DART ENERGY

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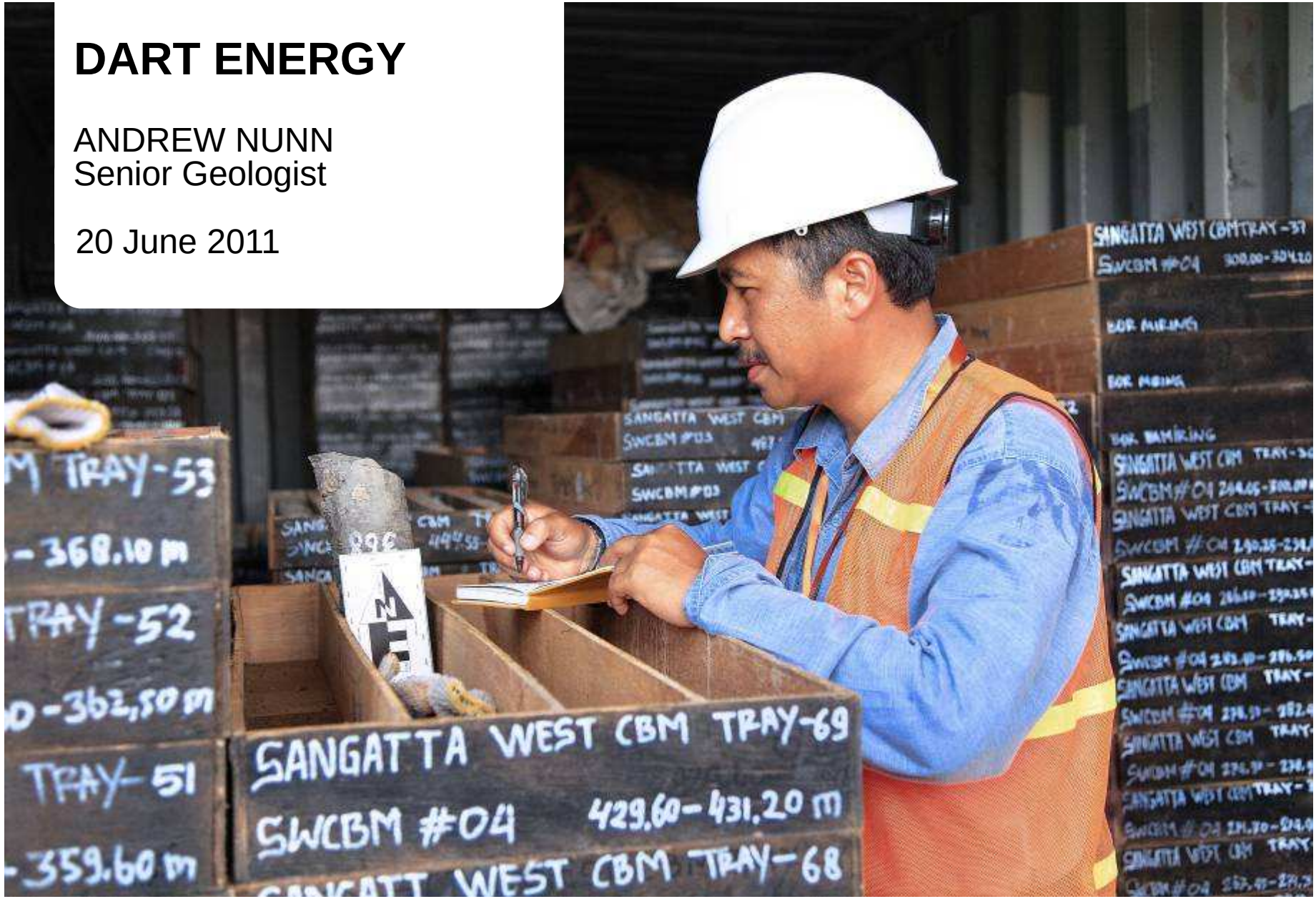
Senior Geologist

20 June 2011



European Coal Bed Methane

Challenges and Cause for Optimism

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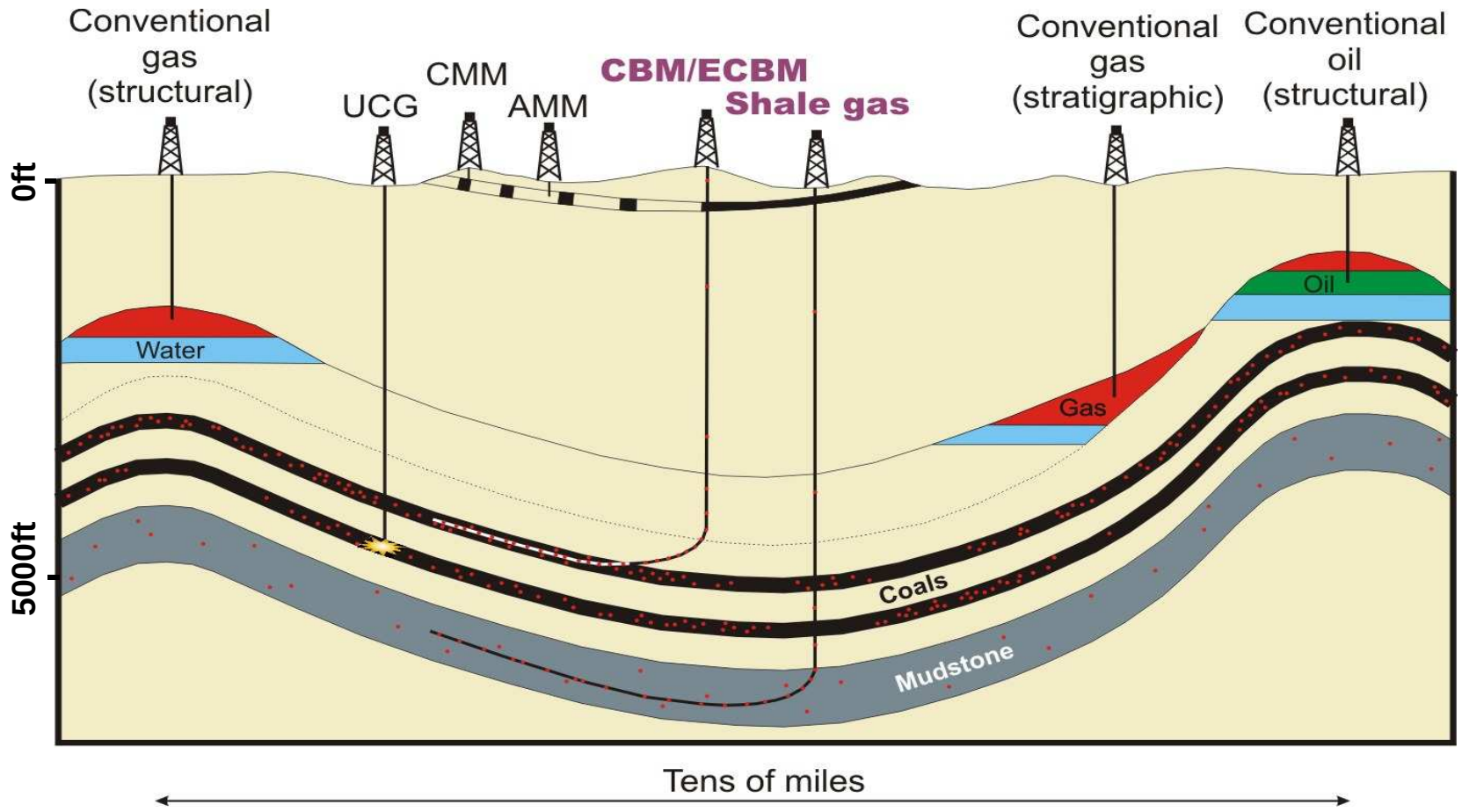
Unconventional v's Conventional Reservoirs



In CBM, coal is the source and the reservoir – concepts of trap and seal don't apply

