# Enhanced Coalbed Methane (ECBM) Technology Introduction

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# *What is Coal?*

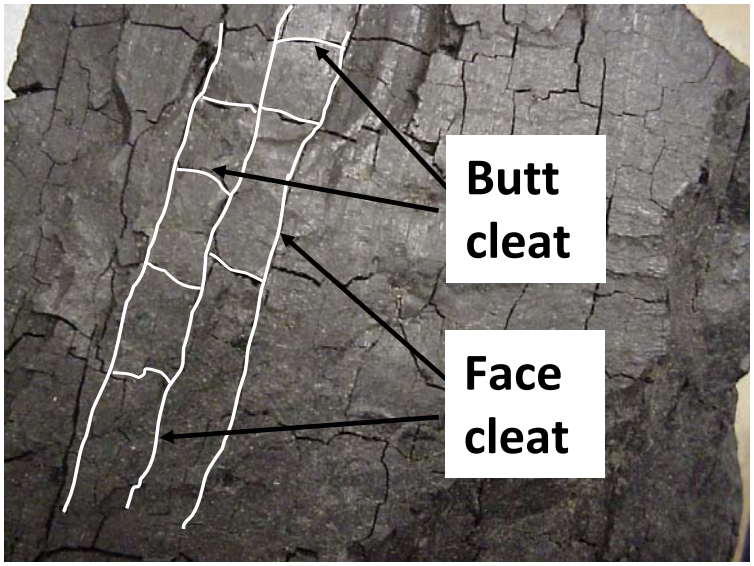
- A readily combustible rock containing more than 50% by weight and more than 70% by volume of carbonaceous material formed from compaction and induration of variously altered plant remains similar to those in peaty deposits – *Schopf (1956)*
- A carbonaceous substance composed of phytogenetic materials – *Spackman (1958)*
- A black rock that burns

# *What is Coalbed Methane (CBM)?*

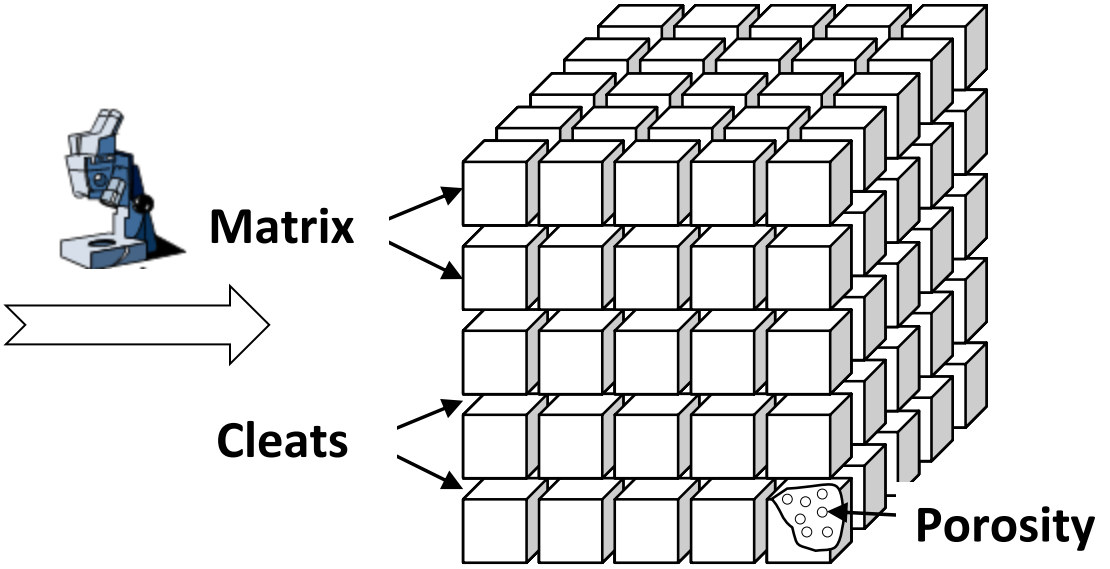
- Gas generated during coalification
- Gas is 85 – 99% methane ($CH_4$)
- Gas is held on coal matrix by adsorption

# *Structure of Coal: Dual Porosity System*

- **Primary porosity**
  ***Coal matrix***
- **Secondary porosity**
  ***Coal cleats***




**Natural fractured coal**




**Dual porosity model**

# *Gas Storage Mechanisms*

- **Gas can exist in a coal seam in two ways:**

  ***Free gas within coal cleats and natural fractures***

  ***Adsorbed layer on the surface of micropores***

- **Because the bulk porosity of the coal cleat system (i.e. secondary porosity) is small (<5%) and initial gas saturation in the coal cleats is typically low (<10%), most of the gas-in-place in coals (>90%) is adsorbed in the coal matrix**

| Total gas Volume | = | Free Gas Volume | + | Adsorbed Gas Volume |
|---|---|---|---|---|

