Modeling Studies on Storage in Coal Seams and CO2-ECBM

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ACBSE-2010, IIC, New Delhi

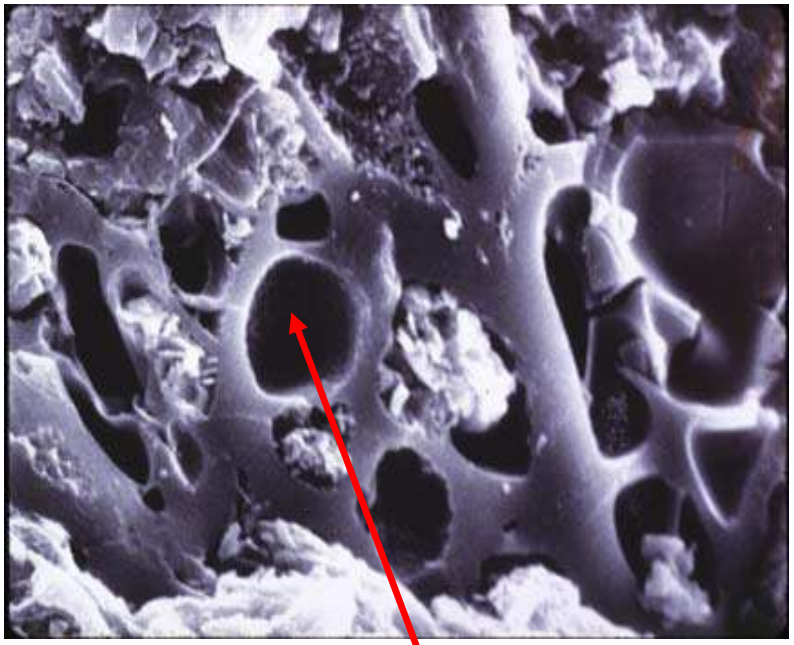
6 August 2010

- *Coal bed methane is natural gas.*
- *It is formed during coalification, the process in which plant material forms coal.*
- *Contained within the coal seams and surrounding rock strata, coal bed methane generally does not escape into the atmosphere unless exposed by coalmining activity.*
- *Released into the mines, the gas becomes Coal Mine Methane, which must be removed from a coal mine for safety reasons.*

Volumes of Gases Generated During Coalification

Methane	2,000 to 5000+ scf/ton (63 to 157 + m^3/t)
Carbon dioxide	177 scf/ton to 6,000+ scf/ton (6 to 188+ m^3/t)
Wet gases	100 to 1,000+ scf/ton (3 to 31 + m^3/t)
Nitrogen	250 to 500 scf/ton (8 to 16 m^3/t)

Dual Porosity of Coal



Microscopic view of the Micropores structure of coal

Fracture system, cleats in coal

Producible CBM

- **Gas content and permeability appear to be the two most critical parameters.**
- **Most successful coal bed methane projects have greater than 100 cubic feet per ton.**
- **Coals which are fractured or have better cleat network, will have better permeability.**
- **Other factors which influence producibility are coal rank, thickness, dip of beds, cleat development, faults or secondary fractures, and depth of cover.**

- **USA tops in the CBM production.**
- **Australia ranks 2nd in the CBM production and development in the world.**
- **Canada ranks 3rd – 5 MMSCMD.**
- **China ranks 4th and producing – 2 MMSCMD.**
- **India ranks 5th in CBM activities.**
- **Indonesia have just started the drilling of CBM wells.**

Note: 1 Million BTU = 1000 cu.ft = 28 m^3 of gas.

INDIA RANKS 5TH IN THE EXPLORATION AND PRODUCTION OF CBM.

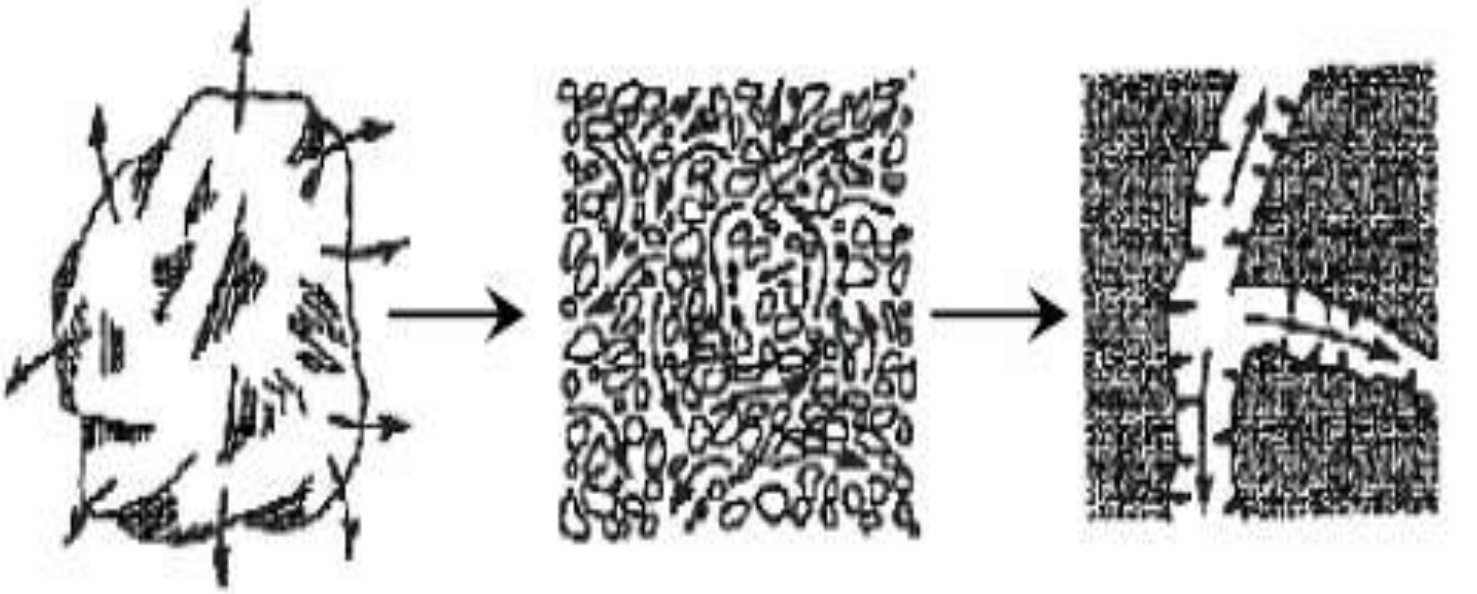
- GEECL- Production Capacity 1 Lakh m^3/day from 23 wells.
Producing – 30,000 m^3/day. Selling 25MSCMD.

- ONGC – Production testing completed in Jharia and Bokaro. 1st well in Jharia produce 20 MCM/day and stabilizes at 7 MCM/day. Started drilling of 1st horizontal-multilateral CBM well in Jharia.

- RIL – Completed drilling of test wells in their Sohagpur East and West CBM blocks. CBM production from a cluster of 5 wells is about 22-25MCM/day.

Other active players in CBM field are Essar Oil, Arrow-GAIL, RNRL- Geo-Petrol, Deep Industries- Coal Gas Mart and BP.