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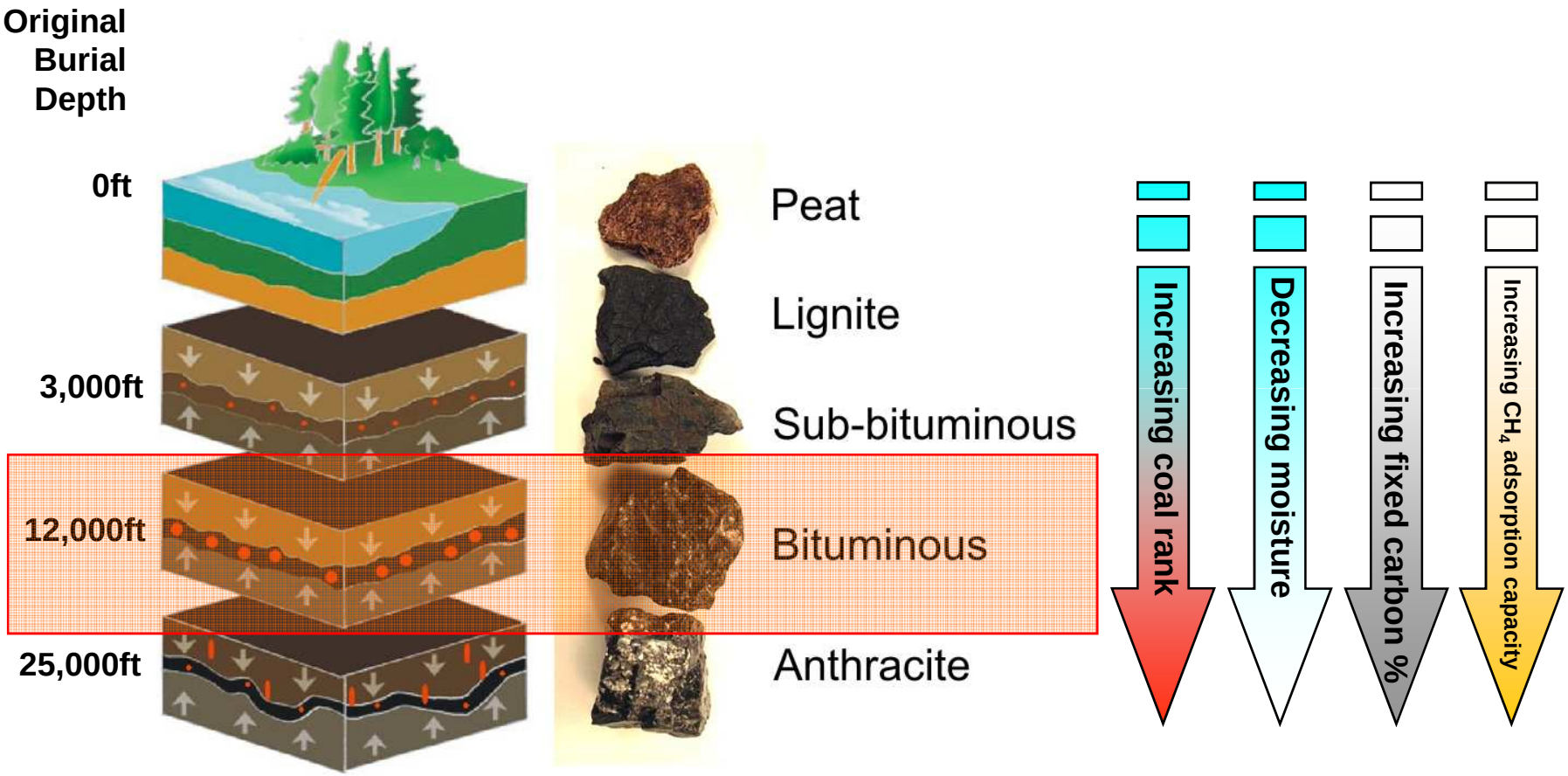
Coalification and CBM



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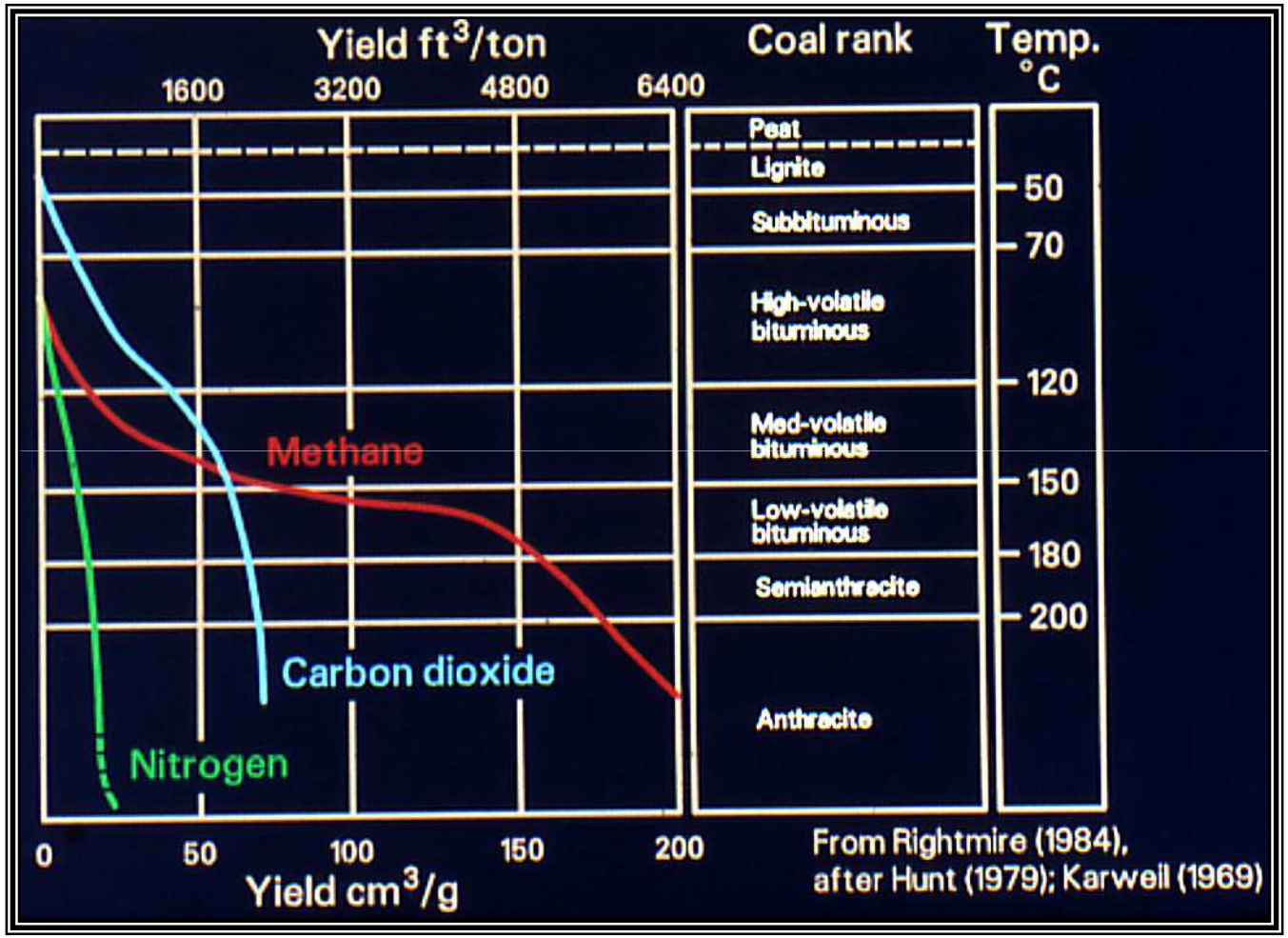
Coalification and CBM



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Effect of Maceral Content on Gas Generation

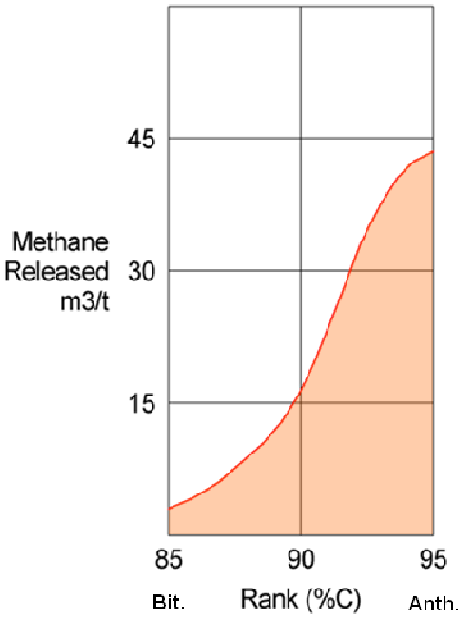
Macerals – the microscopic mineralised remnants of the original coal-forming vegetation

Vitrinite Group

Bright coal originating from woody and cortical plant tissue.