# Gas Storage Mechanisms

## Langmuir Isotherm

$$Gs = \frac{abp}{1+bp}$$

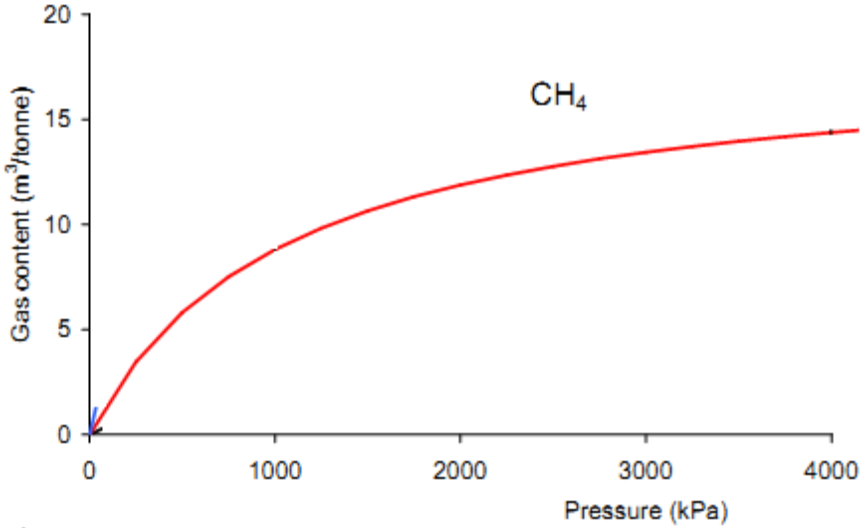
where:

Gs = gas storage capacity, ml/g

a = Langmuir storage capacity, ml/g

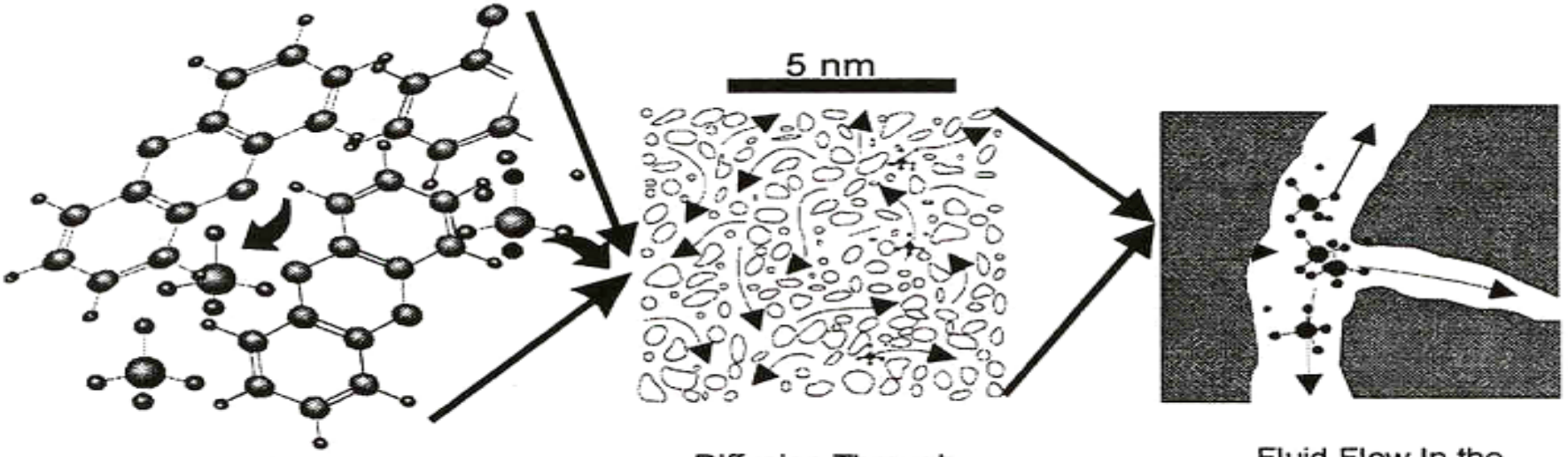
b = Langmuir constant, $MPa^{-1}$

p = pressure, MPa




Typical Langmuir isotherm adsorption curve

# Gas Transport Mechanisms

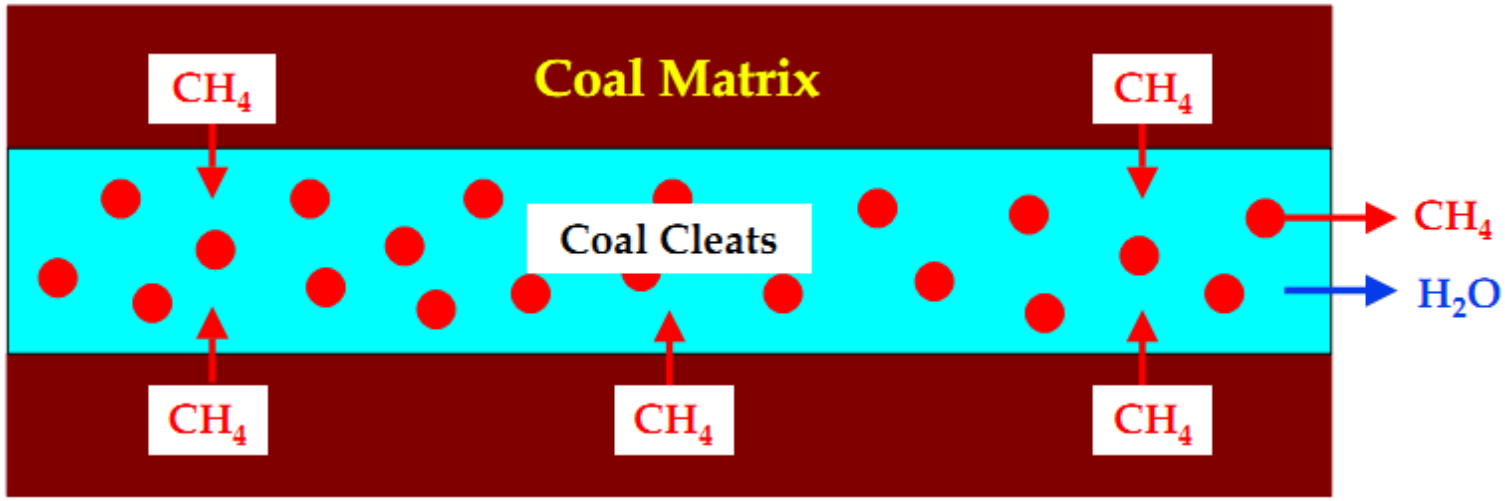



- Controlled by partial pressure
- Follow Langmuir equation

- Controlled by concentration gradient
- Follow Fick's Law

- Controlled by pressure gradient
- Follow Darcy's Law

# CBM Primary Production Mechanisms



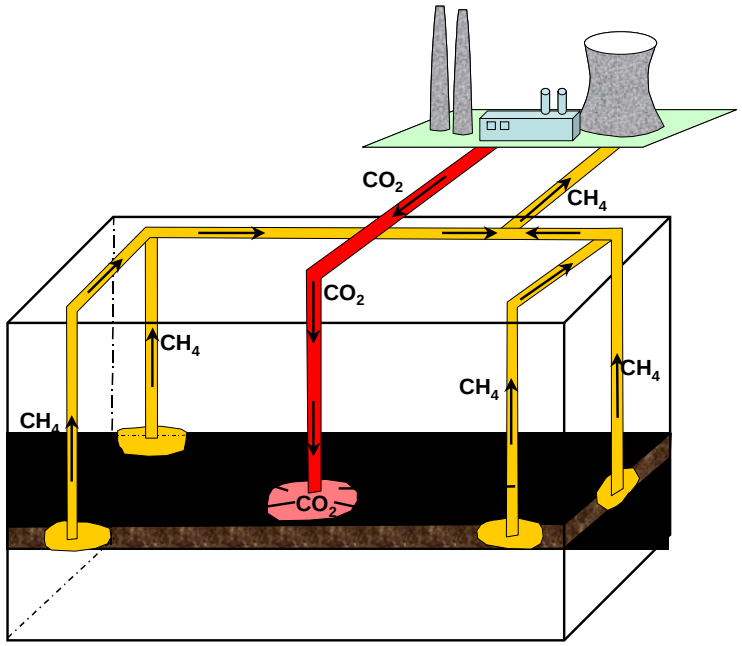

- Reduce cleat pressure by producing water
- Methane desorbs from matrix and diffuses to cleats
- Methane and water flow to wellbore