Transport of Gas



Desorption from Internal Coal Surfaces

(a)

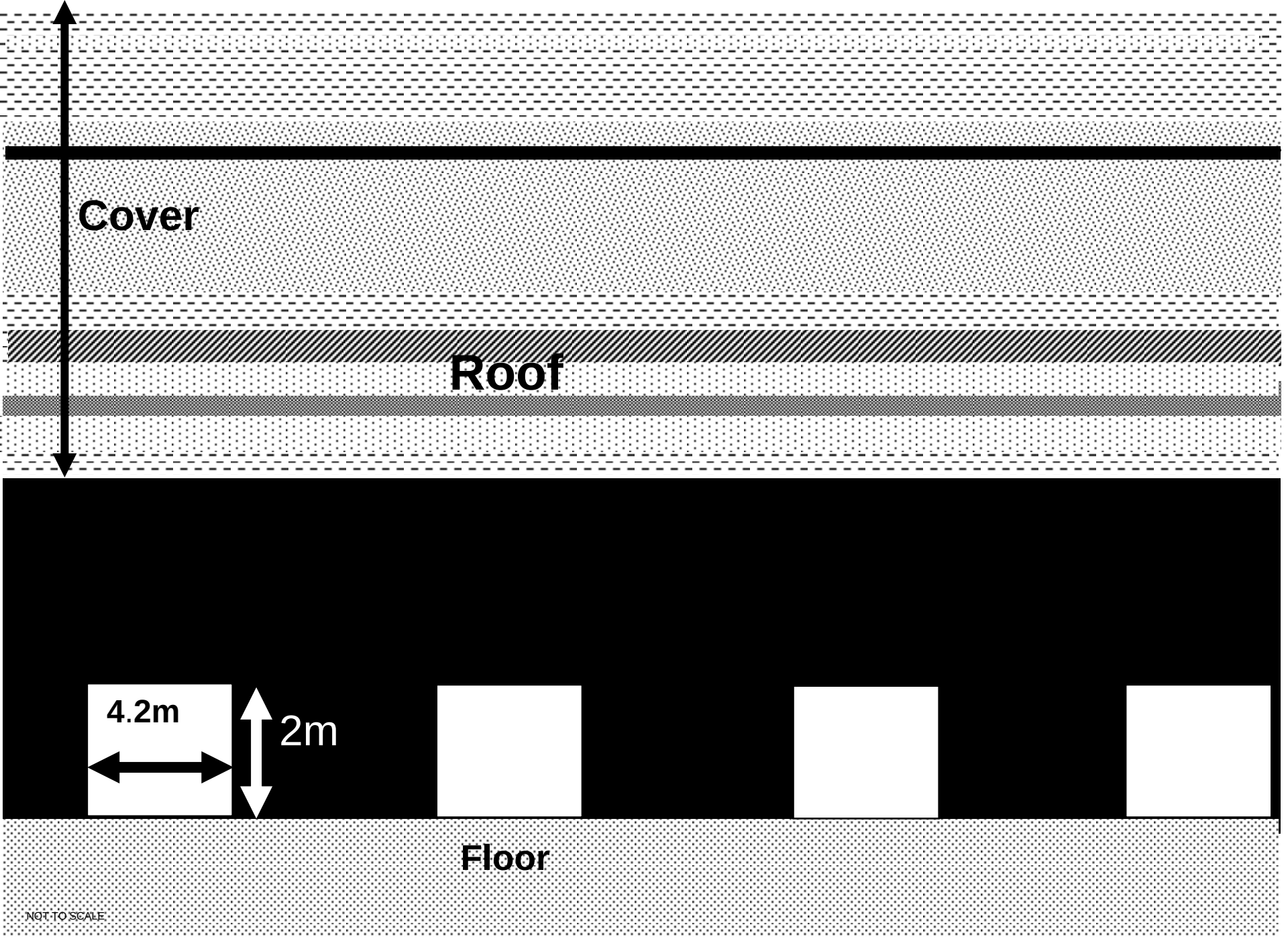
Diffusion Through the Matrix and Micropores

(b)

Fluid Flow in the Natural Fracture Network

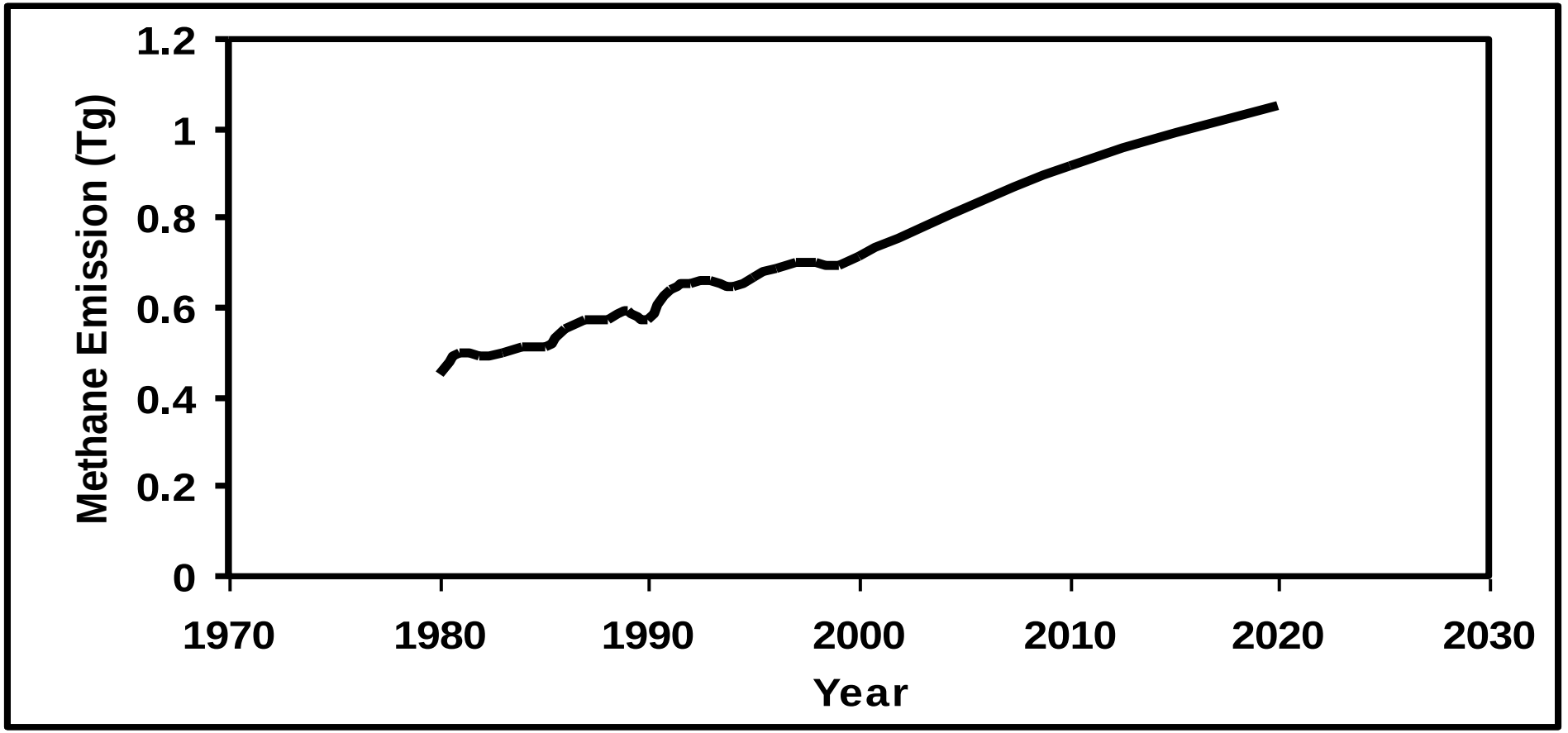
(c)

