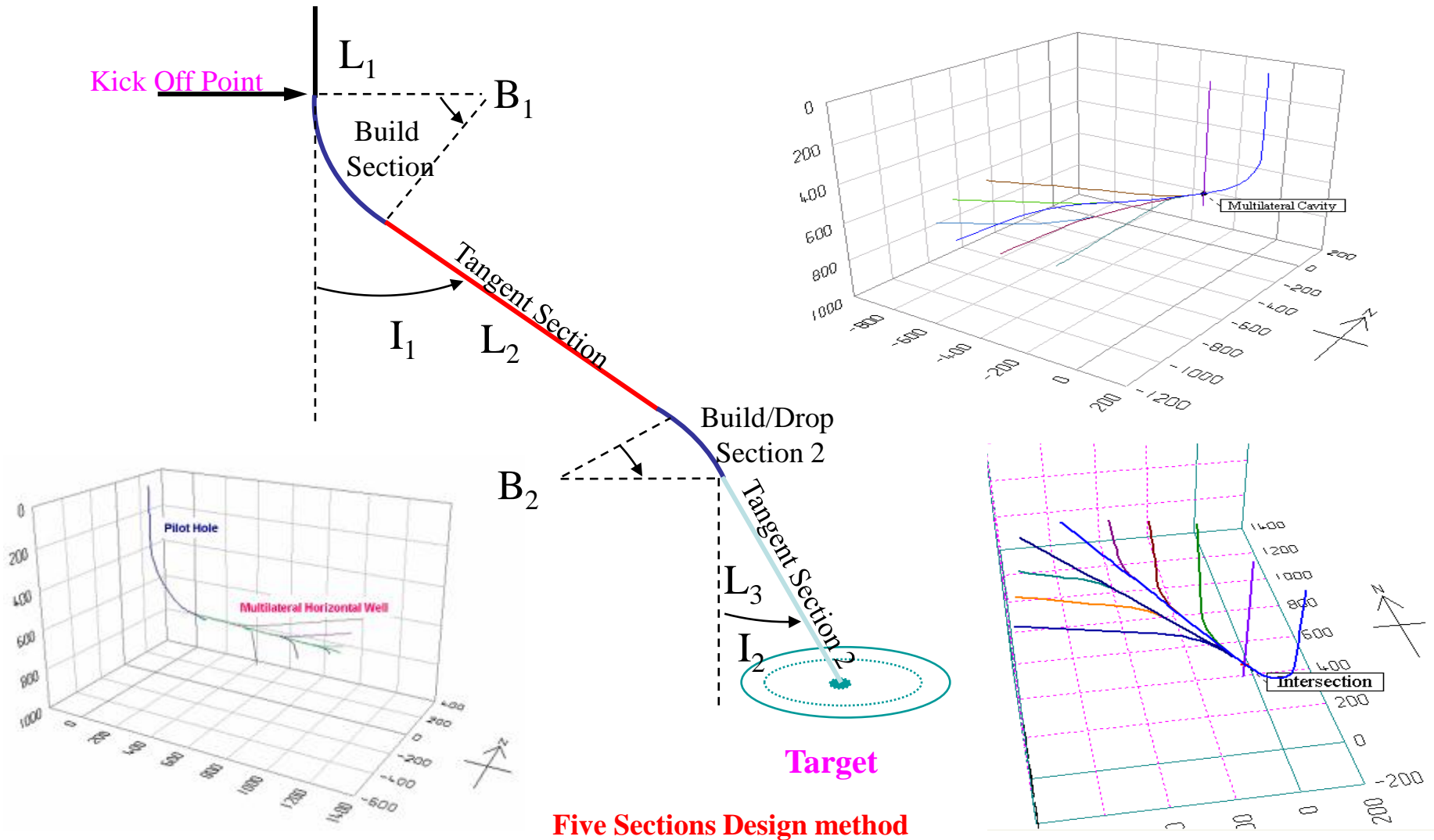
Chart of Pinnate horizontal well's aerated UBD

The water is injected from the horizontal well while the gas injected from the cavity vertical well to make sure that the pinnate horizontal well is drilled in coal seam under balanced.

