



Low Permeability Coal, Investigation and Management 27.6.2012

Ian Gray

Sigra Pty Ltd

93 Colebard Street West, Acacia Ridge, Brisbane Queensland 4110, Australia

Tel: +61 (7) 3216 6344 Fax: +61 (7) 3216 6988

<http://www.sigra.com.au>

Email: info@sigra.com.au



Key Parameters-1

Gas Content

Sorption Pressure – Linked by Sorption Isotherm
to the Gas Content

Reservoir Pressure – Usually initially water
pressure but then
sorption pressure

Diffusion Coefficient

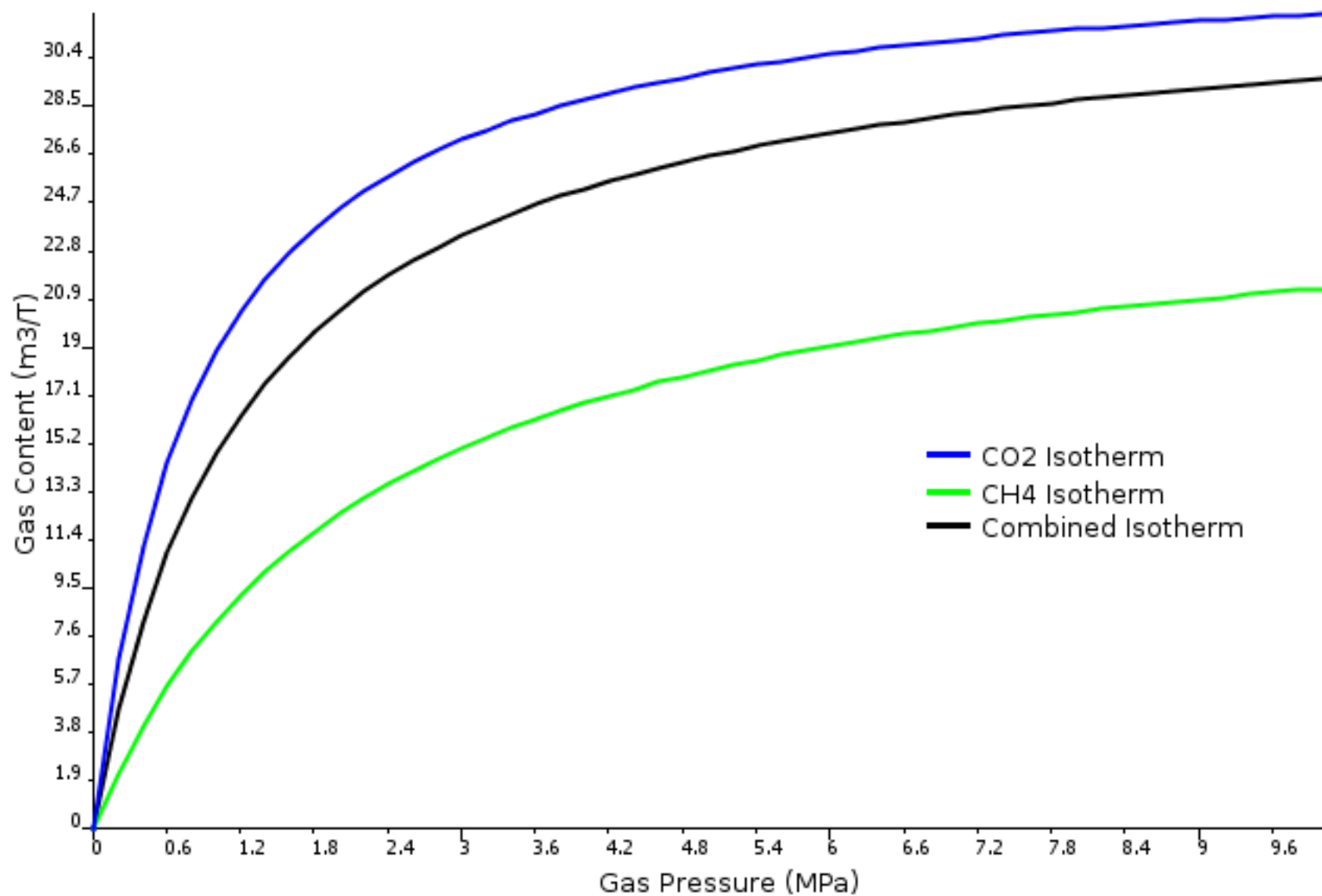
Permeability

Key Parameters-2

- Permeability
- Permeability change with effective stress
- Coal mechanical properties
 - stiffness which is dependent on stress
 - Poisson's Ratio
 - strength
 - toughness = energy to cause breakage

THE IMPORTANCE OF THE SORPTION ISOTHERM

- The sorption isotherm is the relationship between gas content at reservoir pressure
- It is dependent on
 - Coal Type
 - Gas composition
 - Order by which the gas got into the coal?



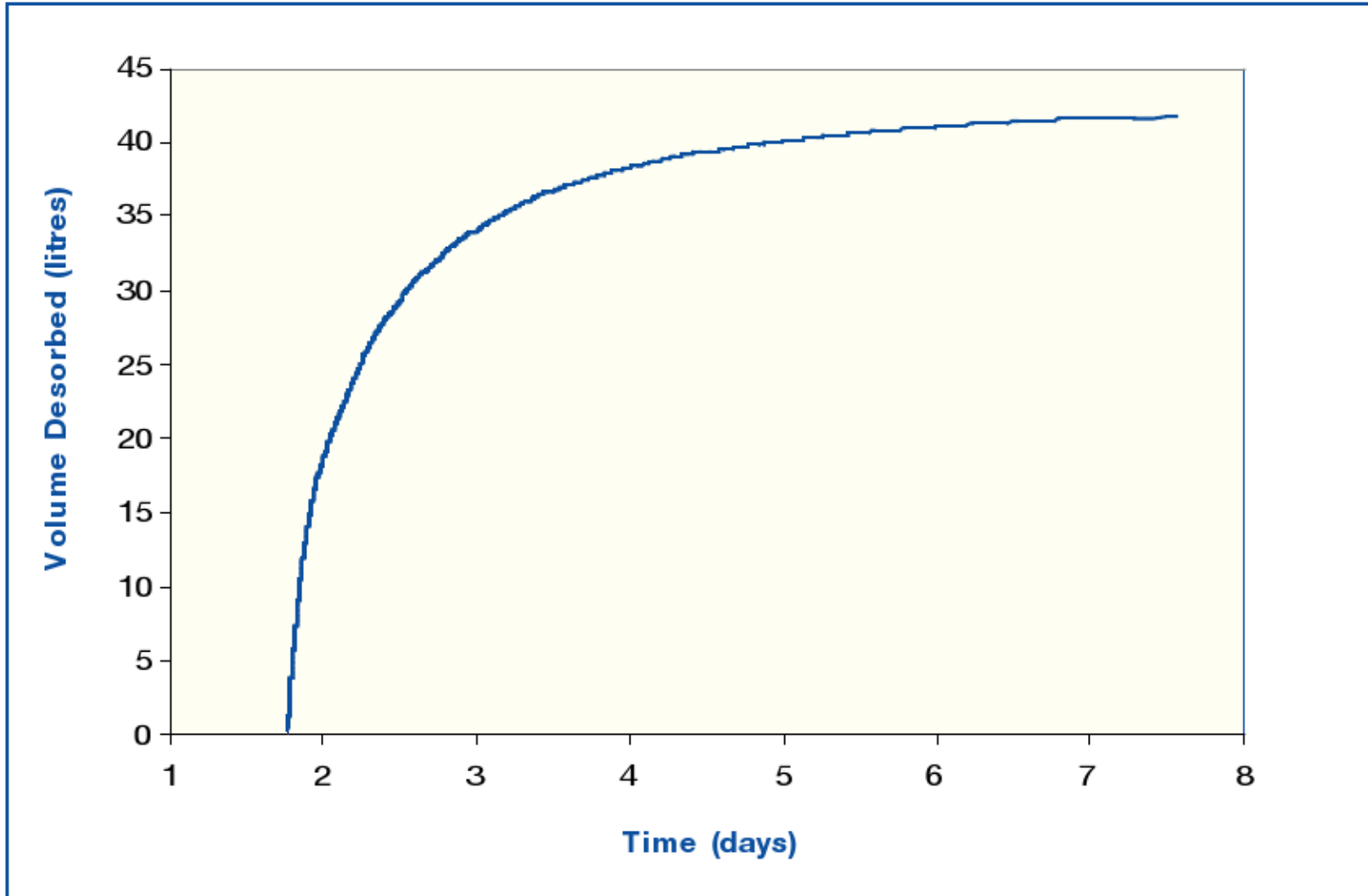
Mixed Gas Isotherms

- Water and Gas competing for storage
- CH₄ vs CO₂ vs H₂O
- Isotherms obtained by re-absorption process
- Have to calculate mixed gas behaviour?
- Need for
- NATIVE SORPTION ISOTHERMS
 - MEASURE WHAT YOU GET OUT OF COAL