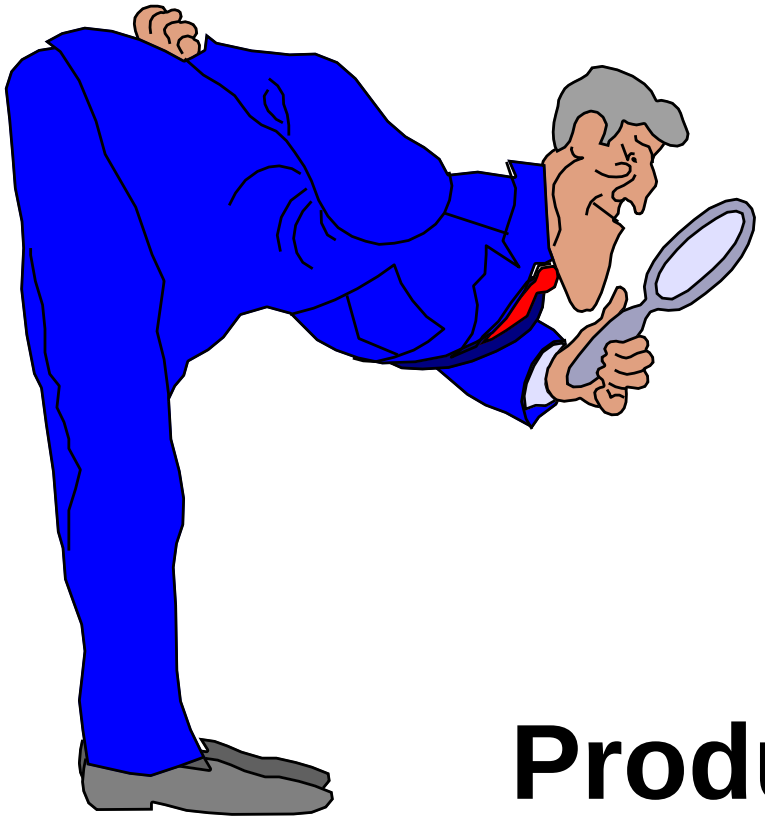
Increasing Size →


Cover
Roof
4.2m
2m
Floor
NOT TO SCALE

What about surface mines???

Trend of CH_4 Emission



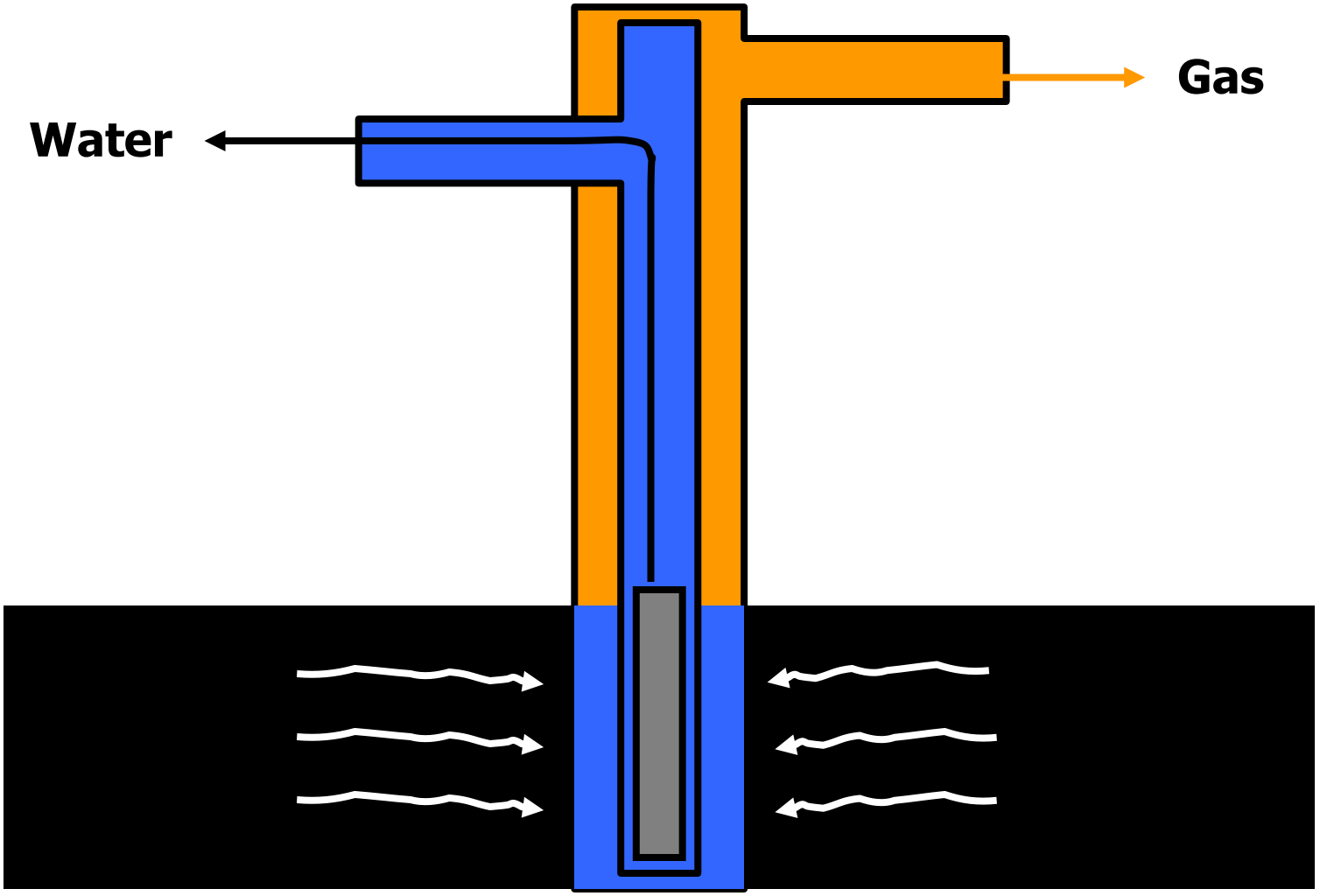


Production of CBM, What really happens?