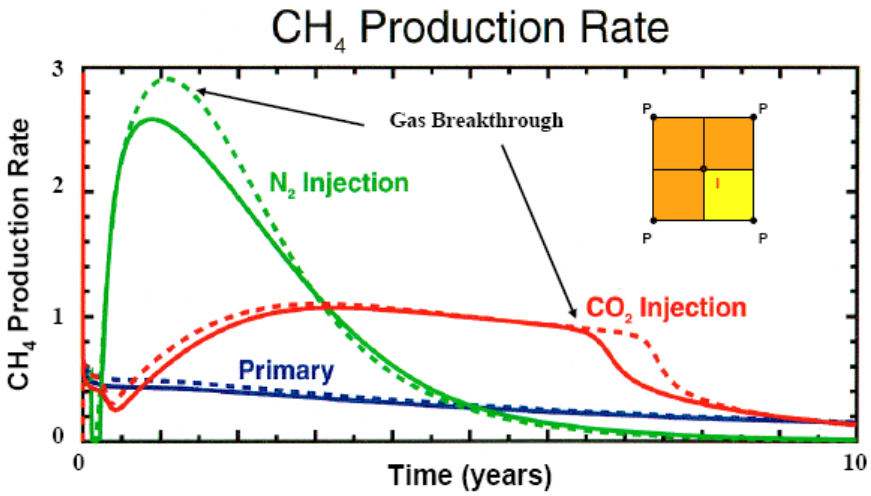
# *Bottleneck of CBM Primary Production*

- Low coal permeability (In China, the initial permeability of 72% of coals < 1mD)
- Low gas flow rate
- Low gas recovery ratio