Up to now, more than 60 pinnate horizontal wells have been drilled with this technology in Qinshui basin.

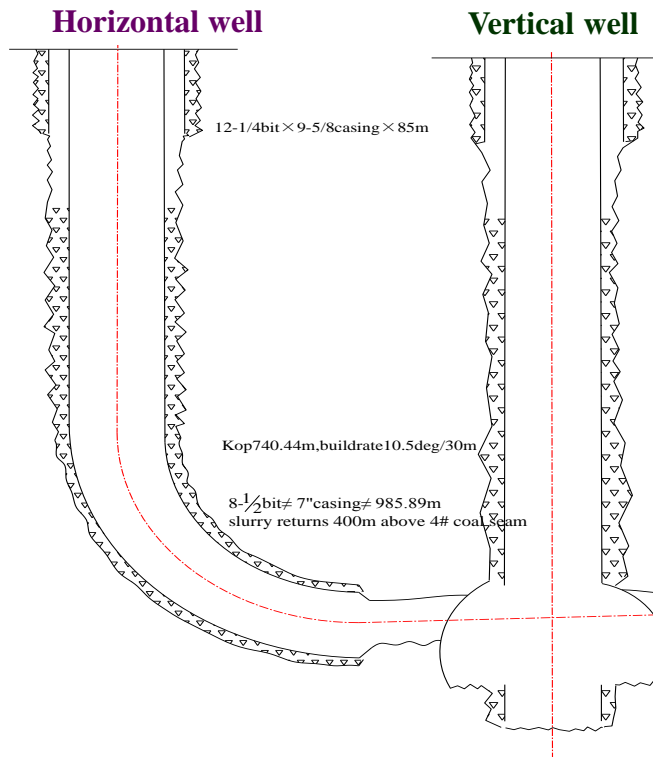
8. Drilling technologies

◆ Any shape of pinnate horizontal wells can be designed with the professional method and software.

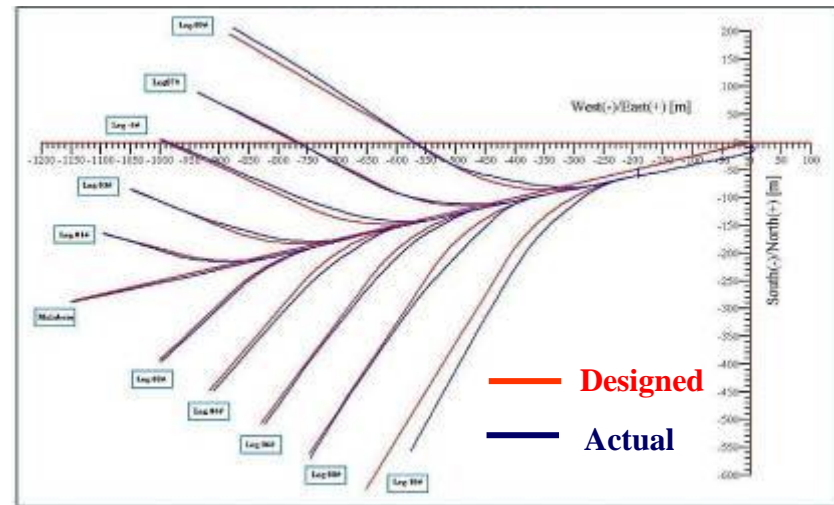


8. Drilling technologies

- ◆ **Well WM1-1** — Examples of multilateral horizontal wells drilled by Langfang Branch-RIPED, CNPC, 2005.



Plane projection of designed and actual Well track of Well WM1-1



The whole drilling footage of the horizontal well is about 7,025m (6,075m in the coal seam). The drilling cycle is 49 days, and the coincidence rate of the actual and designed well track comes as high as 95%.