More oxygen

Coalification gas:

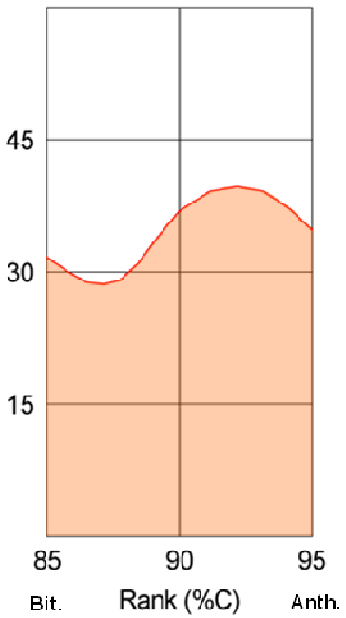


Exinite Group

Comprises spore cases, spores, cuticles and resins

More hydrogen

Coalification gas:

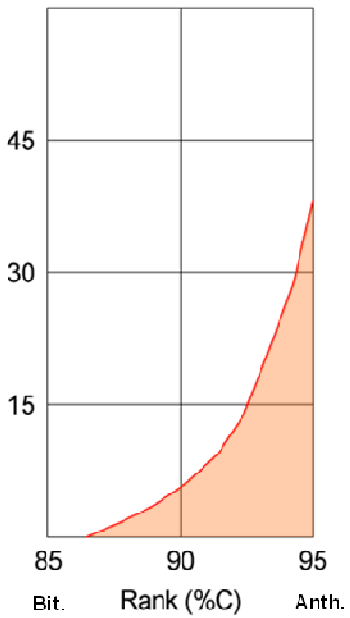


Inertinite Group

Structure with close resembance to woody charcoal with well-developed cellular structure

More carbon

Coalification gas:



Inertinite macerals have:

- Least potential for gas generation during coalification
- Lower chemical/physical adsorption capacity
- Emit free gas from skeletal structure very rapidly
- Desorb very slowly

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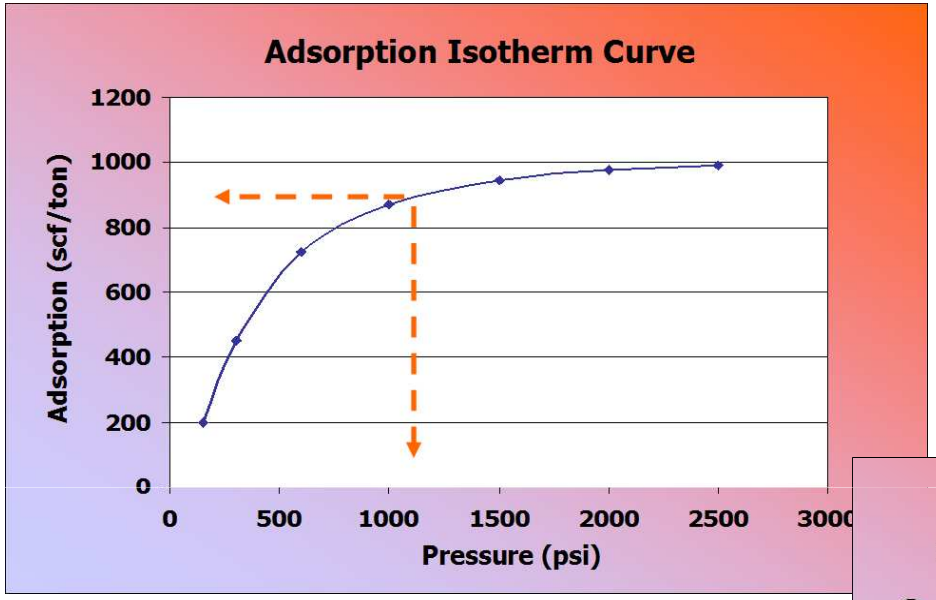
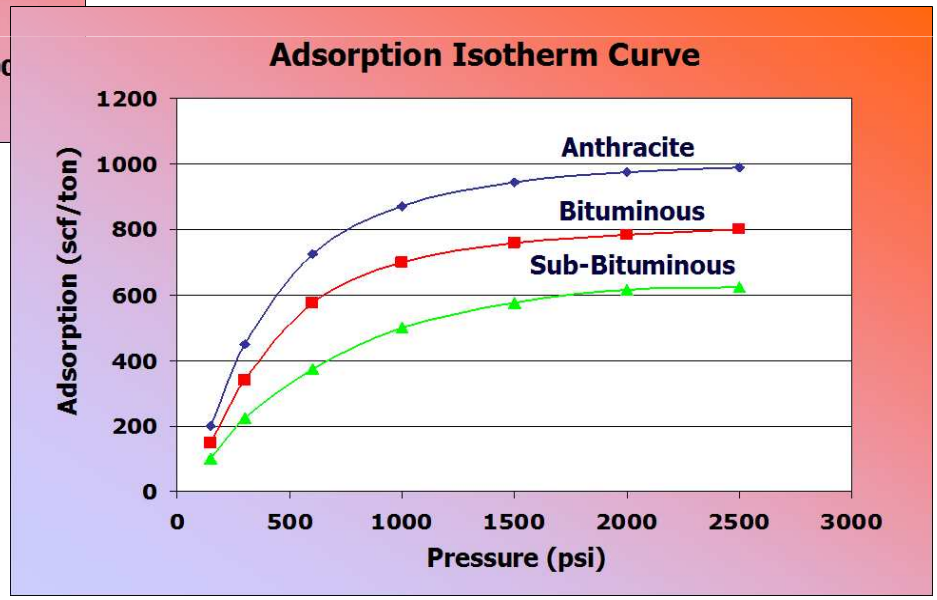
CBM Storage Capacity and Langmuir's Isotherm



Storage capacity of coal is related to formation pressure

Also influenced by coal rank, maceral content and temperature



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Gas Storage Mechanisms in Coal

Effects of Temperature and Pressure

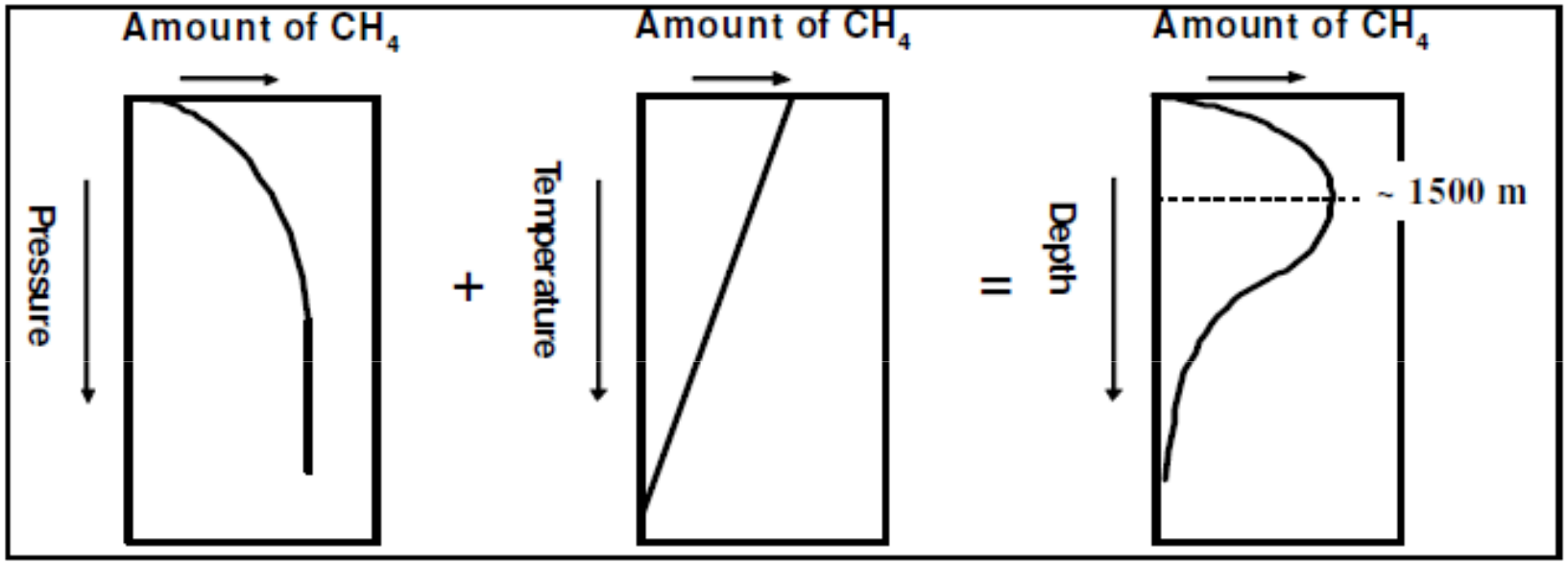

Figure 4-7: *Combined effect of pressure and temperature increase with increasing depth on the amount of methane, assuming normal geothermal gradient and hydrostatic pressure.*