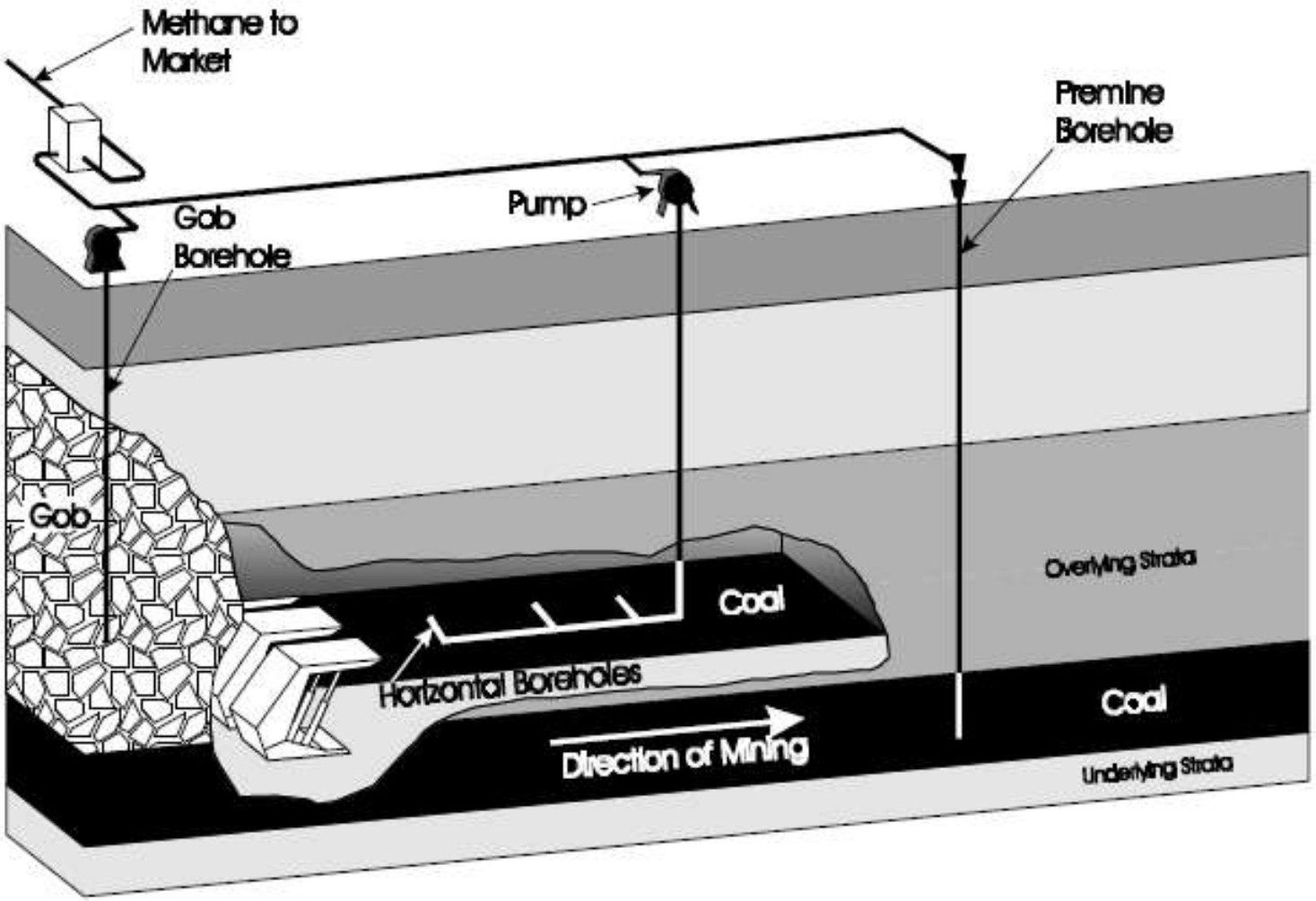
DIFFERENT CATEGORIES OF CBM

- VCBM
- CMM
- AMM
- VAM

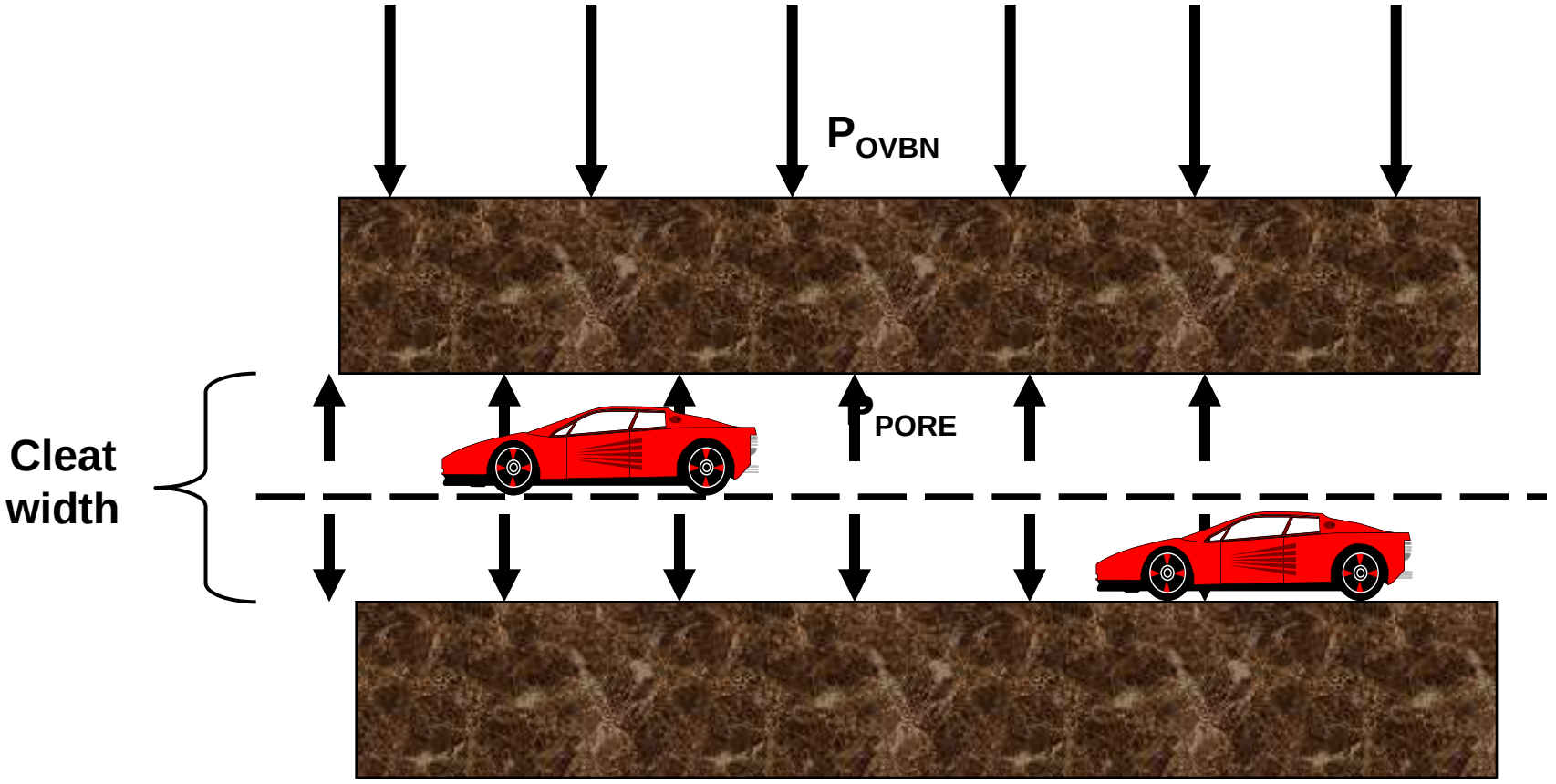
Typical VCBM Well in Production



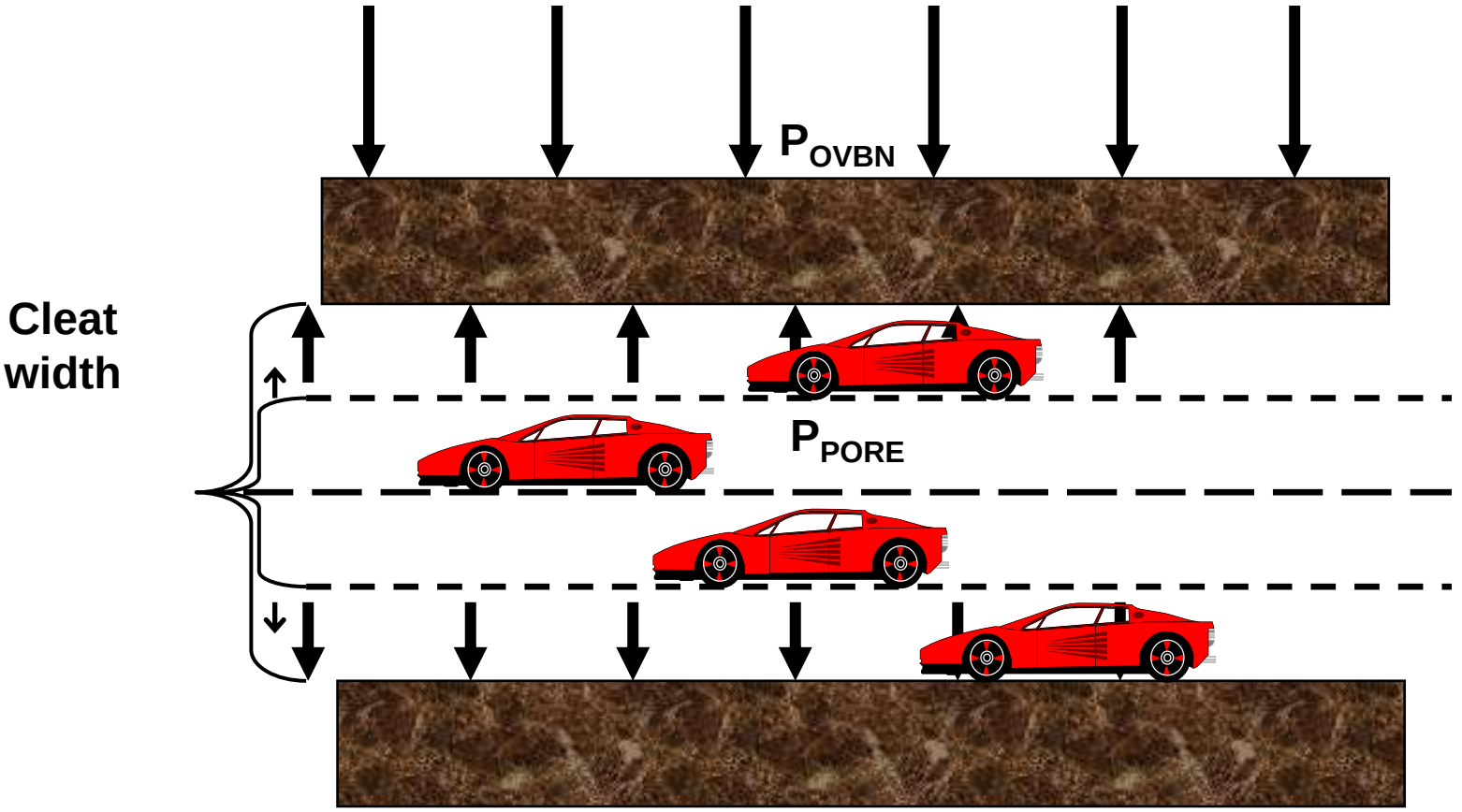