Application of hydraulic fracturing in south Qinshui, Eastern Ordos Basin:

- **3 fracturing fluid systems developed: fresh water, clean fracturing fluid, gelled fracturing fluid. Formation damage and proppant carrying capacity are main factor**
- **Fracturing technology: mini frac, varying discharge, filtration testing, fracture height control, proppant placement with size combination**
- **Sand fracturing scale: 30-40m³ sand, 300- 400m³ fracturing fluid**
- **According to the diagnosis data, fractures half-lengths are within 80- 120m**
- **Most fractured wells' production are steady and higher than 2,000m³/d**

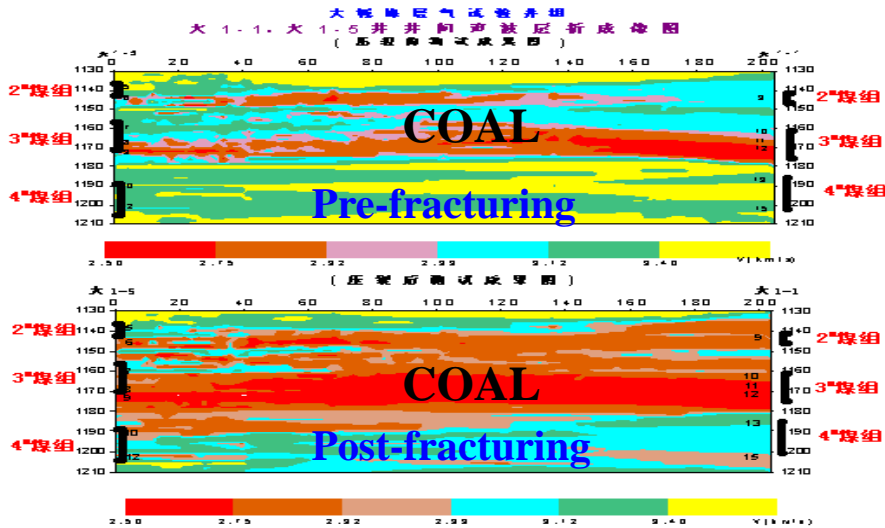


CBM field fracturing

CT test between wells

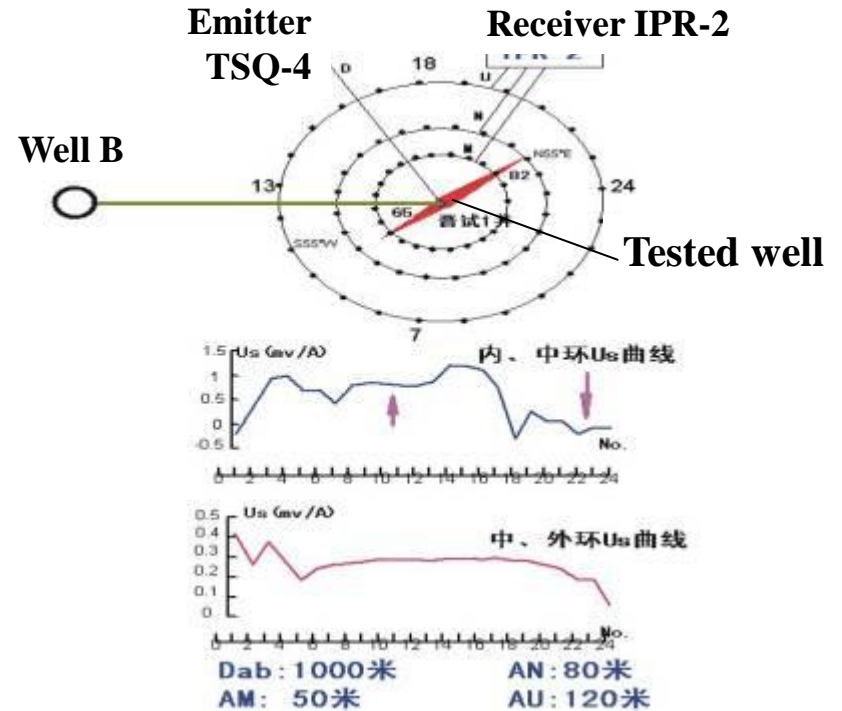
D1-1

D1-5



We take the independent seismic surveillance between 2 wells pre- and post fracturing. According to the difference of seismic attribute, we can easily decide the situations of inter-well communication.