Gas content and storage capacity of coals varies with time depending on temperature and pressure conditions – burial history

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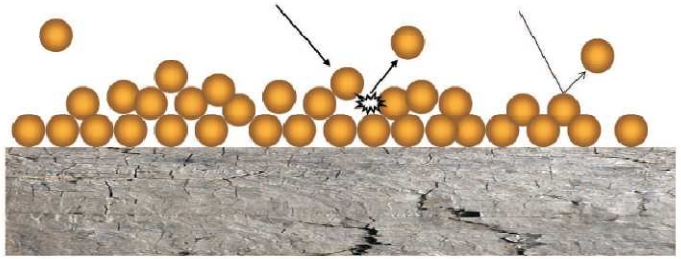
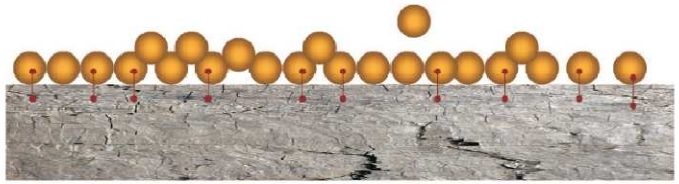
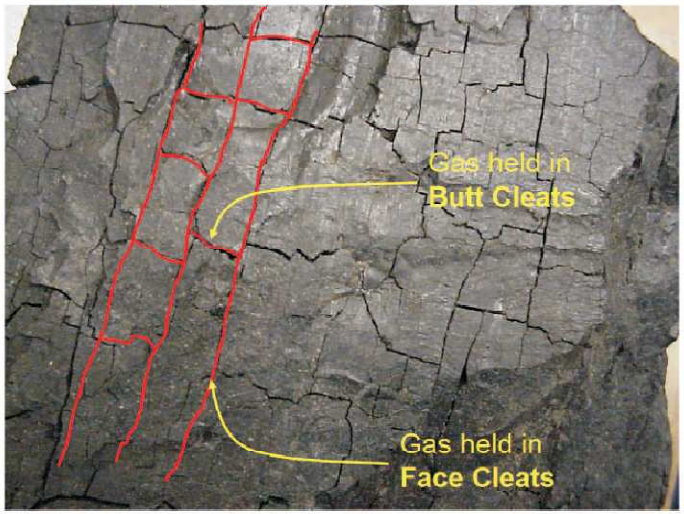
Gas Storage Mechanisms in CBM







1. **Physical adsorption** – intermolecular (van der Waals) forces bind gas to coal surface in micropores

2. **Chemical adsorption** – sharing or transfer of an electron between gas and coal surface in micropores

3. **Free gas** – gas stored in the natural fractures (cleats) and open pores

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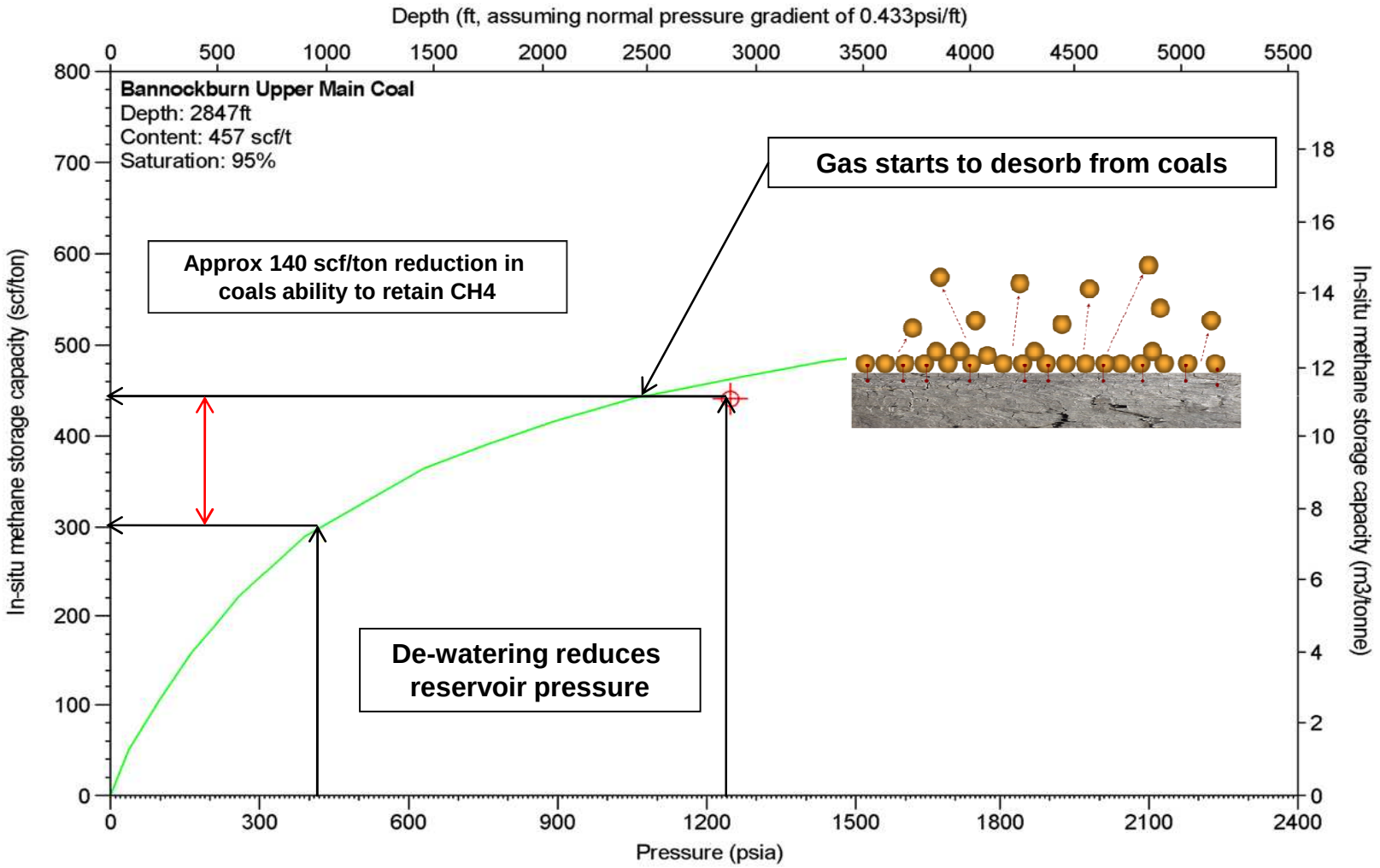
CBM Production Mechanism



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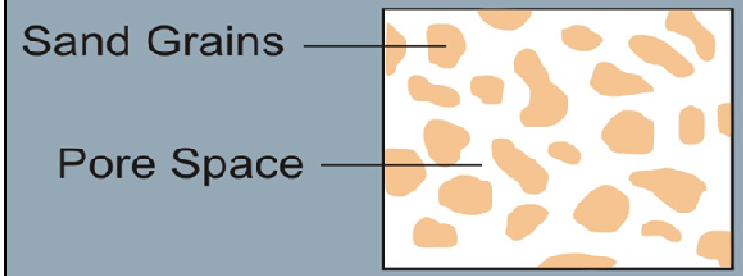
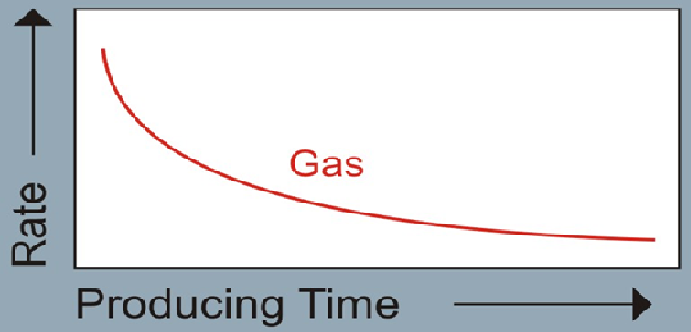
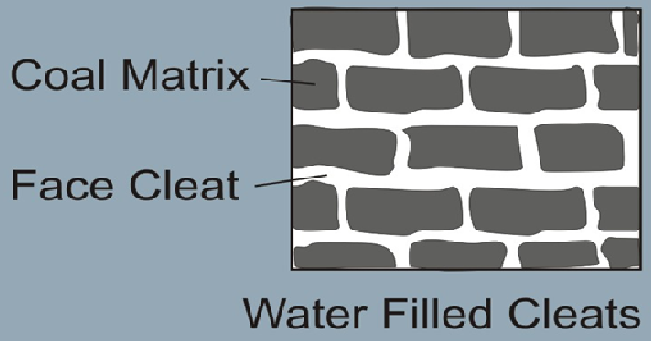
Reservoir Comparison and Production Profile