# Enhanced CBM Technology

## Concept



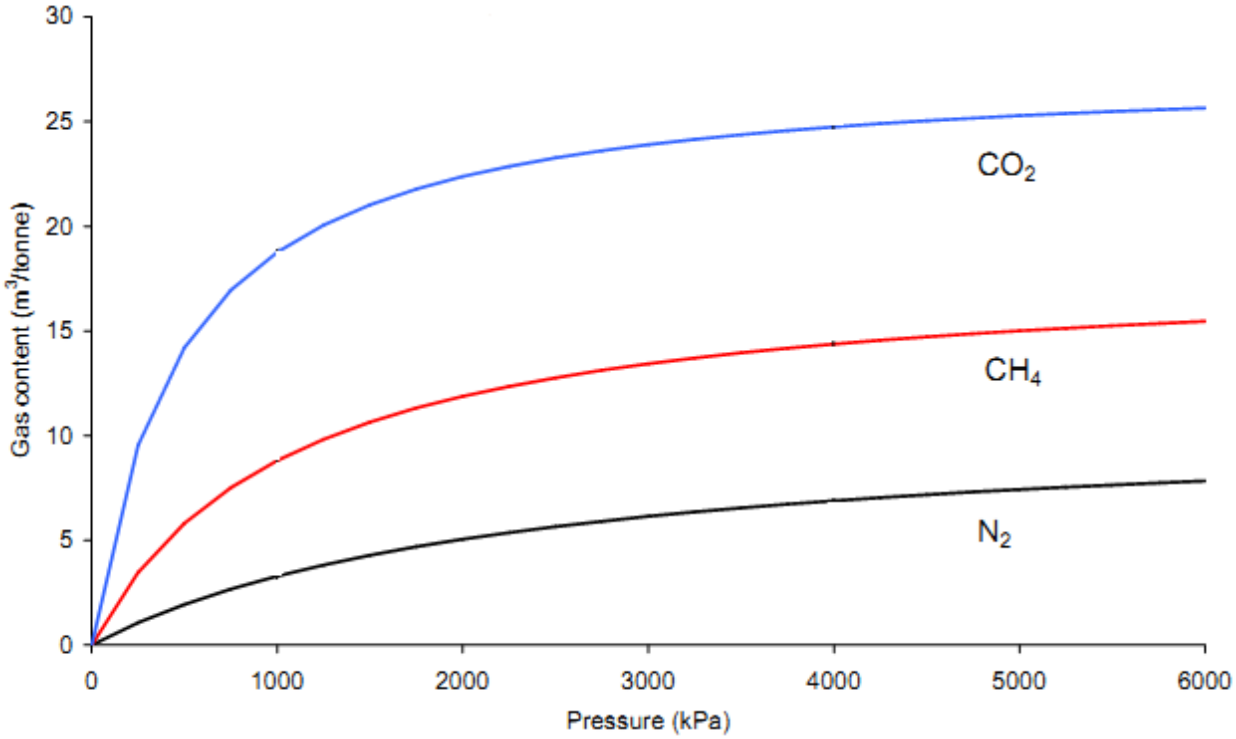




**To inject gas into deep unminable coalbed for enhanced recovery of coalbed methane (ECBM) recovery**

- **Primary porosity**
  *e. i., $CO_2$*
- **Inert gas**
  *e. i., $N_2$*

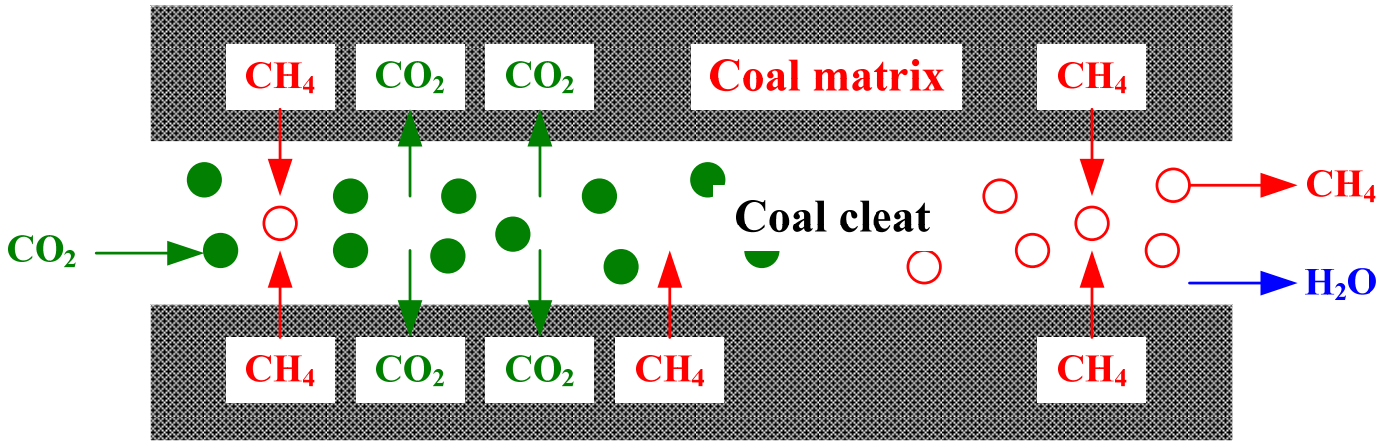
# Enhanced CBM Technology

## Mechanisms



# Enhanced CBM Technology

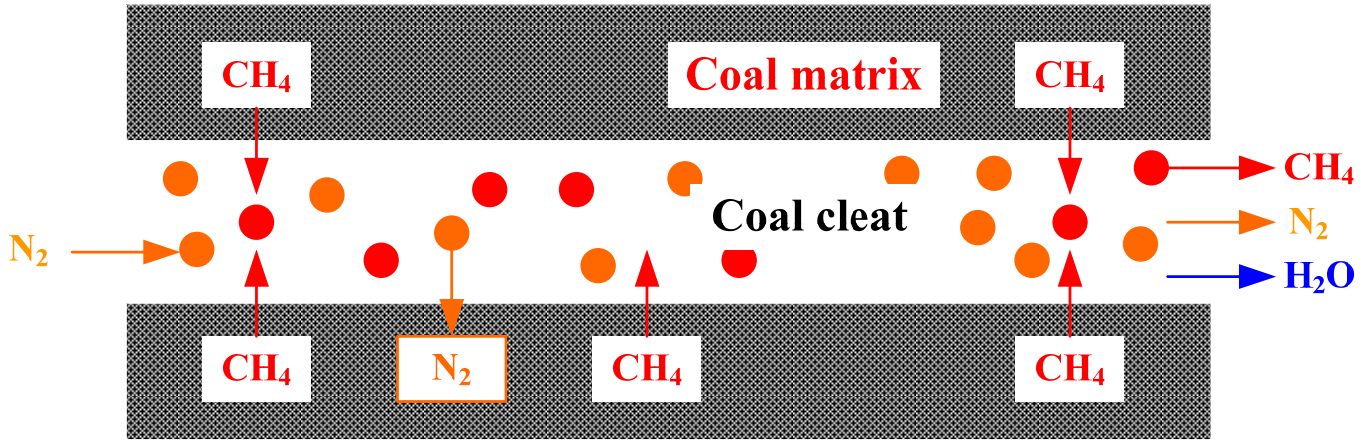
## $CO_2$-ECBM Recovery Mechanisms




- Injected carbon dioxide in cleats
- Increases total cleat pressure
- Carbon dioxide diffuses into matrix and strongly adsorbs onto coal
- Reduces partial pressure of methane in cleats
- Methane desorbs from matrix and diffuses to cleats
- Methane and water flow to wellbore