Ground Potential Monitoring method



Through measuring the ground electric potential difference about different radius & bearing electrode during the fracture process, the fracture's orientation and length can be calculated.

11. Dewatering Technologies

Dewatering technologies include pump selection, water level control, bottom flowing pressure control, etc. There are mainly 2 types pump use in CBM wells:

1. Screw pump

- Be fit for shallow wells(<1500m), and larger water production
- Reduce number of pump-stuck



2. Beam unit + tubing pump(抽油机+管式泵)

—to be fit for low water production (less than 50m³)

—gas production less than 10,000m³/d



12. HSE Management

CNPC has a Strict HSE management system about CBM. No accident about environment, safety, quality and casualties happened in the past 15 years.

Waste Water Treatment:

Each area's produced water would be centralized through a pipeline system, and treated accord with the national standard (GB8978-1996: *synthetic standard of sewage discharge*). The discharge methods include deposition, evaporation and discharging. After attaining irrigation water standard, it would be used to irrigate agricultural or forest land.

OUTLINE

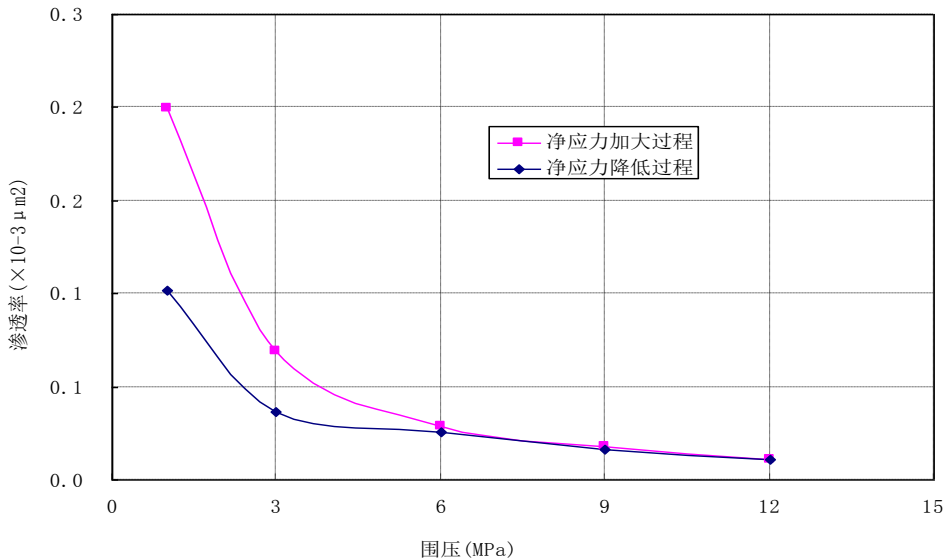
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No.1: how to reduce the damage caused by stronger stress sensitivity of coalbed?

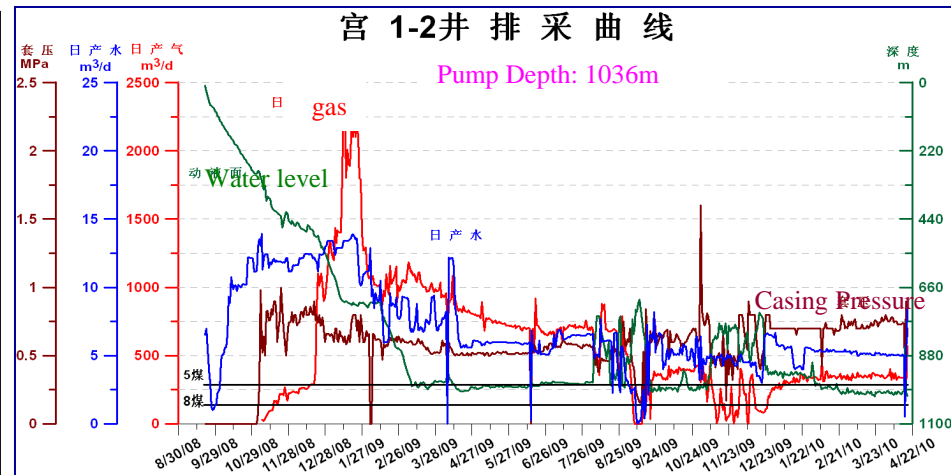
Because of strong plastic property of coal sample, permeability can not completely recover after stress release. The permeability damage is more seriously than other rock.