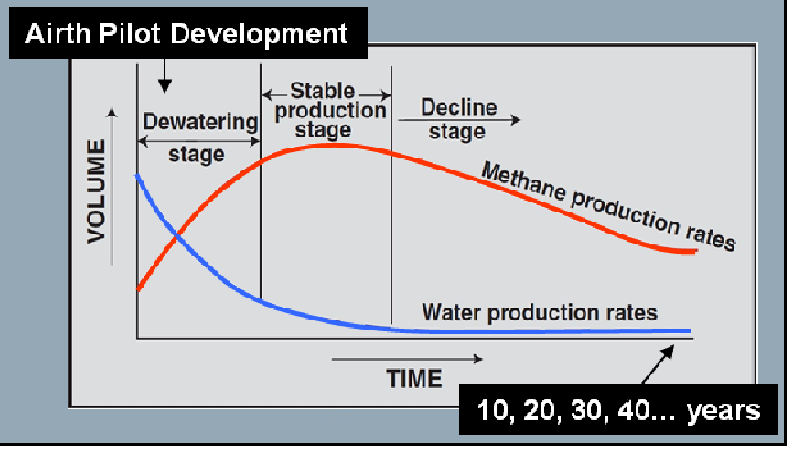
Conventional Gas Reservoir





Coalbed Methane Gas Reservoir





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CBM Play Quality and Success Factors

Coal Specific Criteria

Primary Criteria

Gas Content
Saturation
Permeability
Seam Thickness

Secondary Criteria

Depth
Net Coal
Coal Rank
Maceral Composition
Ash Content
Cleat Orientation
Cleat Mineralisation
Water Saturation
Stress Regime
Faulting / Structure
Burial History

Other Factors

Operational Factors

Topography
Land Ownership / Use
Environmental Designations
Water Disposal Options
Drilling Rig Availability
Service Company Capacity
Local Support / Opposition

Economic Factors

Access to Market
Off-take Infrastructure
Tax Regime
Capital Costs
Flow Rates
Gas Price / Margin

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European CBM
Paradigms and Challenges

General Pessimistic View of European CBM

Basins are	**too small** **densely populated**
Coals are	**too thin** **too deep** **low permeability** **structurally deformed** **undersaturated**
Service Industry is	**almost non-existent** **expensive (O&G focus)**
Stakeholders are	**negative** **unengaged**
No Tax Incentives	

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European CBM
Causes for Optimism

Coals	**high gas contents** **high saturations (locally)** **good net coal thicknesses**
Economics	**high gas prices** **good potential margins** **well developed off-take infrastructure** **effectively infinite market**
Technology	**rapid development of horizontal drilling techniques** **new service companies targeting CBM**
Production	**encouraging early production results in Scotland**
Taxation	**tax royalty regime is more attractive than some PSC regimes**

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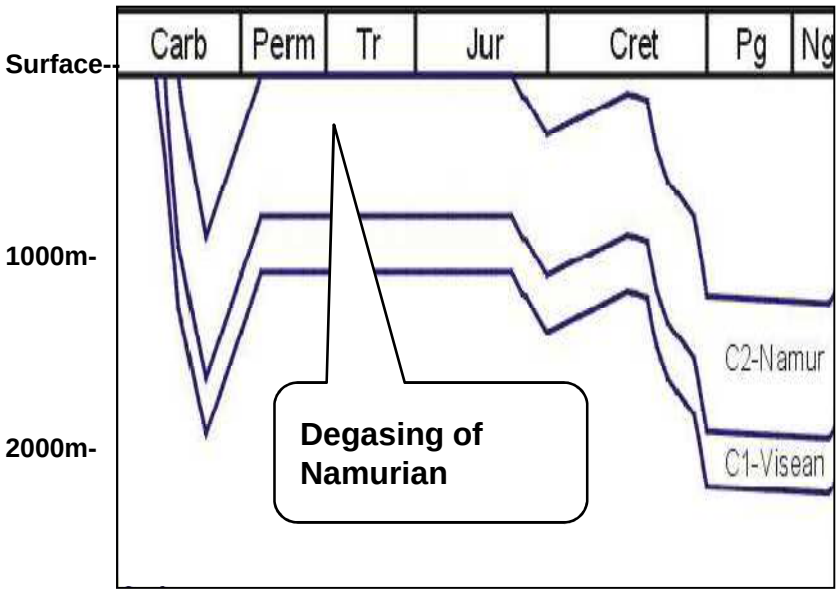
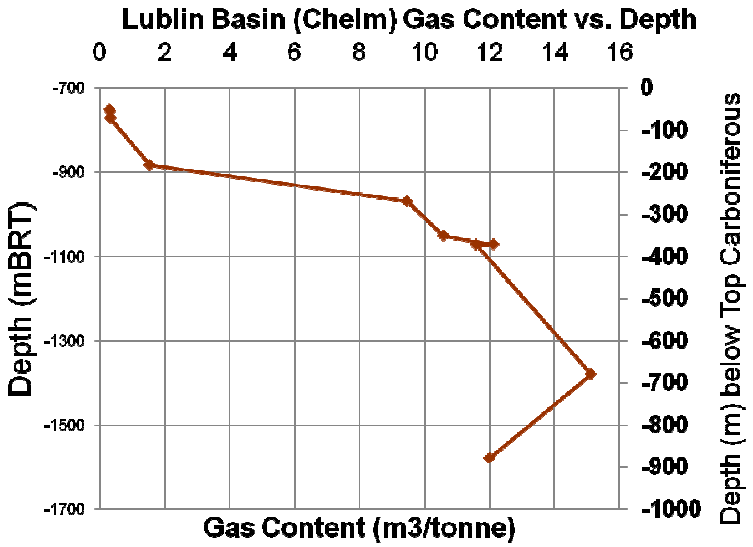
European CBM Challenges

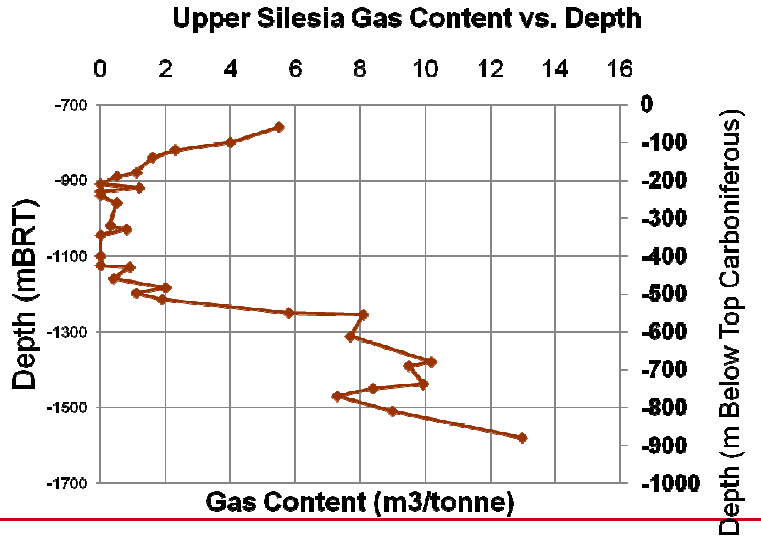
Older Coals with Complex Burial Histories