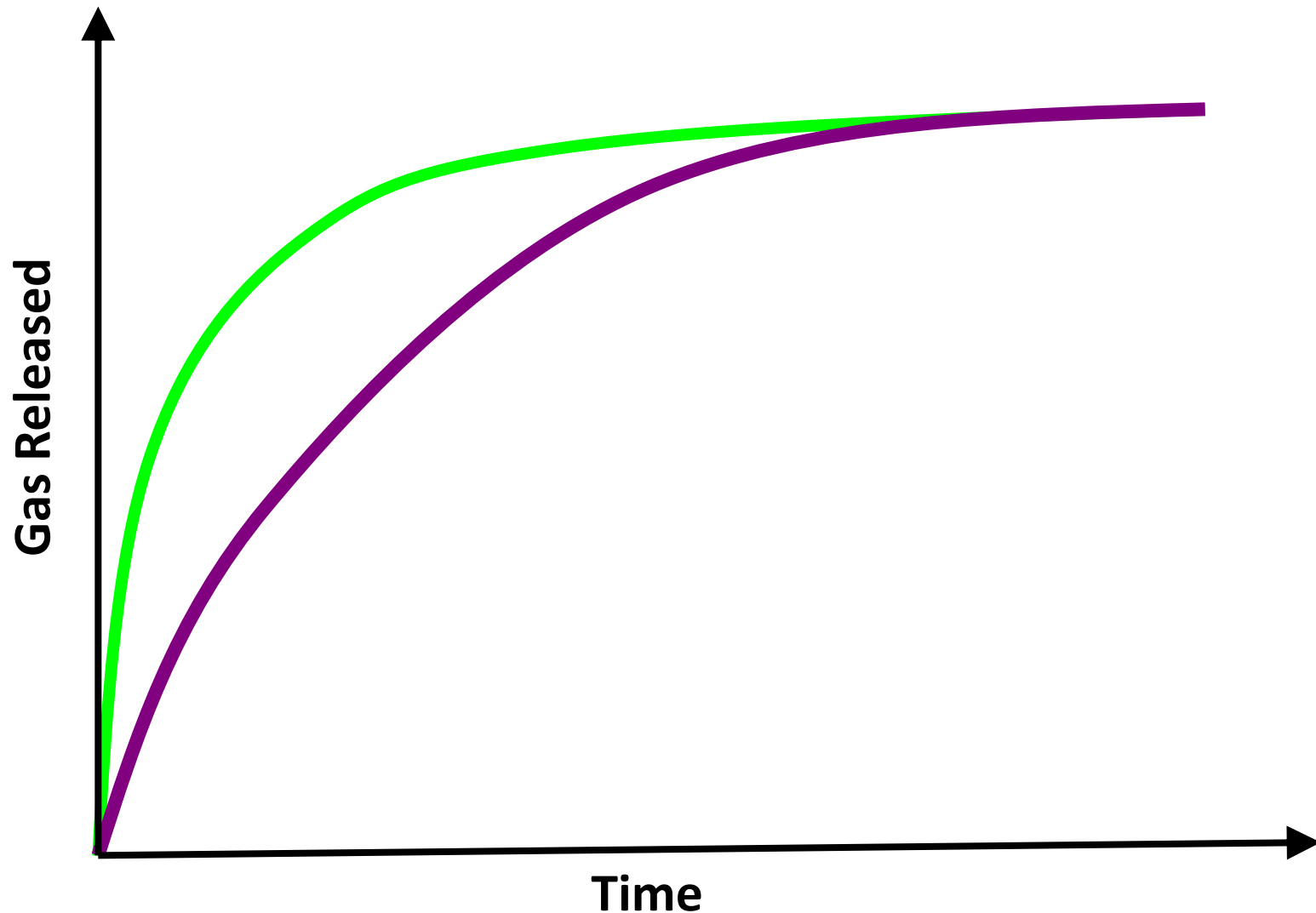
DIFFUSION IS IMPORTANT

- DIFFUSION RATE IS DEPENDENT ON
- GAS CONCENTRATION GRADIENT
- DIFFUSION COEFFICIENT
- Diffusion is the key to gas release from broken coal
 - In an outburst
 - On the face or belt
 - From the goaf

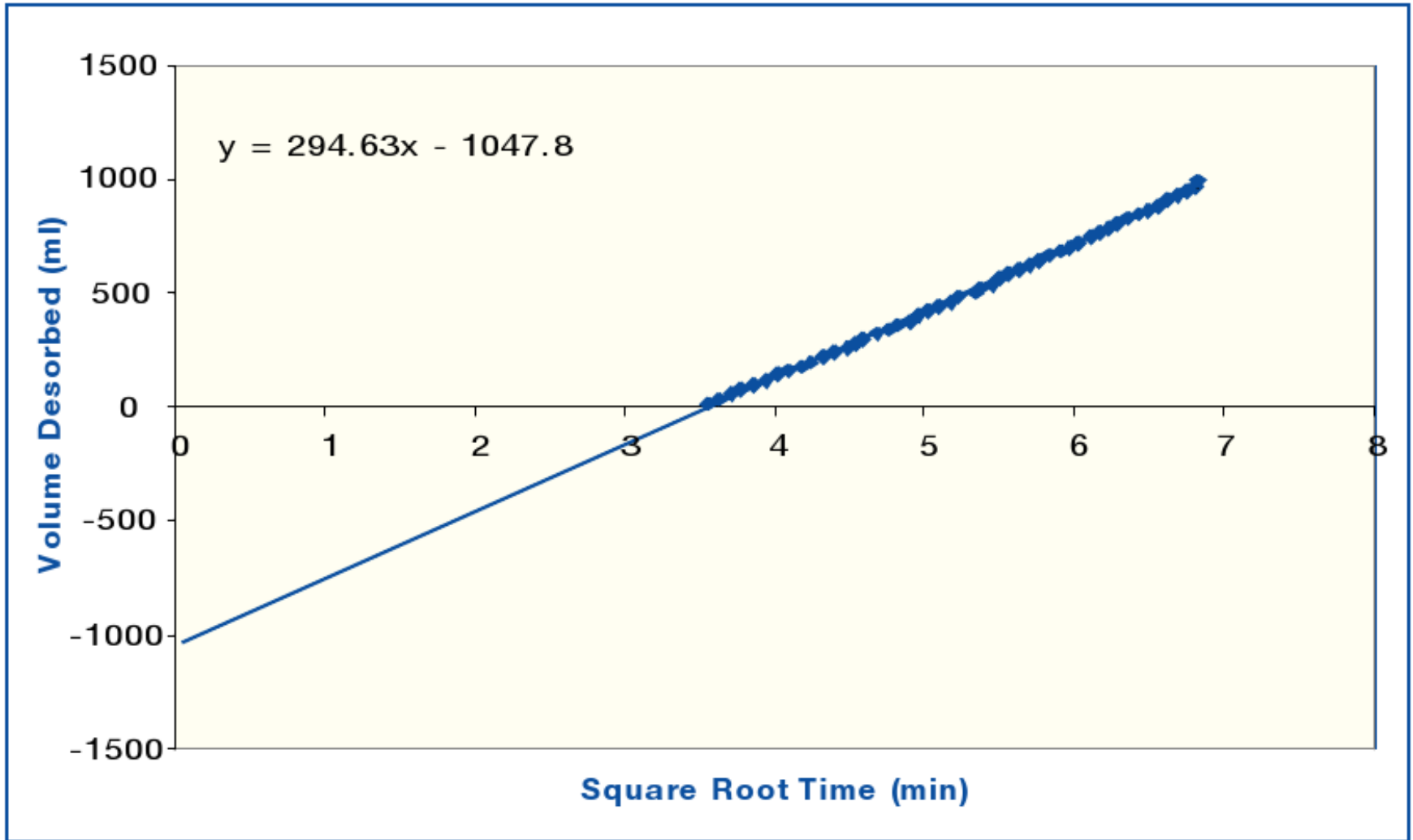
Desorbed Gas Measurement



Core Desorption and Theoretical Diffusion Curves from a Uniform Cylinder



Lost Gas Determination Plot



SHORT TERM DIFFUSION COEFFICIENT

- MAY BE CALCULATED FROM THE SLOPE OF THE INITIAL DESORPTION PROCESS AND THE TOTAL GAS CONTENT OF THE CORE
- IS IN ALL PRACTICALITY A COMBINED MEASUREMENT OF DIFFUSION COEFFICIENT AND CORE FRACTURING
- IN HIGHLY FRACTURED CORE WE SHOULD SIMPLY NOTE THE RATE OF DESORPTION OF THE SAMPLE MASS OF COAL