For oversize dewatering intensity, effective stress of coal increases rapidly. So permeability of fracturing system would be going down to low level quickly, causing the decrease of gas rate.

stress sensitive curve of coal sample
Eastern Ordos

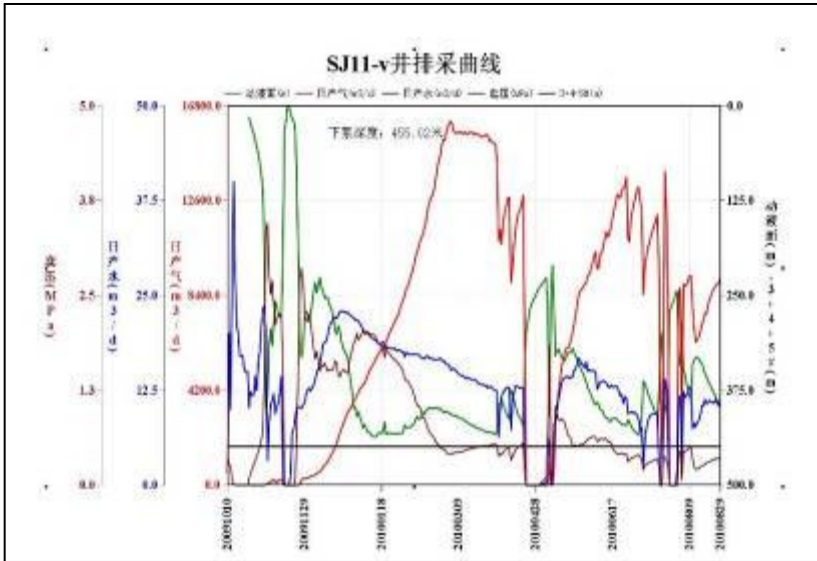


Gong 2 Well Production curve

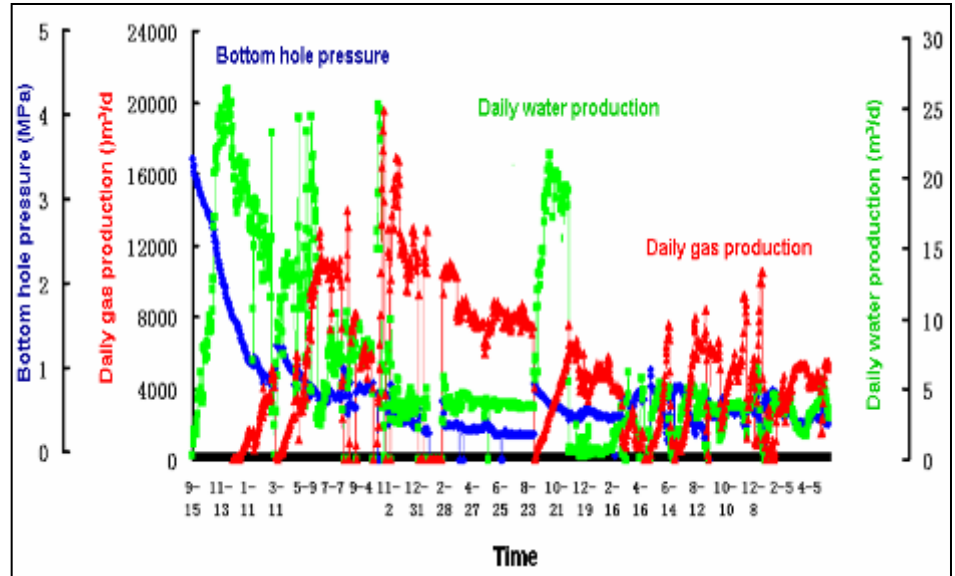


No.2: How to deal with the fine coal during well drainage?