Types of gas drainage and capture techniques in coal mining
Vertical Pre-Mining gob wells and Underground Horizontal wells



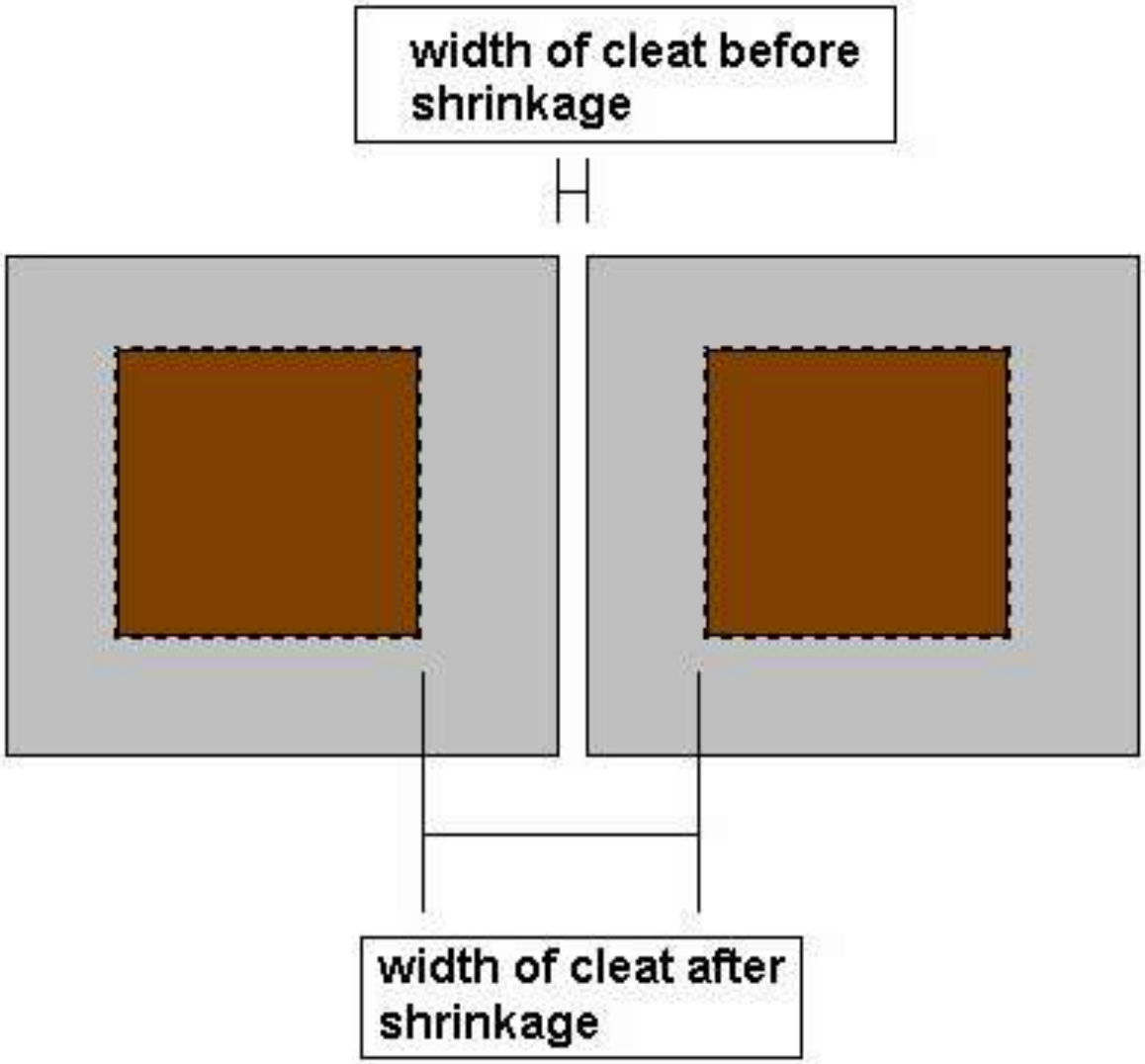
As pore pressure decreases, the net overburden pressure increases.