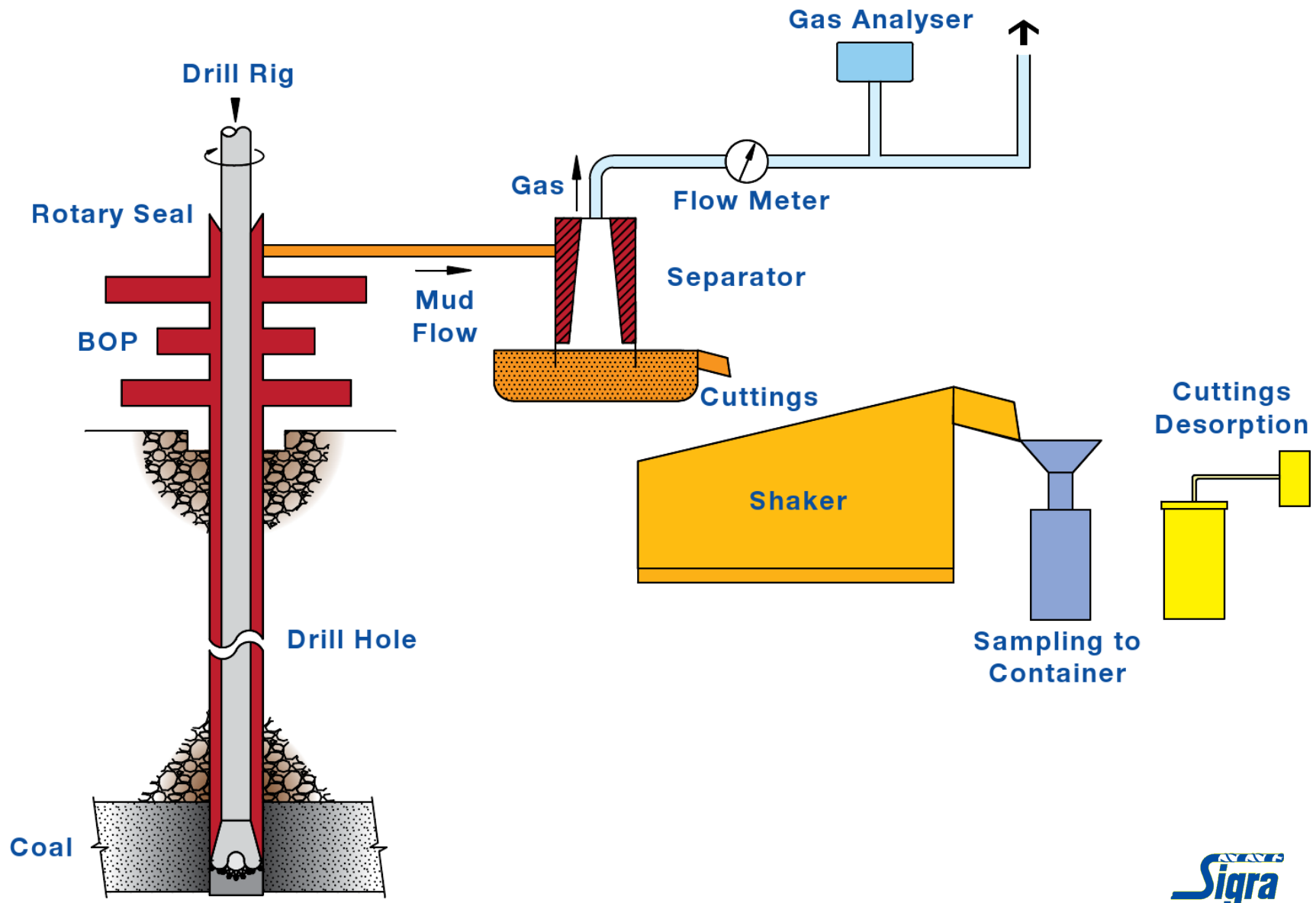
Estimate of Lost Gas is Frequently Wrong!

- Need to pay attention to this if lost gas fraction estimate $> 10\%$
- But lost gas is frequently $> 10\%$ and sometimes reaches 50%
- Need a better process of estimating what is happening
- Sibra simulate the process of core withdrawal to find gas loss under varying pressure in the borehole and on surface.

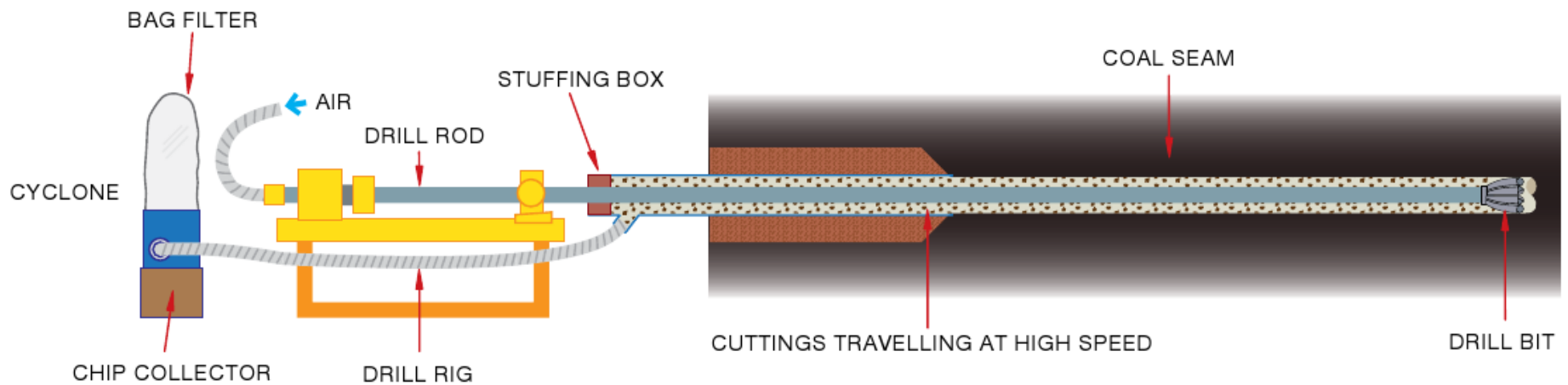
DIFFUSION COEFFICIENT IS AN IMPORTANT OUTBURST PARAMETER

- HIGH GAS CONTENT
 - + HIGH DIFFUSION RATES
 - + SMALL PARTICLES (brittle or broken coal)
 - = HIGH OUTBURST RISK