Gas production curve of well SJ11-V



Gas production curve of well FP1-1



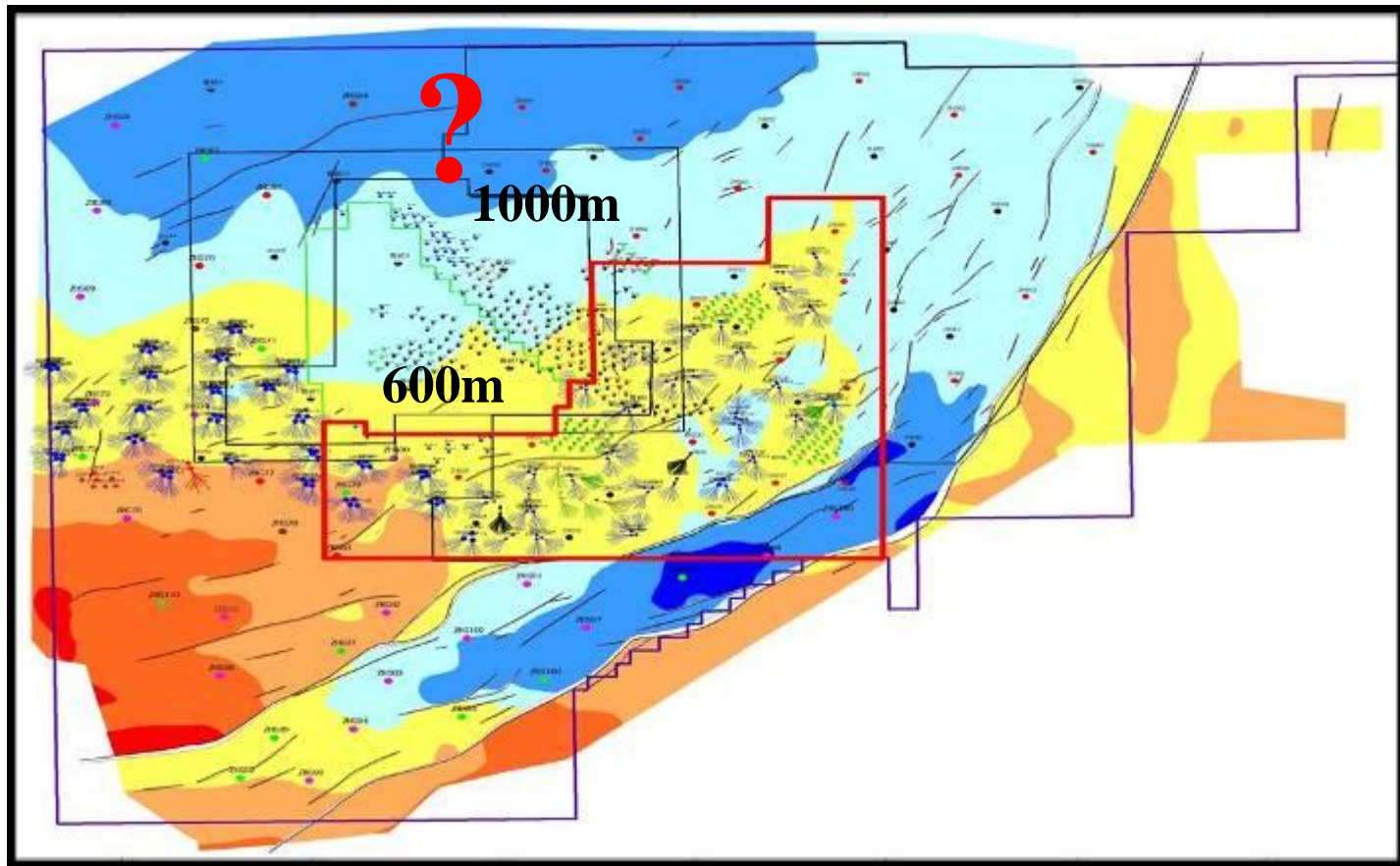
To modify the pumps?

To adjust the drainage parameters?



No.3: Technologies for deeper CBM resources (over 1000m) should be studied.

The Depth of Main Coalbed in Southern Qinshui Basin



Thanks !