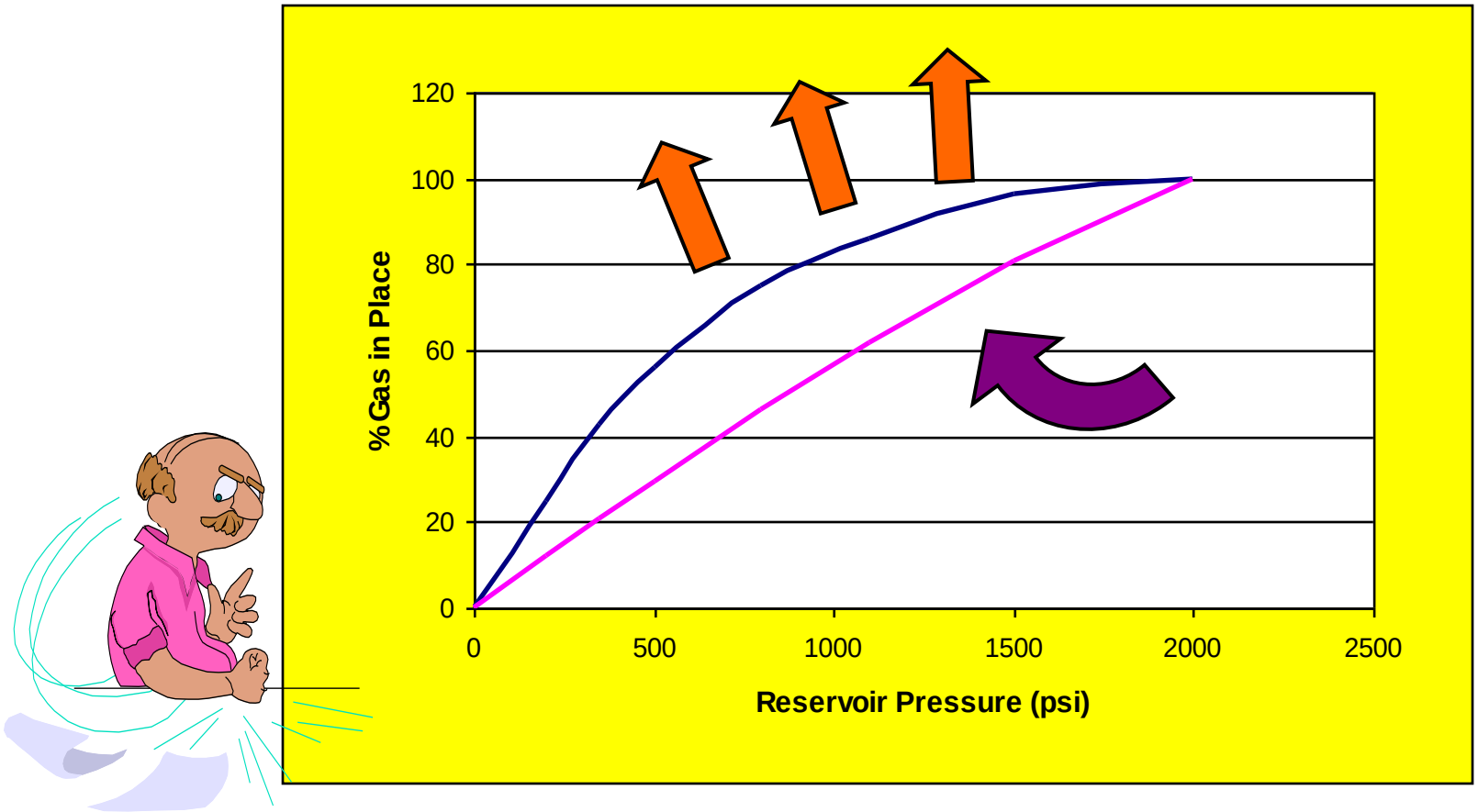
A mitigating factor is that as the pore pressure decreases, the desorbed gas will effectively shrink the volume of the coal. This tends to intensify the cleating in situ.



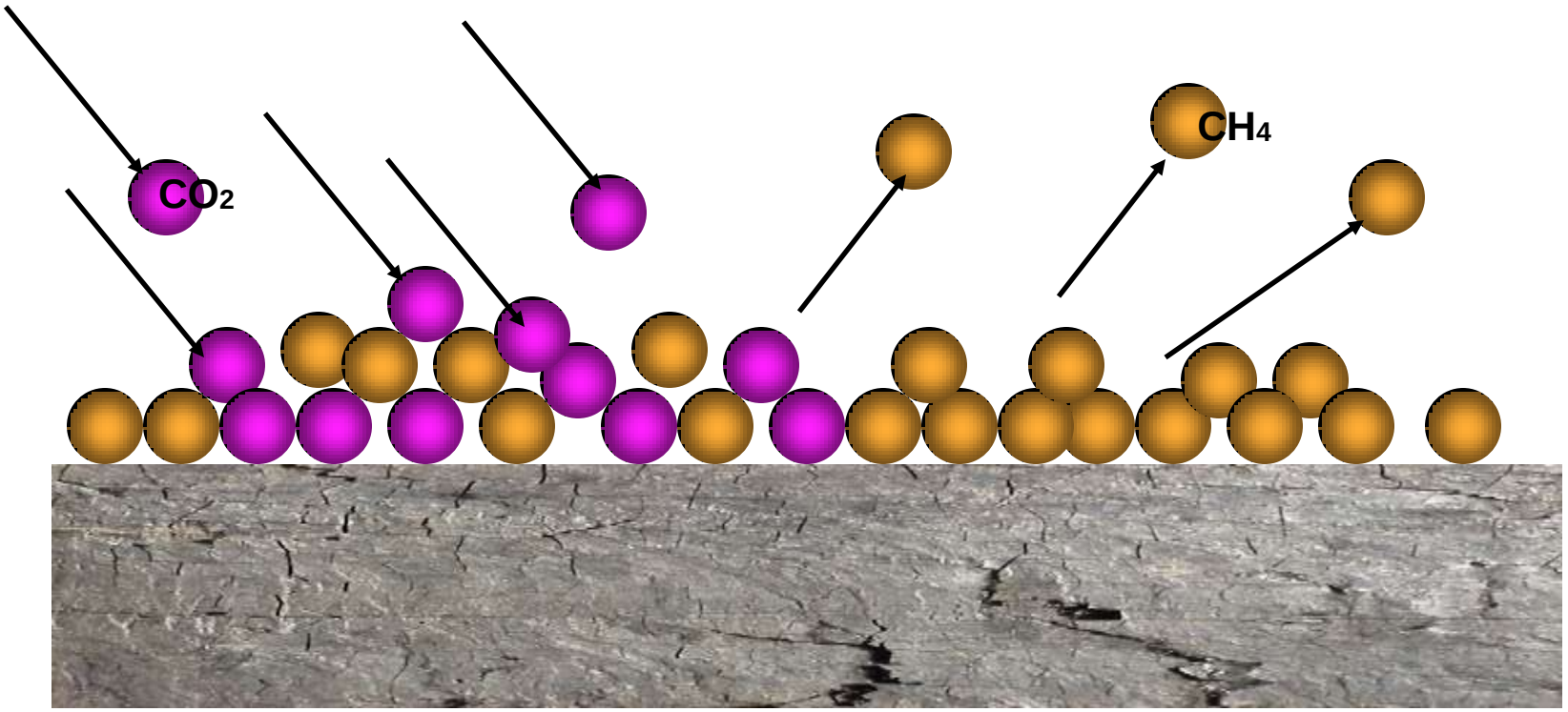
Coal matrix shrinkage



What about Enhanced Gas Recovery ?!?