Complex interplay between pressure and temperature

Lublin Basin:Target Namurian coals







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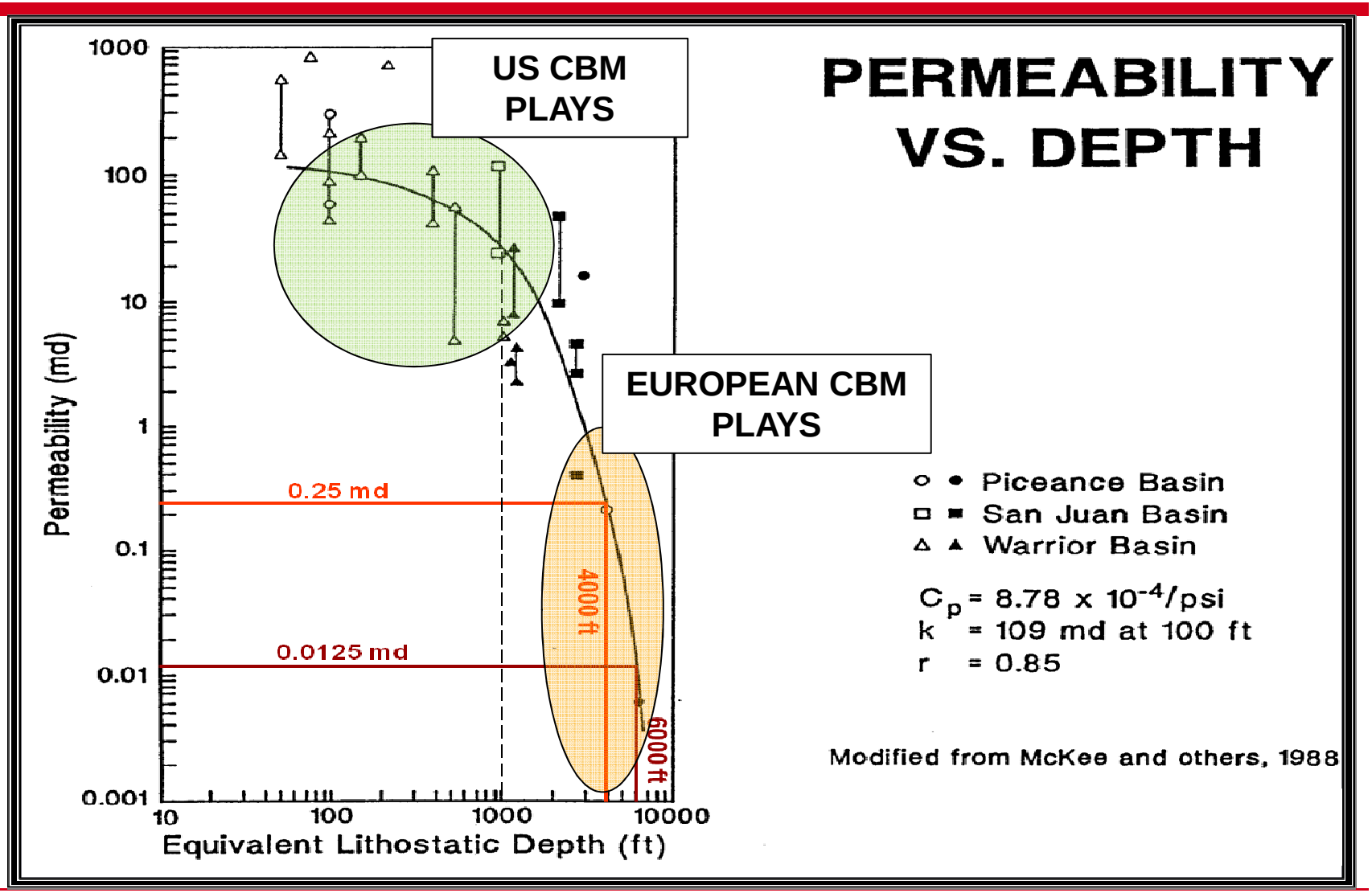
European CBM Challenges
Permeability



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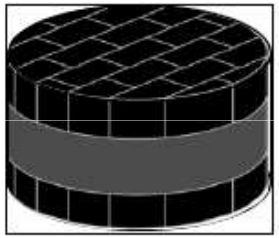
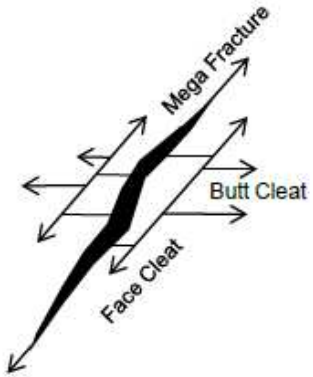
European CBM Challenges
Permeability

Primary flow mechanism =

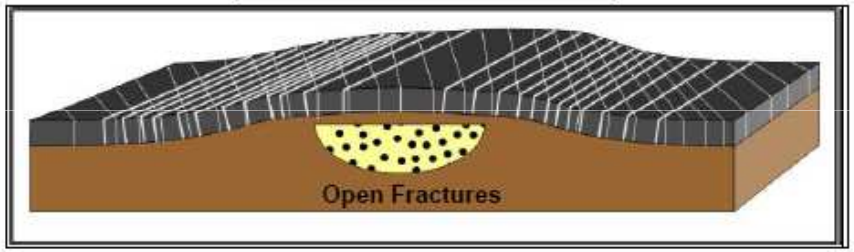
Endogenetic Cleats + **Tectonic Fractures**

Coalification process + regional stress regimes =

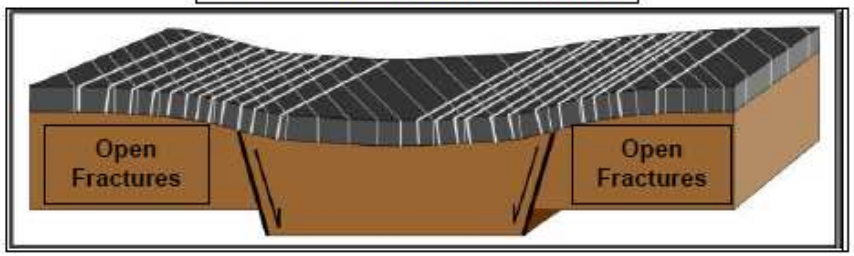




Compactional Drape



Post Depositional Faulting



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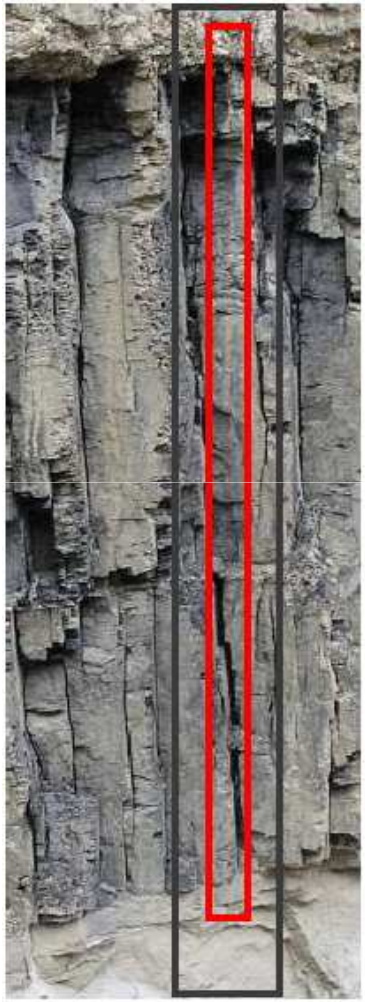
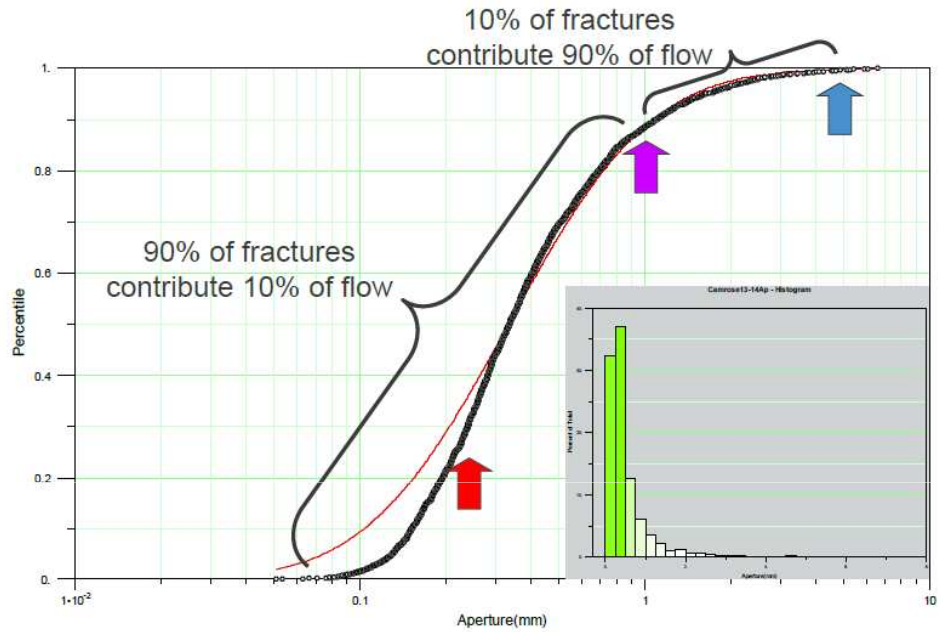
European CBM Challenges