Gas Content Without Coring Process

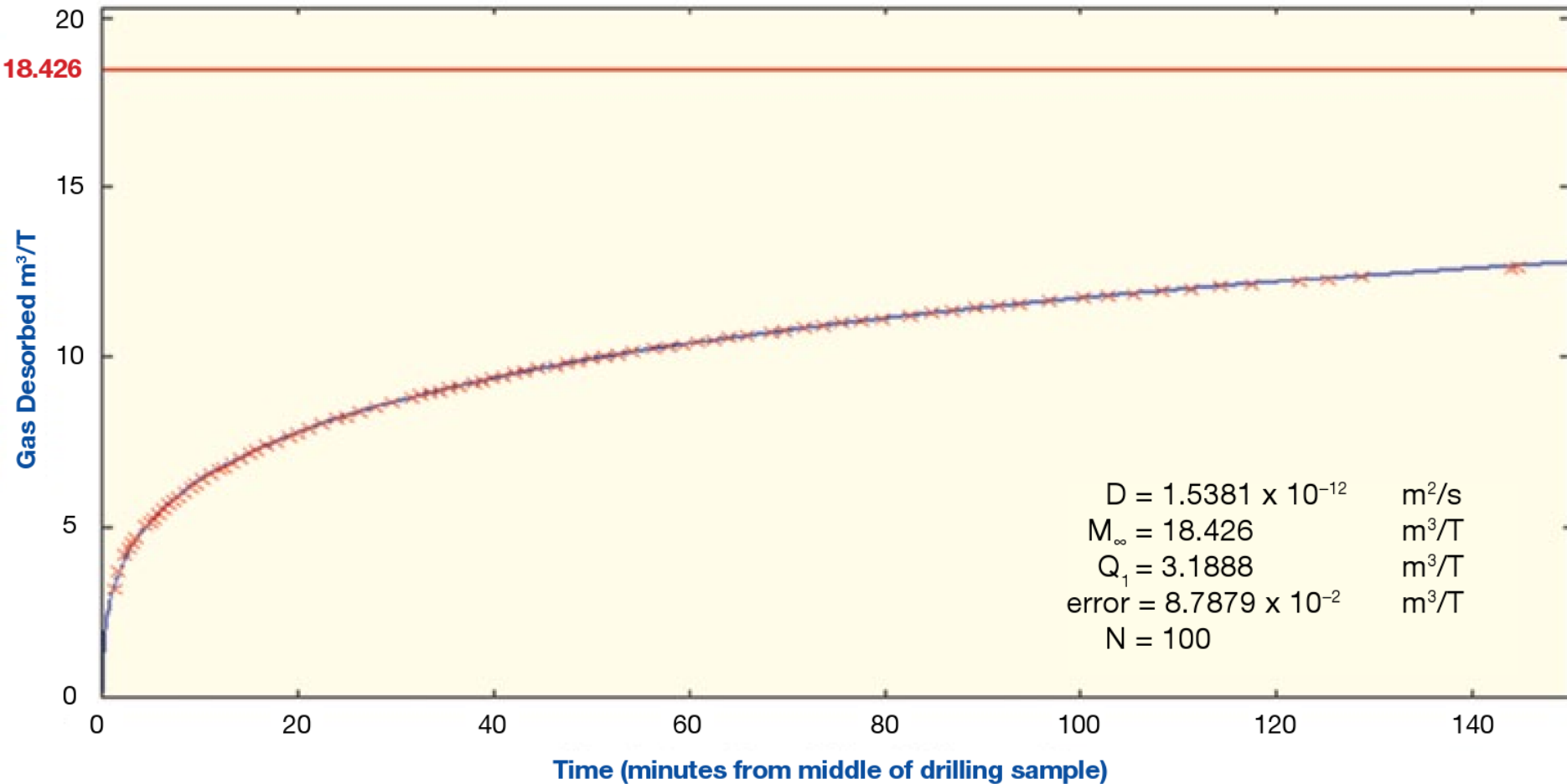


Dry Drilling Sampling System

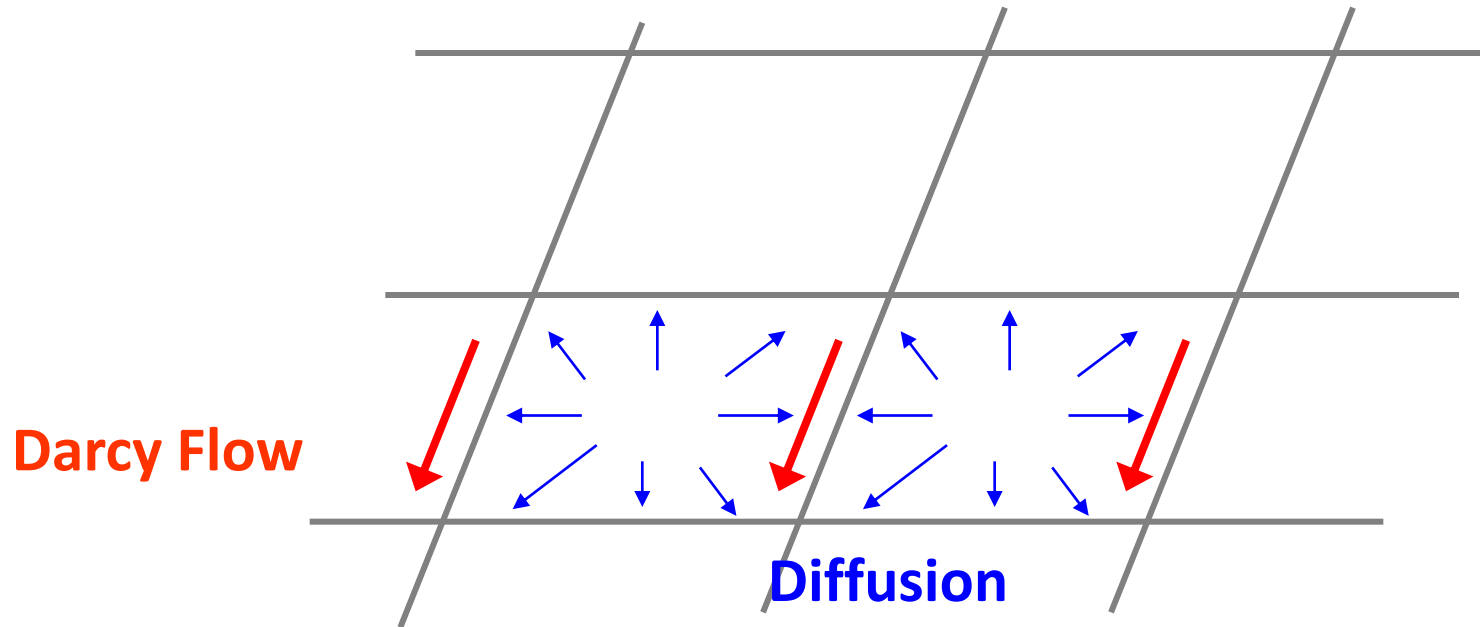


Dry drilling sampling system

Modelled Gas Desorption vs. Recorded Gas Desorption



Gas Flow In Coal



Darcy Flow

$$V = -\frac{k}{\mu} \cdot \frac{dp}{dx}$$

Diffusion

$$F = -D \frac{dC}{dx}$$

INVOLVES WATER AND GAS
THOUGH SOME DRY SEAMS DO
EXIST

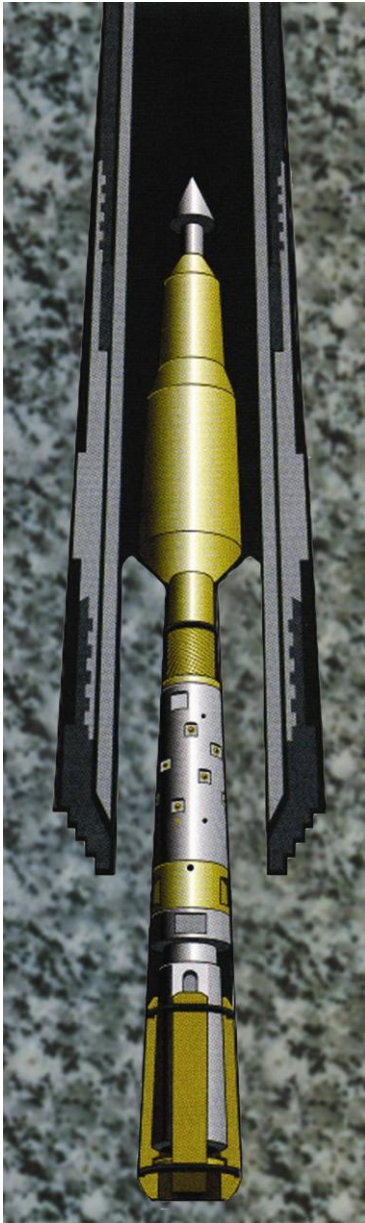
DROPPING WATER PRESSURE TO ACHIEVE
DESORPTION MUST BE ACHIEVED FIRST IN A
WET COAL