# Enhanced CBM Technology

## $N_2$-ECBM Recovery Mechanisms

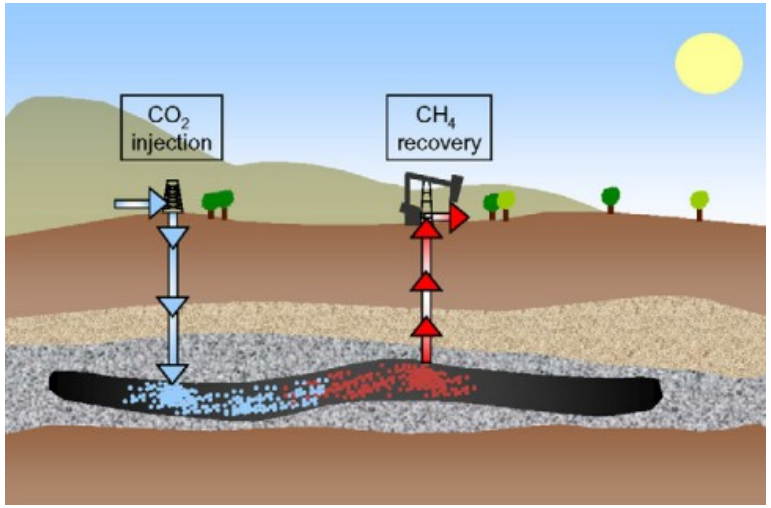



- Injected nitrogen into cleats
- Increases total cleat pressure
- Nitrogen diffuses into matrix and weakly adsorbs onto coal
- Reduces partial pressure of methane in cleats
- Methane desorbs from matrix and diffuses to cleats
- Methane, nitrogen and water flow to wellbore

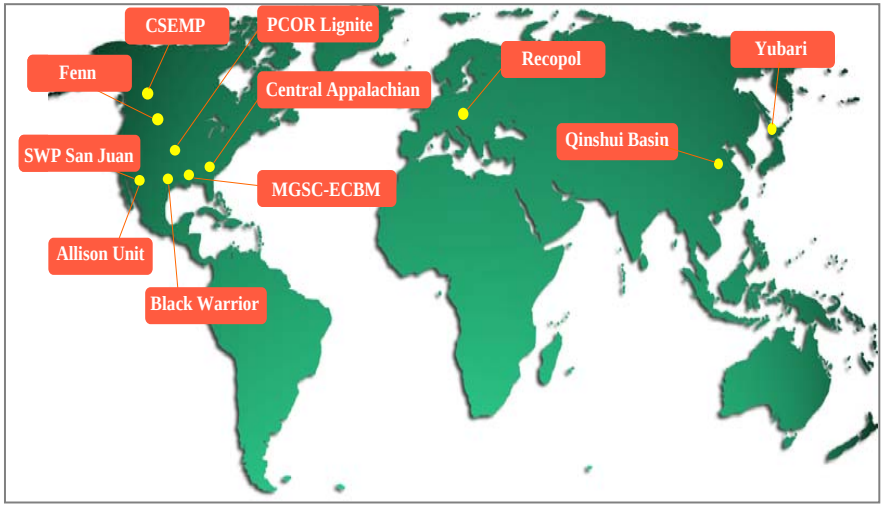
# *Why $CO_2$-ECBM attract more attention?*

- **$CO_2$ is stored – Greenhouse gas reduction**
- **and at the same time the recovery of coalbed methane is enhanced -**