Permeability

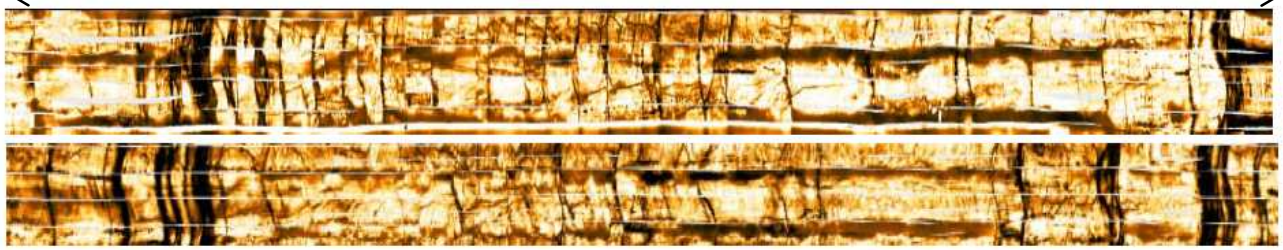


0.1-0.2m



Luthi and Souhaite (1990)

10m



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European Challenges
Stress Sensitivity v's Coal Shrinkage

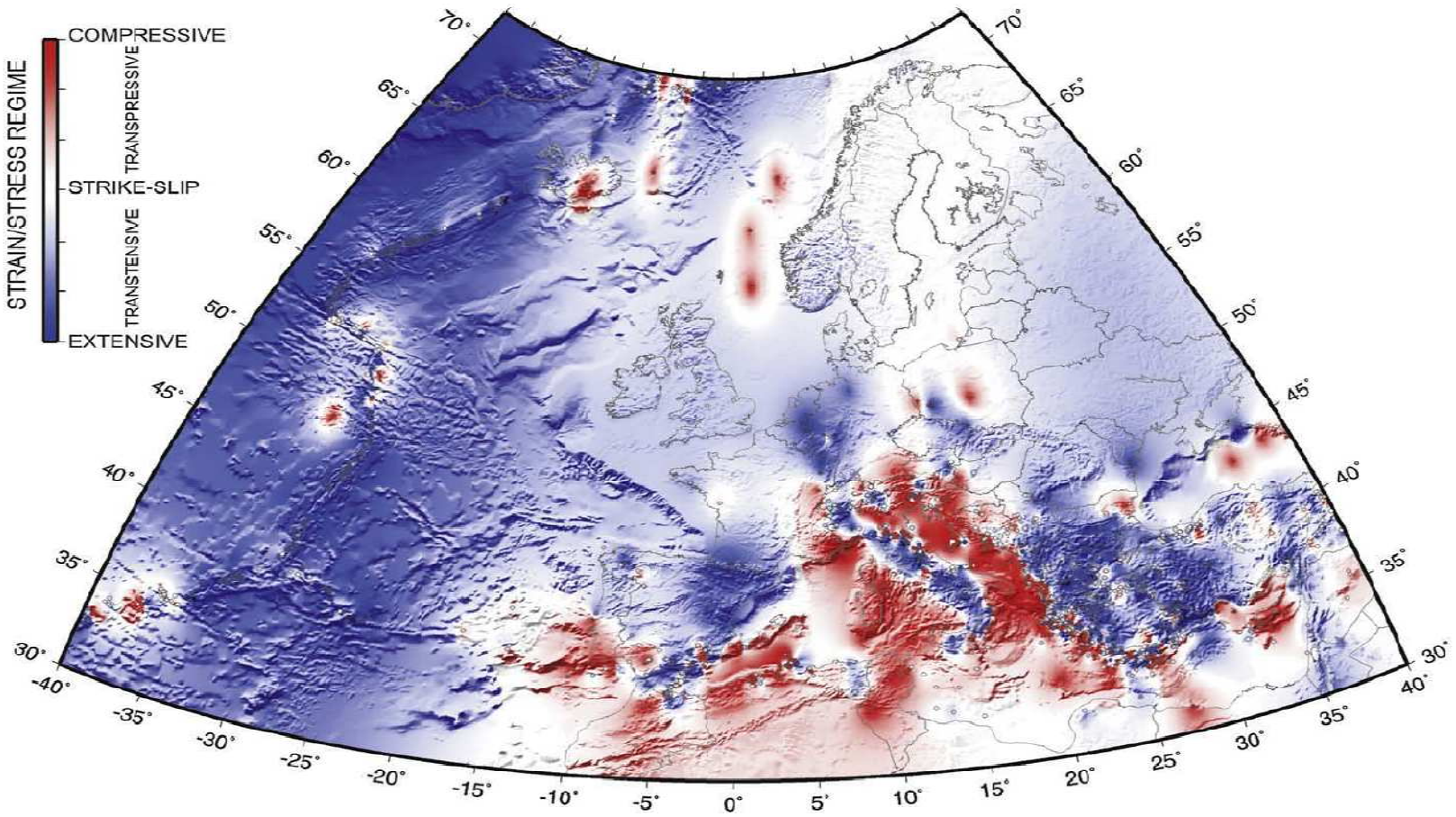


Fig. 5. Continuous strain–stress regime map for western Eurasian Plate overlaying topography. The individual k' values calculated for each focal mechanism from the "Slip Model" (Reches, 1983; De Vicente, 1988), were firstly filtered calculating a mean value in squares of 15 min in size and then interpolated to a 15-minute regular grid. See text for further explanation.