THE RATE LIMITING STEP IN GAS DRAINAGE MAY
THEN BE EITHER DIFFUSIVE FLOW OR
PERMEABILITY

DIFFUSION GOVERNS IF THE CLEAT SPACING IS
HIGH

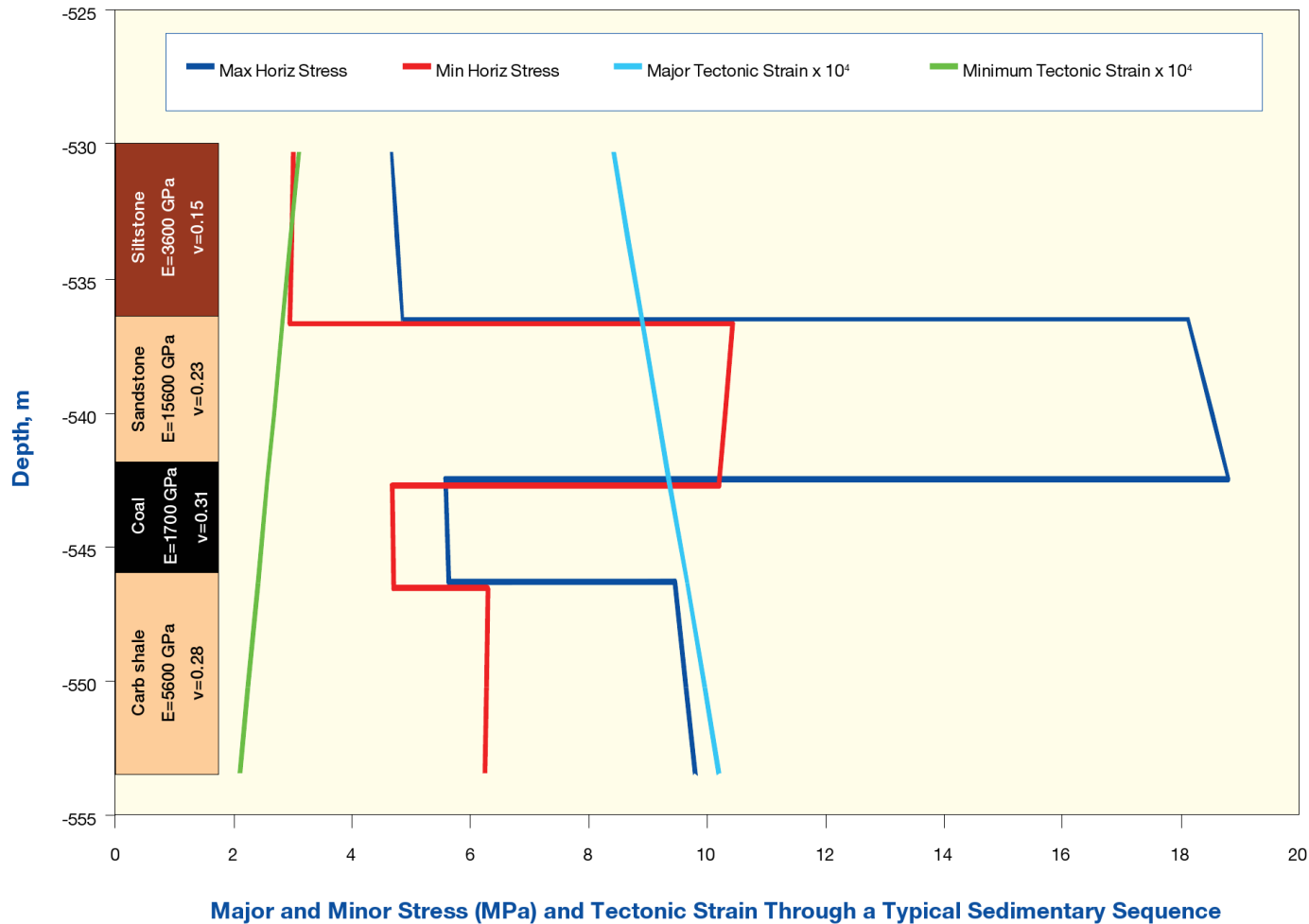
LOW PERMEABILITY COALS

- NO CLEATS
- FILLED CLEATS
- HIGHLY STRESSED
 - PERMEABILITY MAY CHANGE BY ORDERS OF MAGNITUDE WITH CHANGES IN EFFECTIVE STRESS



Siga Stress Measurement Tool

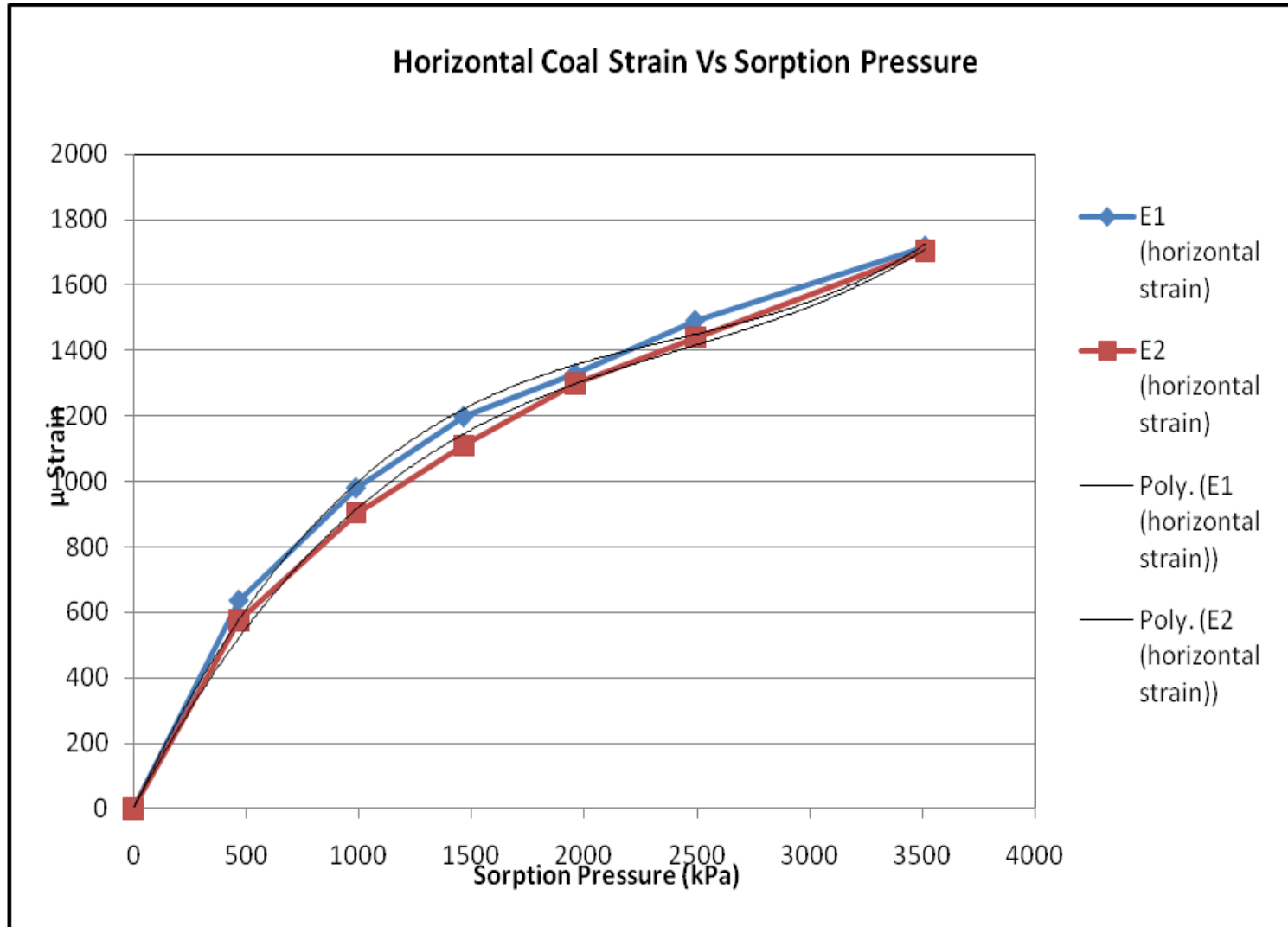
Layered Sedimentary Strata with Varying Stiffness and Poisson's Ratio

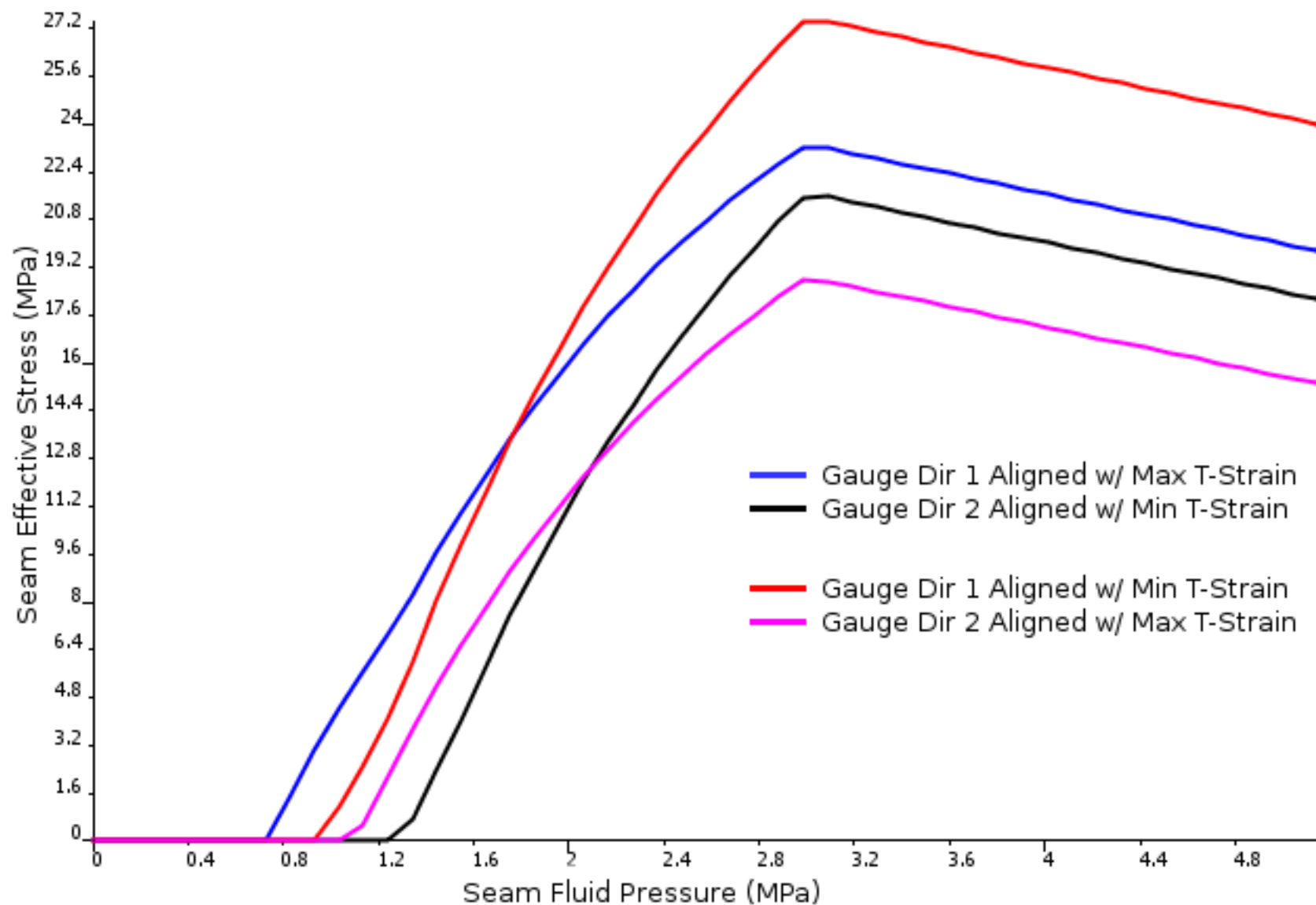


THE IMPORTANCE OF STRESS PATH

- THE EFFECTIVE STRESS IN COALS CHANGES WITH DRAINAGE DUE TO LOWERING FLUID PRESSURE AND DUE TO THE EFFECTS OF SHRINKAGE
- WHICH DOMINATES?