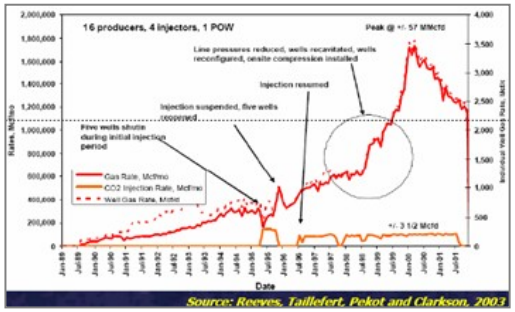
# $CO_2$-ECBM Pilot Test in The world



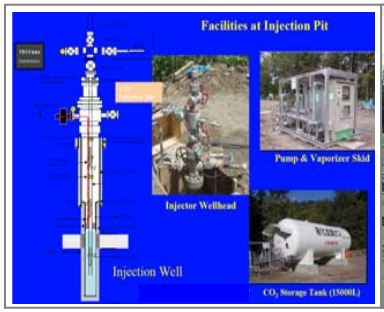

Schematic of $CO_2$-ECBM




Distribution of pilot test in the world




USA




Japan

UN

Canada+China

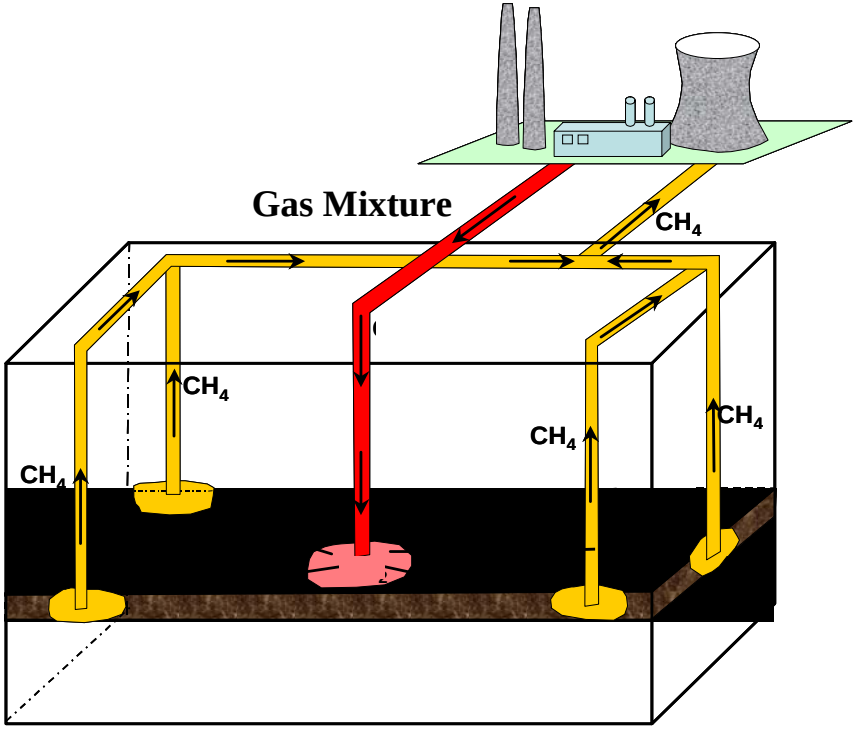
# Challenges of $CO_2$-ECBM in China

**However, pure $CO_2$ as a displace gas has following problems:**

1. **Making the coal swell and therefore reducing its permeability; In China, the initial permeability of 72% of coals < 1mD.**
2. **It is difficult to identify "unminable" coal at present; The ECBM projects may conflict with mining.**

# Gas mixture ECBM

## *Mechanisms*



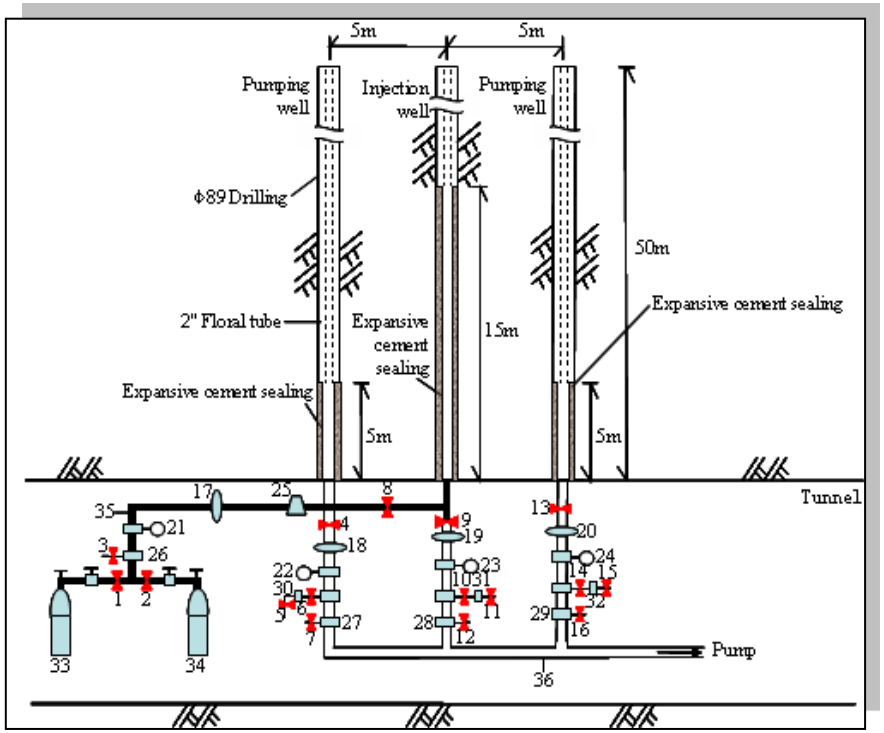

**The concept of G-ECBM technology is to inject gas mixture, consisting mainly of $N_2$ and $CO_2$, into the coalbed through the injection wells to displace the methane from the coal and drive it to the production wells.**

# G-ECBM: Features

- Balancing the preferential sorption role of $CO_2$ and permeability-enhancing role of $N_2$.
- Suitable for low-permeability and minable coals, help to control gas outburst and enhance methane recovery, therefore, attract the interest of enterprises.
- Lowering, even eliminating the cost of gas purification.