Affinity of CO_2 Adsorption for Coal



Comparative Adsorption of CO_2 and CH_4

- **Studies conducted so far supports stronger affinity of CO_2 to the coal molecule.**
- **2 to 3 molecules of CO_2 may displace one molecule of methane**
- **It means carbon dioxide is preferentially adsorbed onto the coal structure over methane (2:1 ratio).**
- **Methane sorption capacity for Indian coals has been investigated by CIMFR.**
- **Understanding controls on CO_2 and CH_4 adsorption in coals is important for the modeling of both CO_2 sequestration and CBM production.**

CBM Reservoir Modeling

- Three-dimensional, two phase, single, dual or triple porosity simulator for modeling gas and water production from coal seams
- Two-phase flow of gas and water occurs in the cleat system
- The cleat system is assumed continues and provides flow paths to producing wells
- The two systems are coupled by use of a desorption isotherm at the matrix-cleat interface
- Cartesian (x-y-z) and radial (r-ɵ-z) coordinate system for multi-well problems.
- Single well problems also may be run using either Cartesian or radial geometry

CBM Reservoir Simulation

- **Three-dimensional; two phase; single, dual or triple porosity simulation for modeling gas and water production from coal seams.**
- **Generally a dual porosity model based on the idealization of fractured media by Warren and Root is considered.**
- **Two-phase flow of gas and water occurs in the cleat system.**
- **The cleat system is assumed continues and provides flow paths to producing wells.**
- **The two systems are coupled by use of a desorption isotherm at the matrix-cleat interface.**
- **Both Cartesian (x-y-z) and radial (r-ɵ-z) coordinate system for multi-well problems.**

Desorption and Diffusion Theory for Coalbeds

Single gas sorption model

Desorption of pure gas is described by a Langmuir isotherms, which relates the coal cleat pressure, p, to the equilibrium matrix gas concentration, C(p), according to

$$C(p) = V_L p/(P_L + p)$$

Where V_L is the maximum amount of gas that can be absorbed, and P_L, a characteristic pressure, is measure of the residence time for a gas molecule on the surface.

The gas flow through the matrix, Q_m is described mathematically by Fick's first law of diffusion expressed in the form

$$Qm = V_m/T[C - C(p)]$$

Where C is the average matrix concentration, V_m is the bulk volume of a matrix element, T is the "sorption time" defined by

$$\tau = 1/D\sigma$$

Where D is the diffusion coefficient and σ is the warren and Root shape factor which depends on the size of the matrix element. Alternately, a shape factor may be defined in terms of the surface area of a matrix element, Am , such that

$$\sigma = aAm/Vm$$

Dual –porosity/single-permeability model for coalbeds

Coalbed methane reservoir represents a well–defined dual porosity/single-permeability system. The basic equation governing fluid flow in the coal cleats (fractures) are mass conservation equations for gas and water:

Conservation of gas :

$$\nabla\left[b_g M_g\left(\nabla p_g + \nabla Z\right) + R_{gw} b_w M_w\left(\nabla p_w + \gamma_w \nabla Z\right)\right]_f + q_m + q_g = \frac{\partial}{\partial t}\left(\phi b_g S_g + R_{sw}\phi b_w S_w\right)_f$$

Conservation of water:

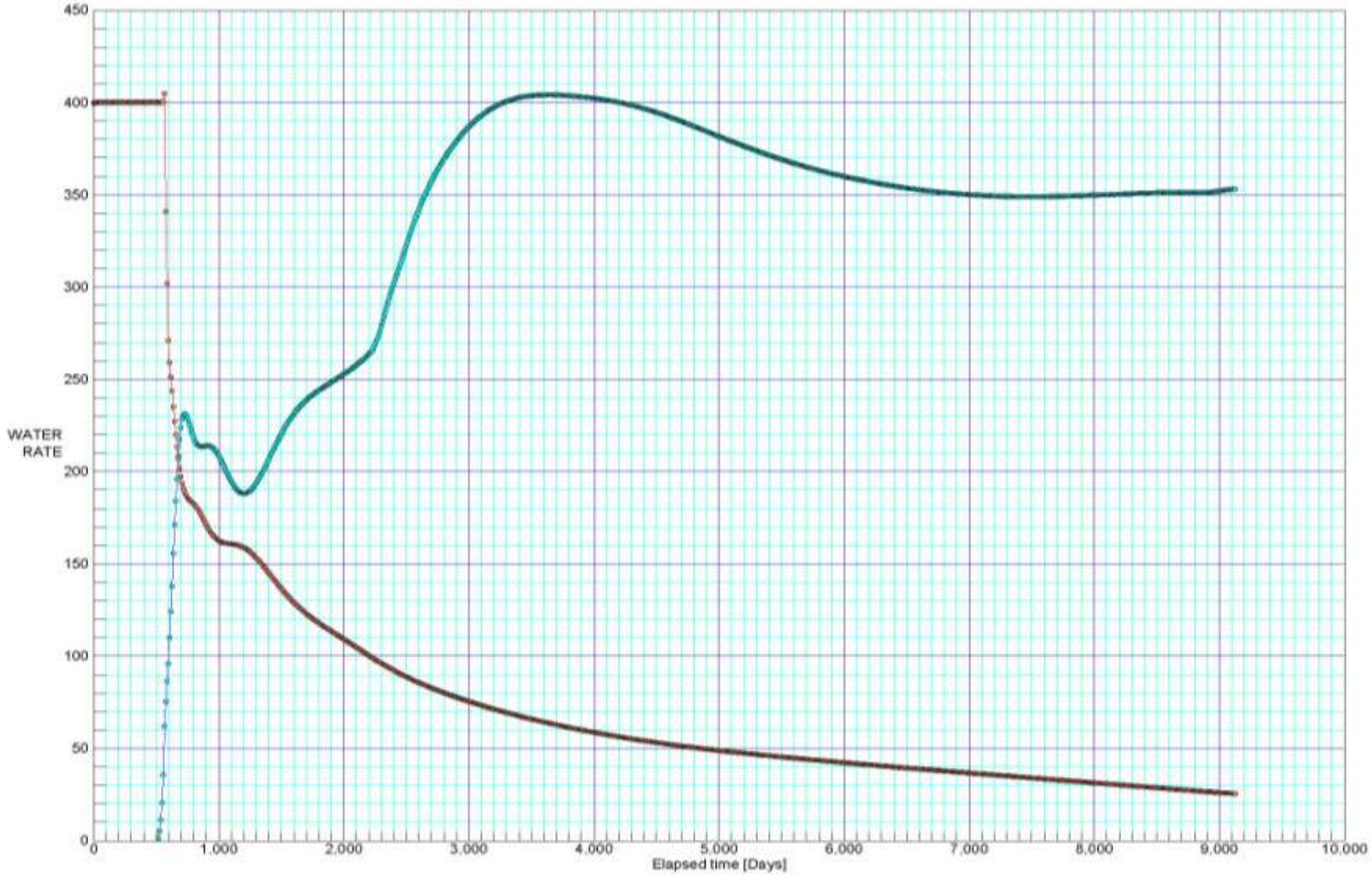
$$\nabla[b_w M_w(\nabla P_w + \gamma_w \nabla Z)]_f + q_w = \frac{\partial}{\partial t}(\phi b_w S)_f \qquad where, M_n = kk/\mu_n$$