Horizontal Coal Strains vs. Sorption Pressure





Not all seams show reducing stress

- In higher stress environments (deeper – higher tectonic strain) the stress path will show increasing effective stress.
- The same applies to cases where the sorption pressure is low
- fluid pressure reduction = increase in effective stress without shrinkage

Carbonates in cleats

- Carbonates in cleating reduces permeability
But
- If the carbonate can be removed by acid
(leaching through acid hydrofracturing)
- Then a small amount of carbonate that can be removed will de-stress the coal leading to improved pathways for fluid and de-stressing
- 0.25 % carbonate removal
may equal total de-stressing



Mining Tight Highly Gassy Coals

- Old European Practise to mine an initial seam in a sequence
- Mining of one seam de-stresses adjacent seams and permits gas drainage
- Assumes that one seam can be mined safely
- This is rate dependent – traditionally the rates are low

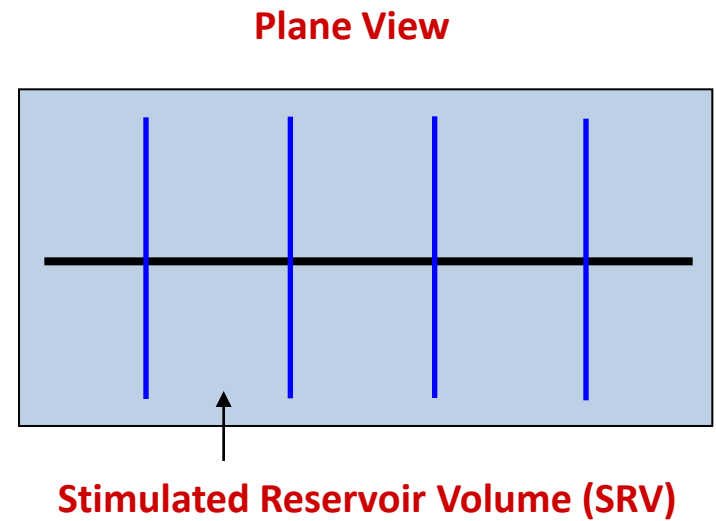
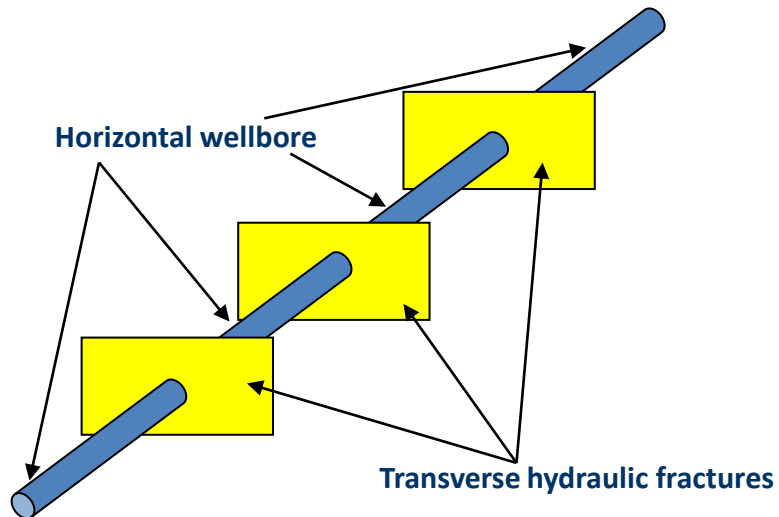


Tight Shale Gas Extraction

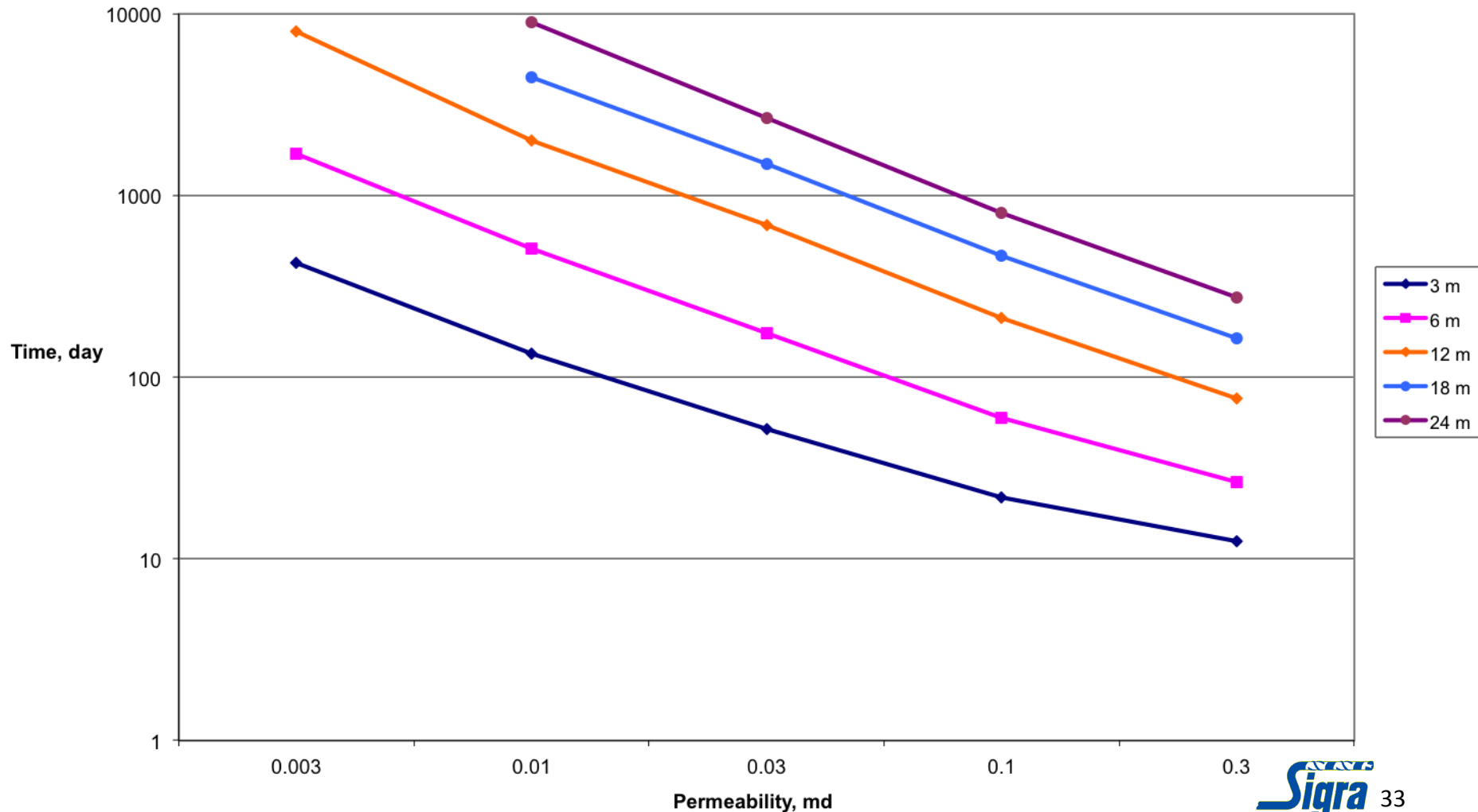
- Formation must be gassy
- Drill sub horizontal wells in tight formation
- Undertake multiple hydrofracturing from horizontal well
- Create primary permeability

Combine Old European and Tight Gas Practise

- Ideal Concept - Horizontal Wells with Transverse Fractures
- This is not a normal fracture initiation orientation from a hole.