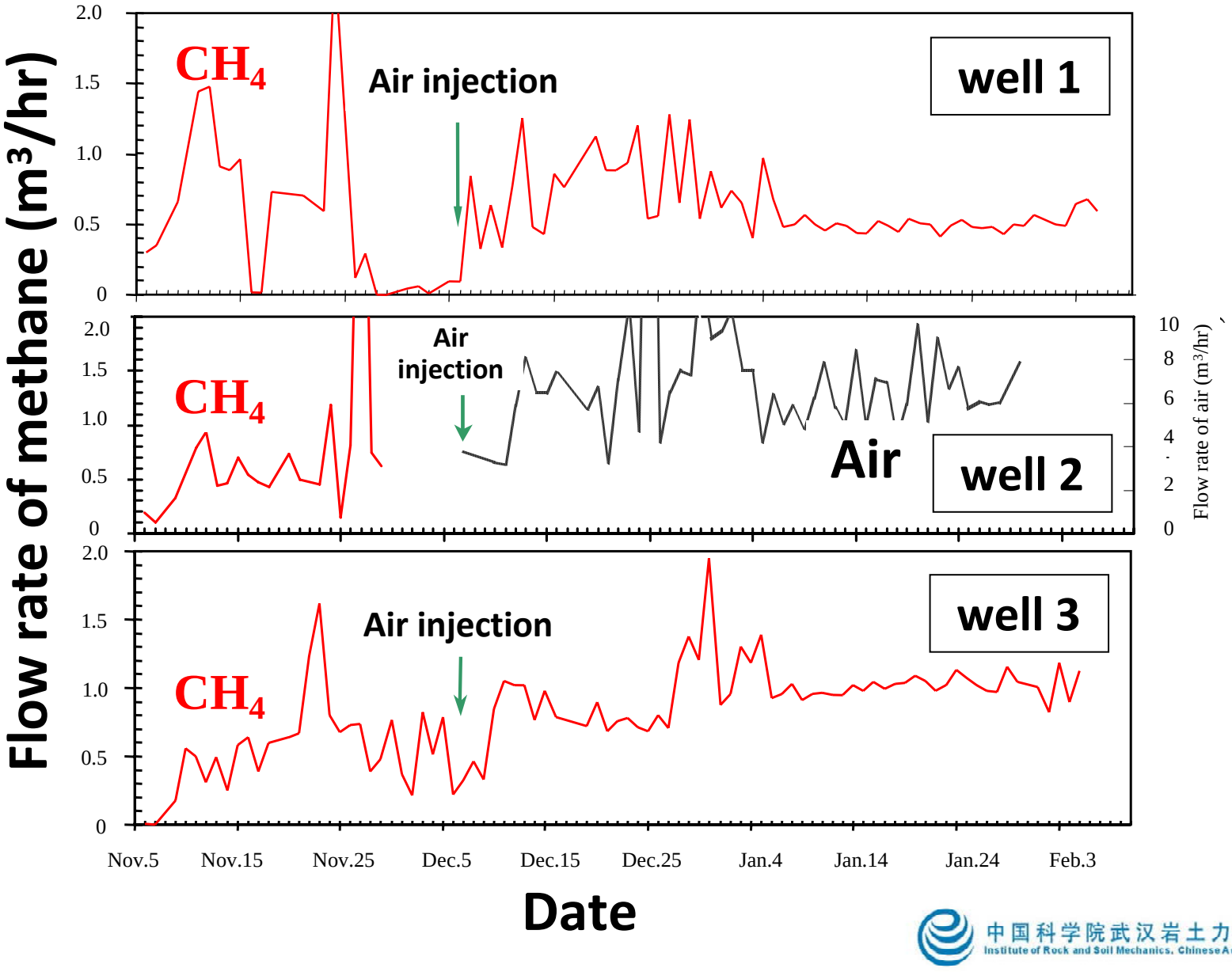
# Pilot Test in Pingdingshan Coal Mine

## Overview of the Test




- Fat coal
- 620m deep tunnel
- Initial permeability is 4 μD
- 3 test wells＋220 existing production wells

# Results of pilot test



# Pilot test summary

| The number of ring hole | Average flow rate of $CH_4(m^3/hr)$ | Average concentration of $CH_4(\%)$ |
|---|---|---|
| 1# hole | 0.86 | 23.5 |
| 2# hole | 0.422 | 43.4 |
| 3# hole | 0.63 | 8.6 |
| Boring holes nearby (220 by traditional method) | 0.13 | 6 |
| Comparation ECBM with traditional method | 5.7 | 2.7 |

Comparing with 220 conventional production wells, the average single-well flow rate and the average concentration of the $CH_4$ of the test wells increased by 4.7 times and 1.7 times, respectively

# Thank you for your attentions!