Subscript *f* indicates fractured systems, bn (n= g or w) is gas or water shrinkage factors, γn (n = g or w) is water and gas gradient, R_{sw} is gas solubility in water and Pg and Pw are related by the capillary pressure

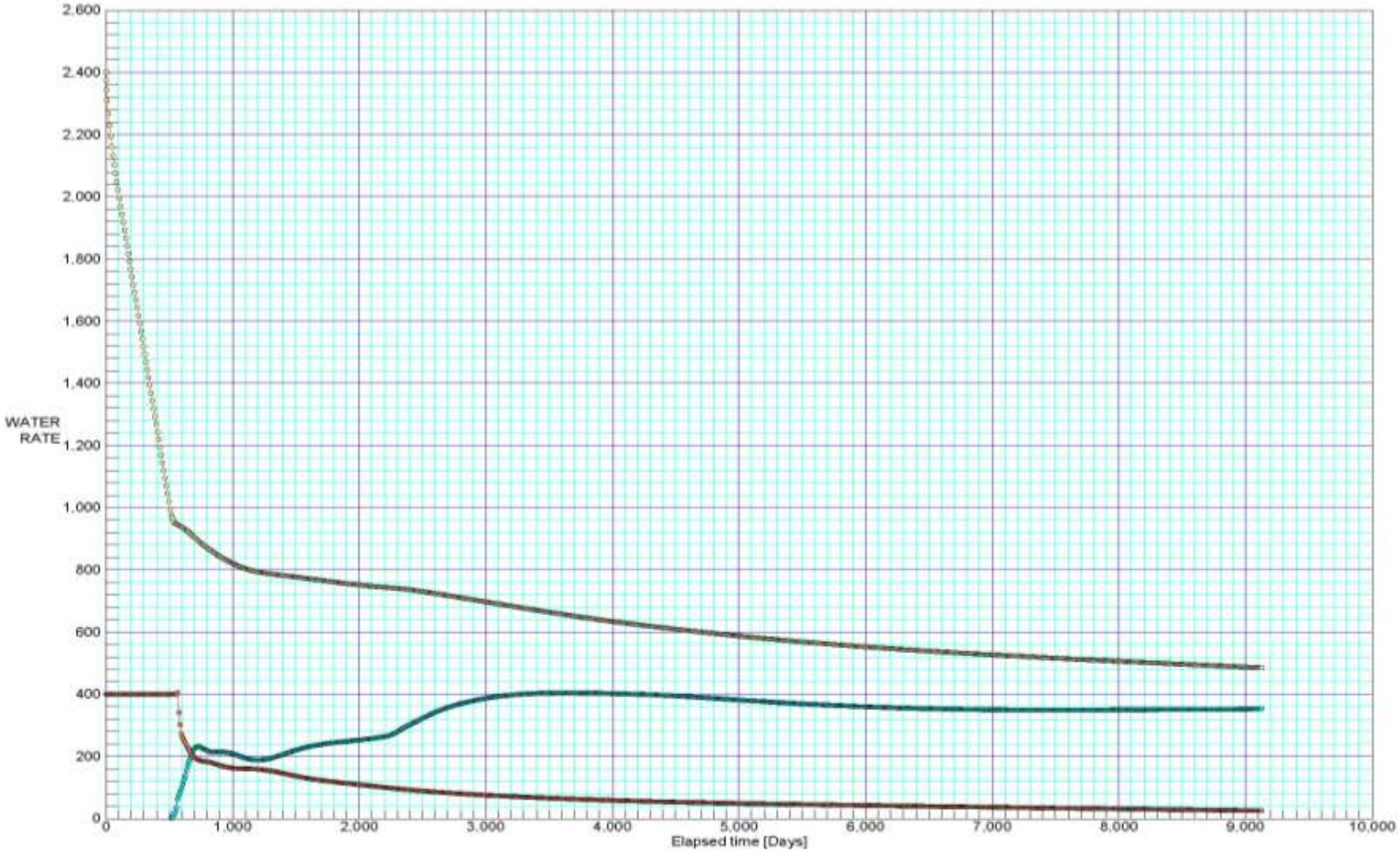
Parameters for CBM Reservoir Simulations and modeling

S.NO	Parameters	1st Layer	2nd Layer	3rd Layer
	Lignite Seams	Kalol Seam	Sobhasan Top	Sobhasan Bottom
1	Geometry	XYZ		
2	Grid System	6 6 2		
3	Grid Spacing	1312 feet		
4	Average Reservoir Temperature	149^0 f		
1	No of days (TMAX)	9125		
2	No of time Steps	999		
3	Unit System	English		
4	Reservoir Phase (MCODE-1)	GAS-WATER		
5	Gas Composition	0.95% in fraction		
6	Dual porosity/Single permeability	YES		
7	Single Component (methane) System	YES		
8	Solution Gas	NO		
9	Gas readsorbed	YES		
11	Initial gas desorption pressure(PD1)	980 PSI	973 PSI	900 PSI
12	Langmuir Pressure (PL)	975 PSI	899 PSI	841 PSI
13	TAU1 and TAU2 (Sorption Time)	2 Days	2 Days	2 Days
14	Langmuir Volume (VL)	28.81	29.87	30.54
15	Water Rate Per day	400 STB/day		
16	Gas Content	14.4418 scf/cuft	15.5254 scf/ft	15.7875 Scf/cuft
17	Permeability (Kx;Ky;Kz)	15 15 2 md	15 15 2 md	15 15 2 md
18	Depth of well below sea level (EL)	4790 feet	4890 feet	4995 feet
19	Gas-Water Contact (GWC)	2654 feet		
20	Initial reservoir pressure below sea leavel (PWRIG)	1450 PSI		

Gas and water rate production at Mehsana



Falling Pressure with Gas and water rate production



POSSIBLE AREAS FOR DEEPER (>300M) LEVEL COAL RESOURCE

- *South Eastern part of Jharia Coalfield*
- *Eastern part of Raniganj Coalfield*
- *Western part of Ib-River & Talcher Coalfield*
- *Westcentral part of Mand-Raigarh Coalfield*
- *Central part of main basin, Singrauli Coalfield*
- *Eastern part of Birbhum-Rajmahal Coalfield*
- *Eastern part of Pench-Kanhan Coalfield*
- *Central part of north Godavari Coalfield*

Summary

- CBM may be produced in pockets in India.
- CMM may also be produced in selected mines.
- ECBM may be initiated at few locations in deeper coal seams.
- This would reduce the load of atmospheric methane and store CO2 in deep seated coal.

THANK YOU

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