Drainage times Vs frac spacing for 15 to 3 cu.m/tonne methane



Drilling in coal may not be possible

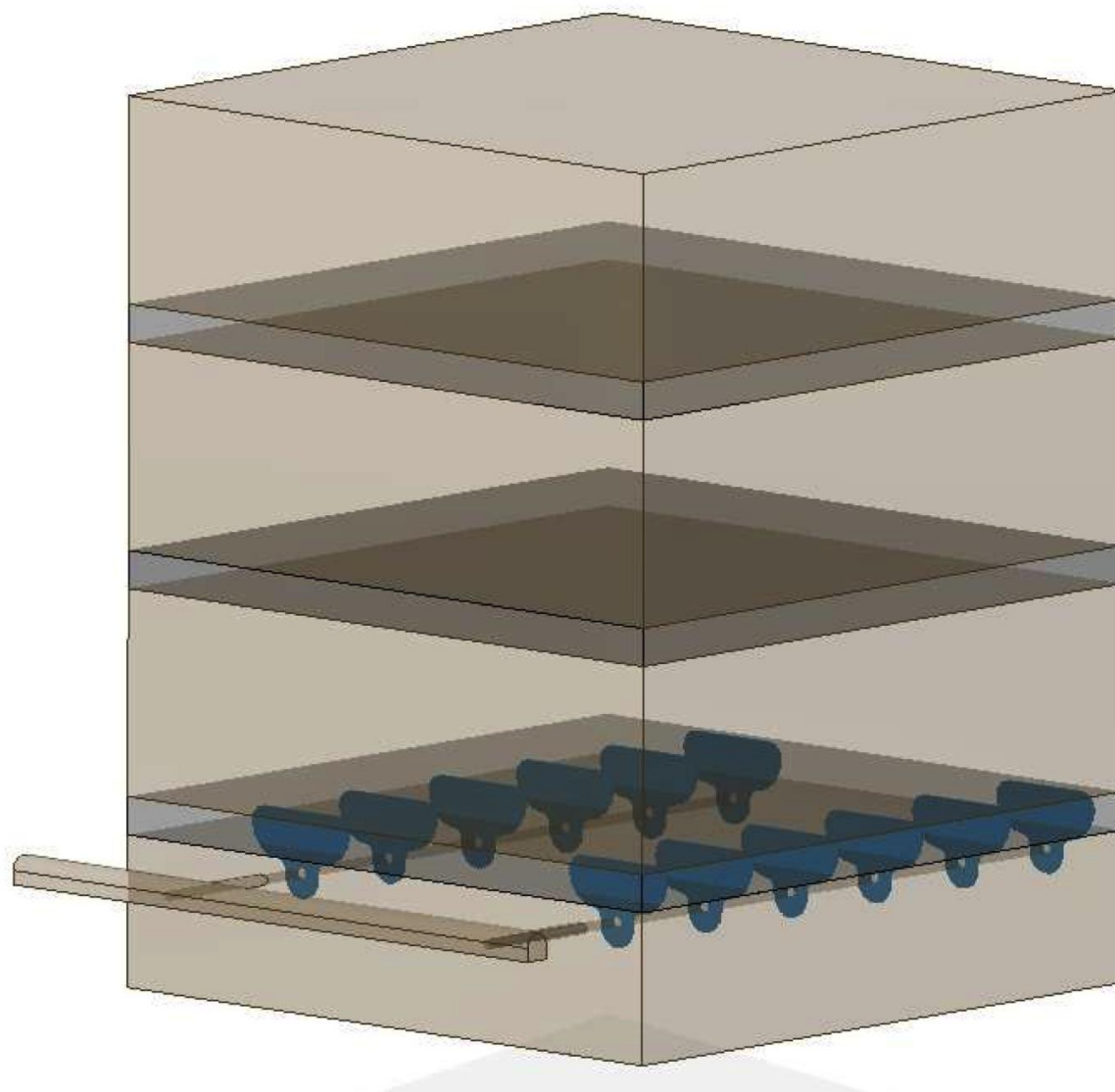
- High effective stresses and weak coals make it impossible to maintain an open hole.
- If it is possible to drill it is not possible to maintain the hole – as the fluid pressure decreases the effective stress at the borehole wall increases and the hole collapses
- Casing in coal is not practical option in coals and certainly not steel casing for hydrofracture

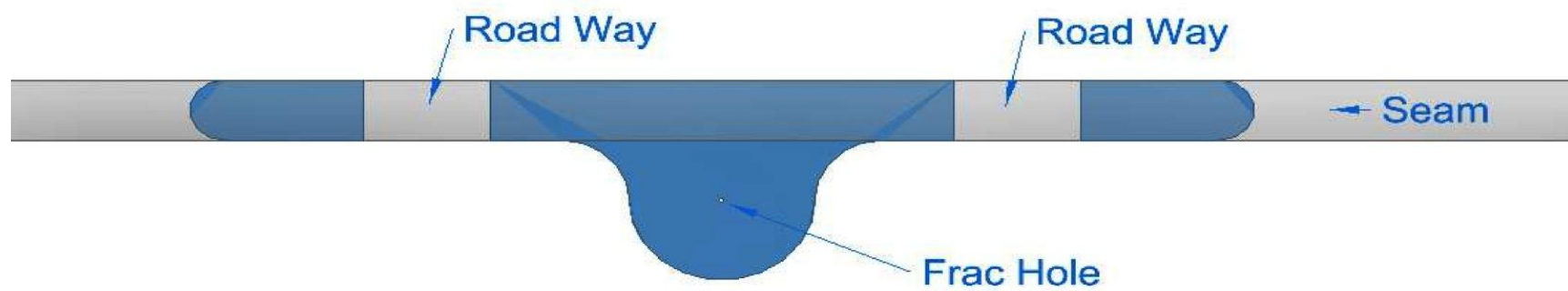
Drill out of the Coal and Hydrofracture

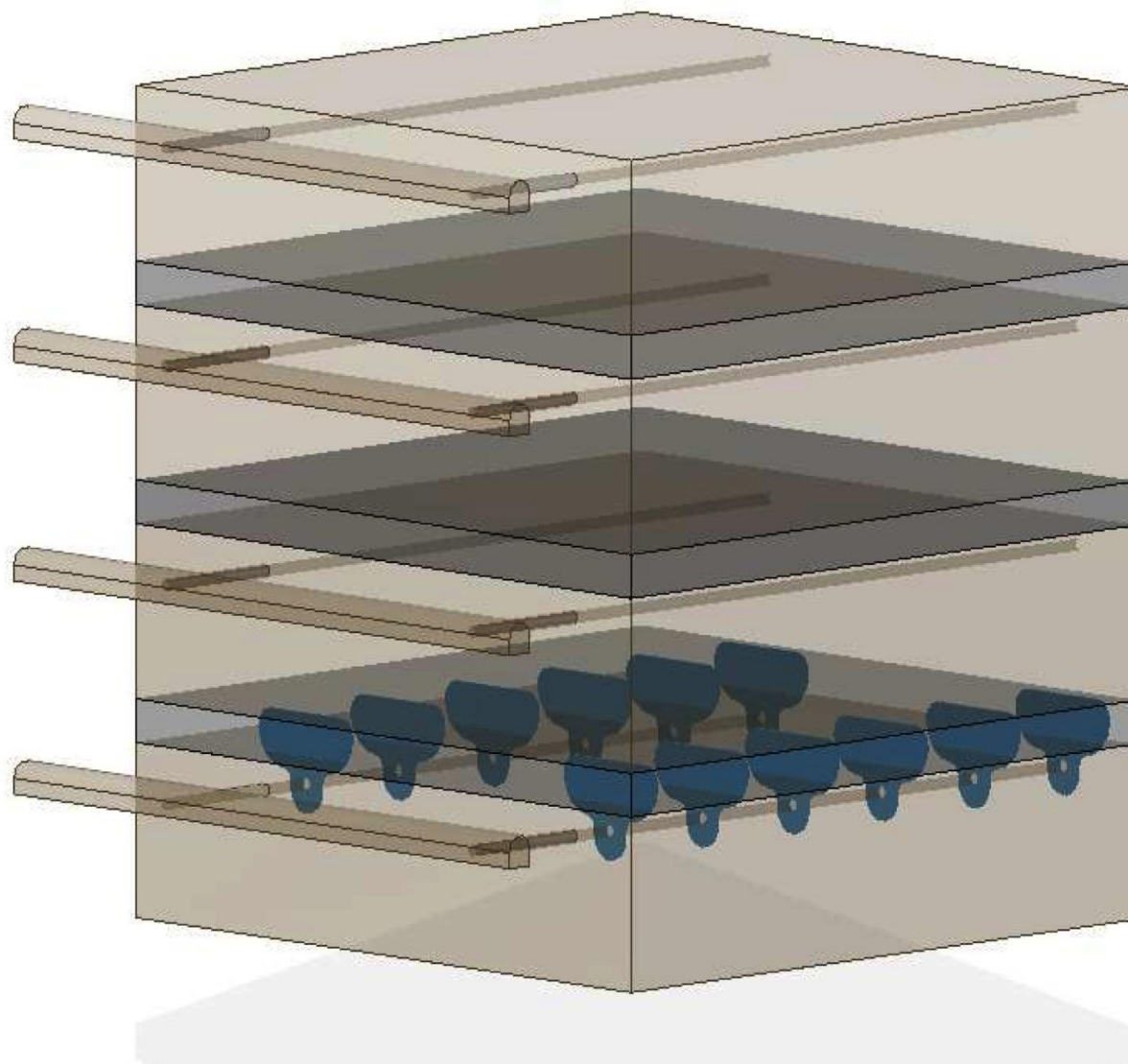
- The minimum stress must be horizontal to get a vertical fracture
 - Dependent on tectonic strain and stiffness
 - High stiffness and tectonic strain lead to the minor stress being vertical = horizontal fracture
- The hole can be cased, cemented and perforated.
- Multiple fracturing points from hole into the seam

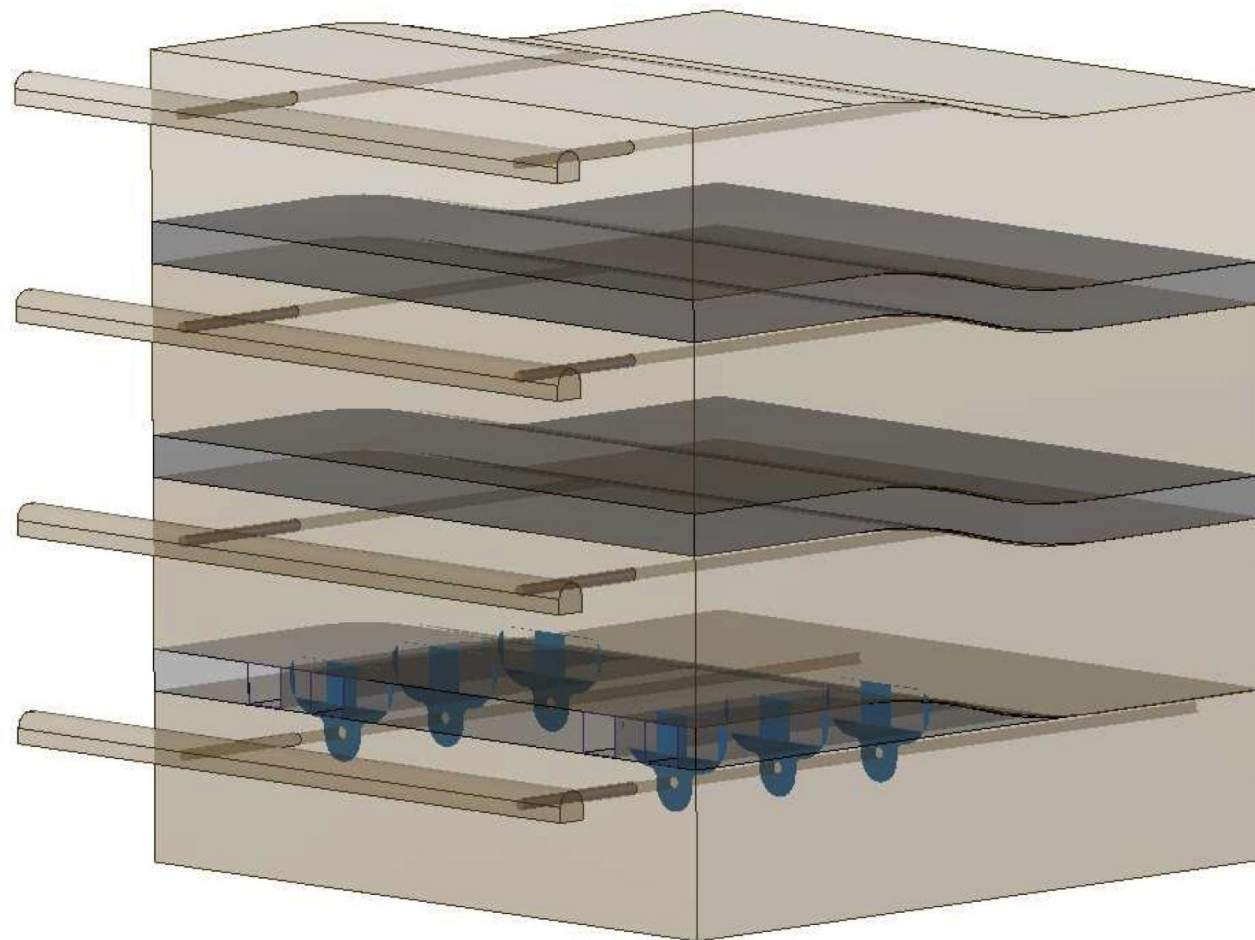
Degassing Block an Issue

- Typically Europeans & Asian mines use abutment stress ahead of the longwall to crush the coal
- Gas is gathered by multiple holes in seam (which may crush out) or by cross measure holes (expensive).
- Consider slot cutting



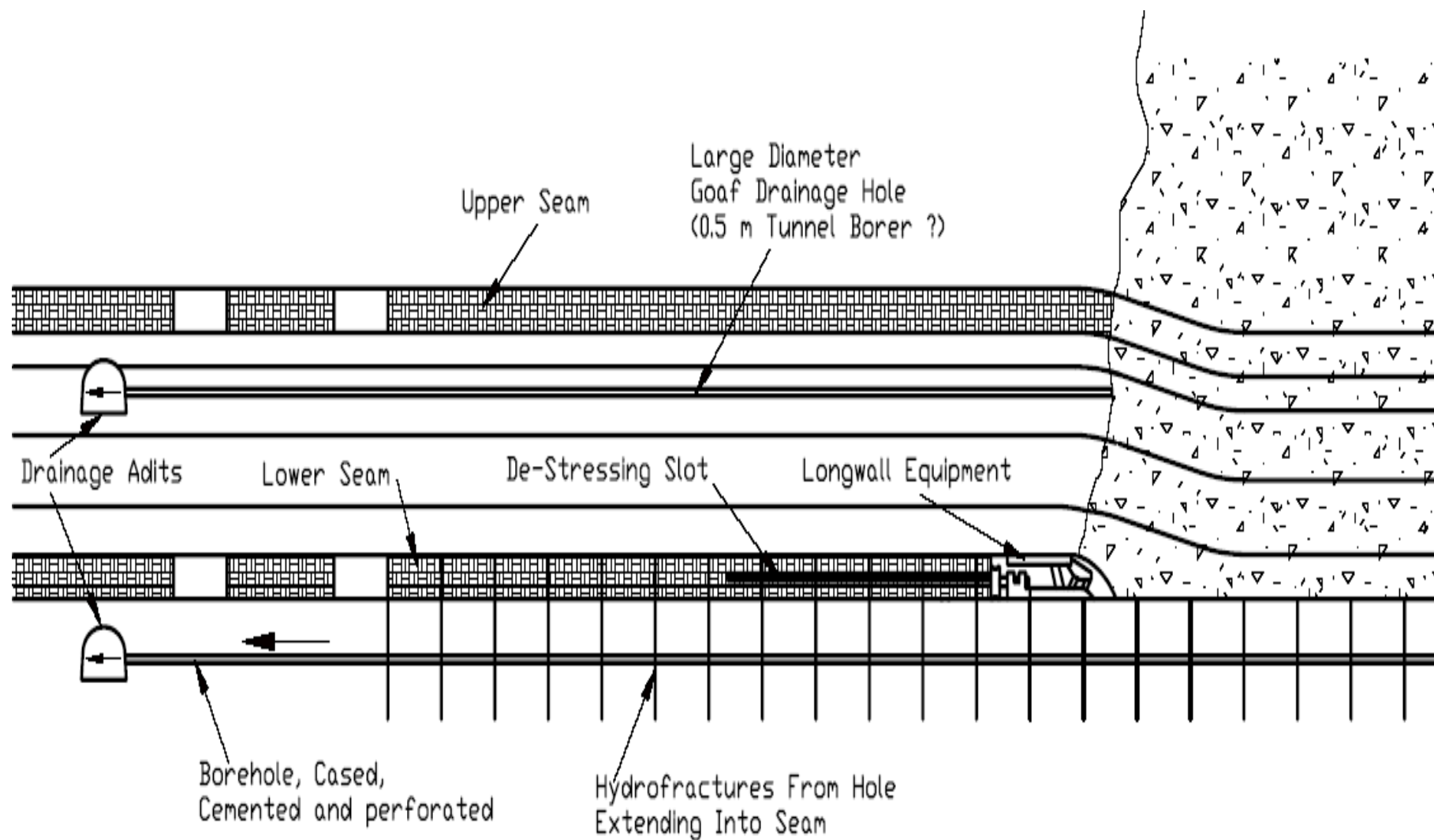






Mining Method

- Multi level mining
- Improves reserve
- Need to mine and entry seam
- Uses mining to de stress other seams
- Need for good goaf drainage
- Consider all drainage from rock drivage





Thank You

Sigra Pty Ltd

93 Colebard St West, Acacia Ridge, Brisbane Queensland 4110, Australia

Tel: +61 (7) 3216 6344 Fax: +61 (7) 3216 6988

<http://www.sigra.com.au>