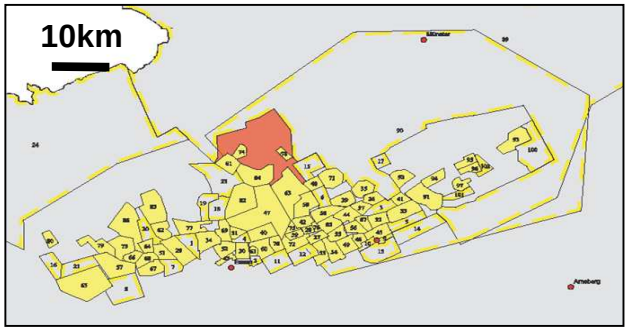
European Challenges
Scale

Europe

Central Valley of Scotland Coalfield 250km²

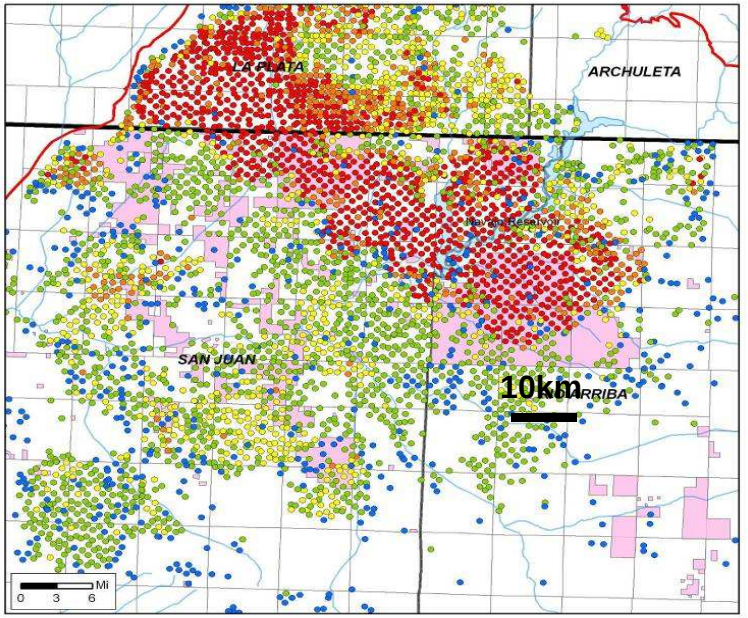
10km

The Ruhr Valley Coal Field c.3000km²



North America

San Juan Development: 7000km²



>29,000 wells

Source: ARI Inc

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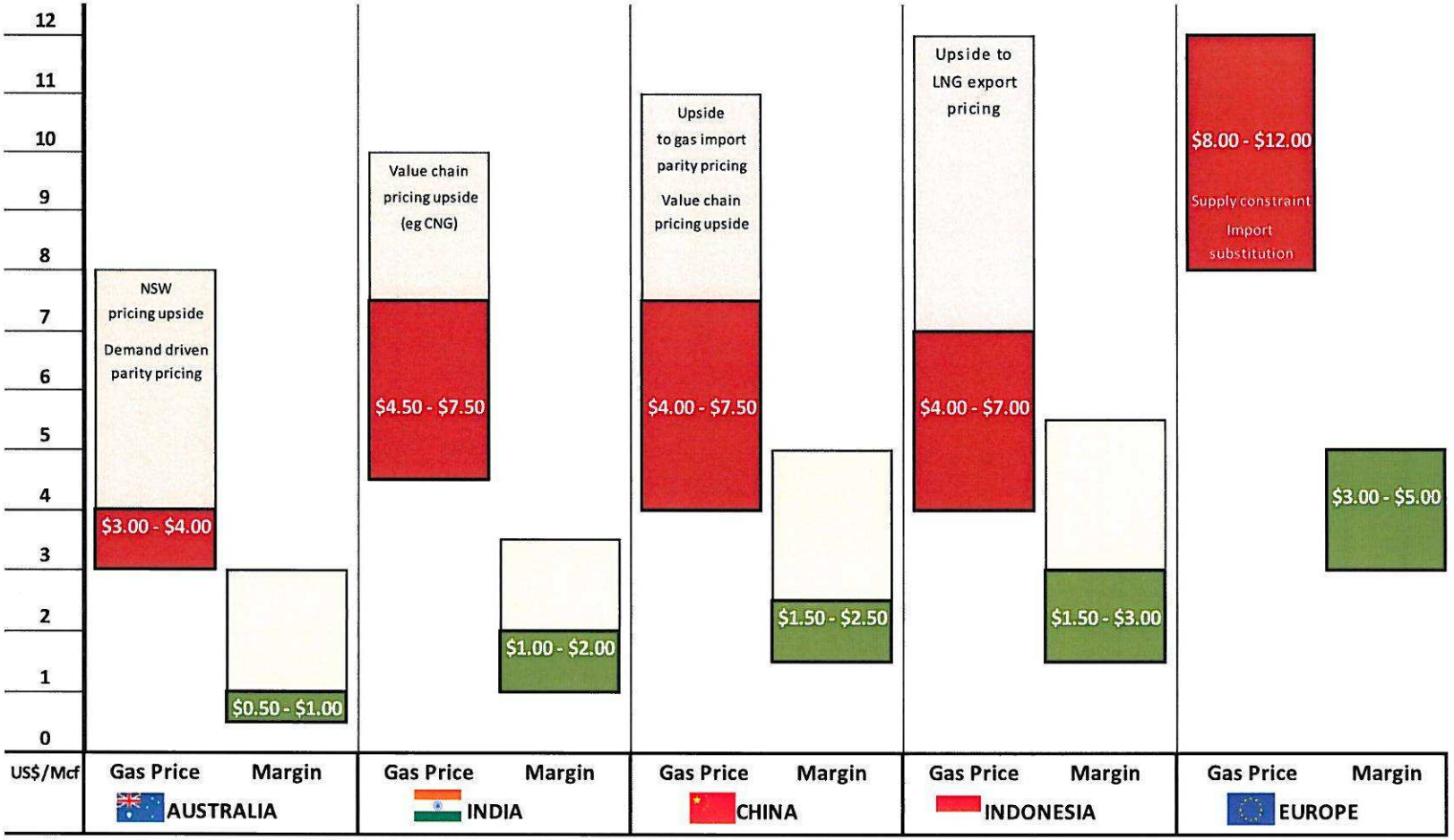
European Benefit

Market and Gas Price



Margin reflects Dart estimate of range of available margin to contractor net of opex, capex, and Government take (taxes, royalties); does not reflect impact of PSC economics

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Early Success in Scotland

PEDL133 Pilot Project

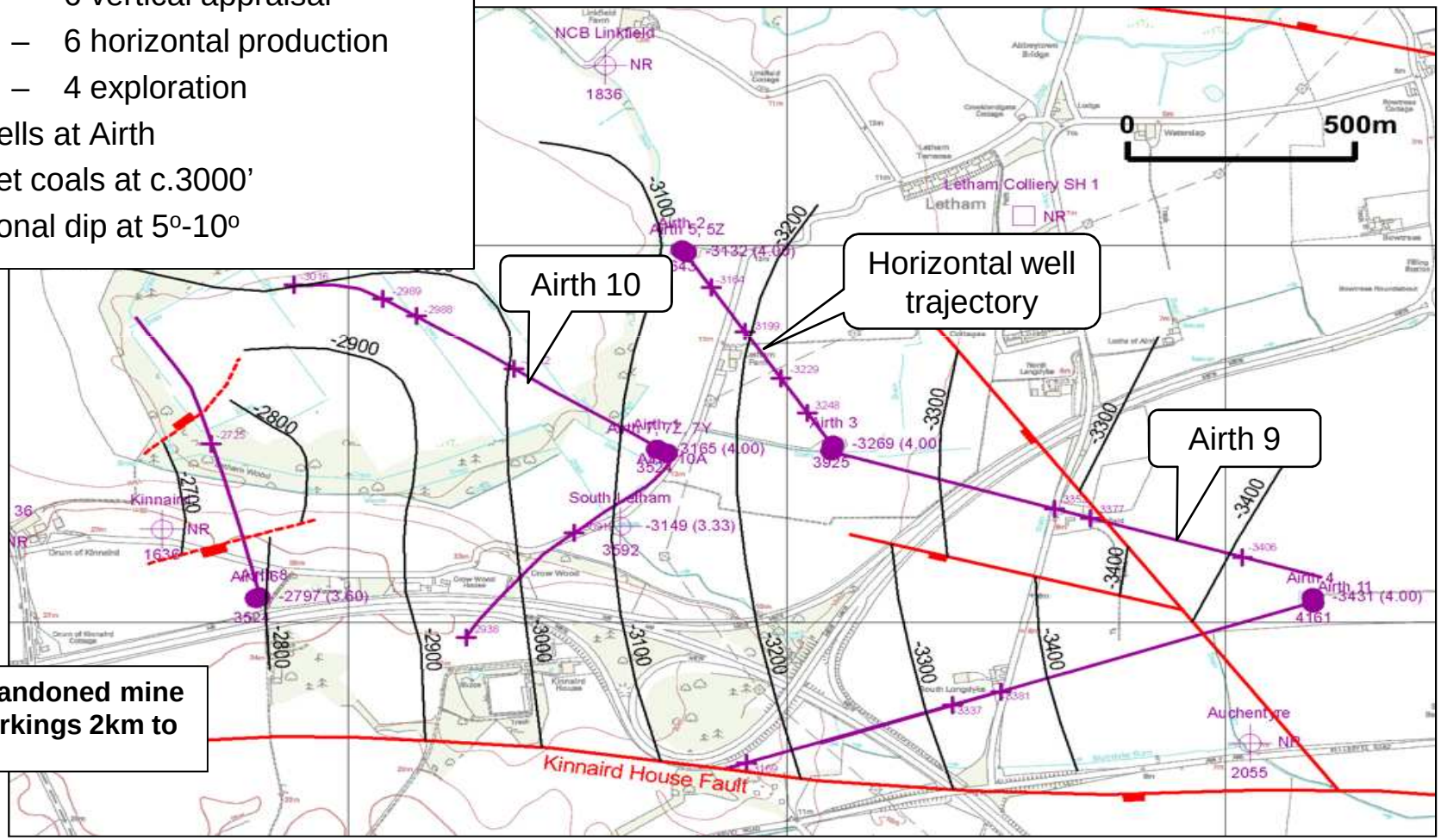
16 CBM wells drilled
- 6 vertical appraisal
- 6 horizontal production
- 4 exploration

12 wells at Airth

Target coals at c.3000’

Regional dip at 5º-10º

Airth Pilot

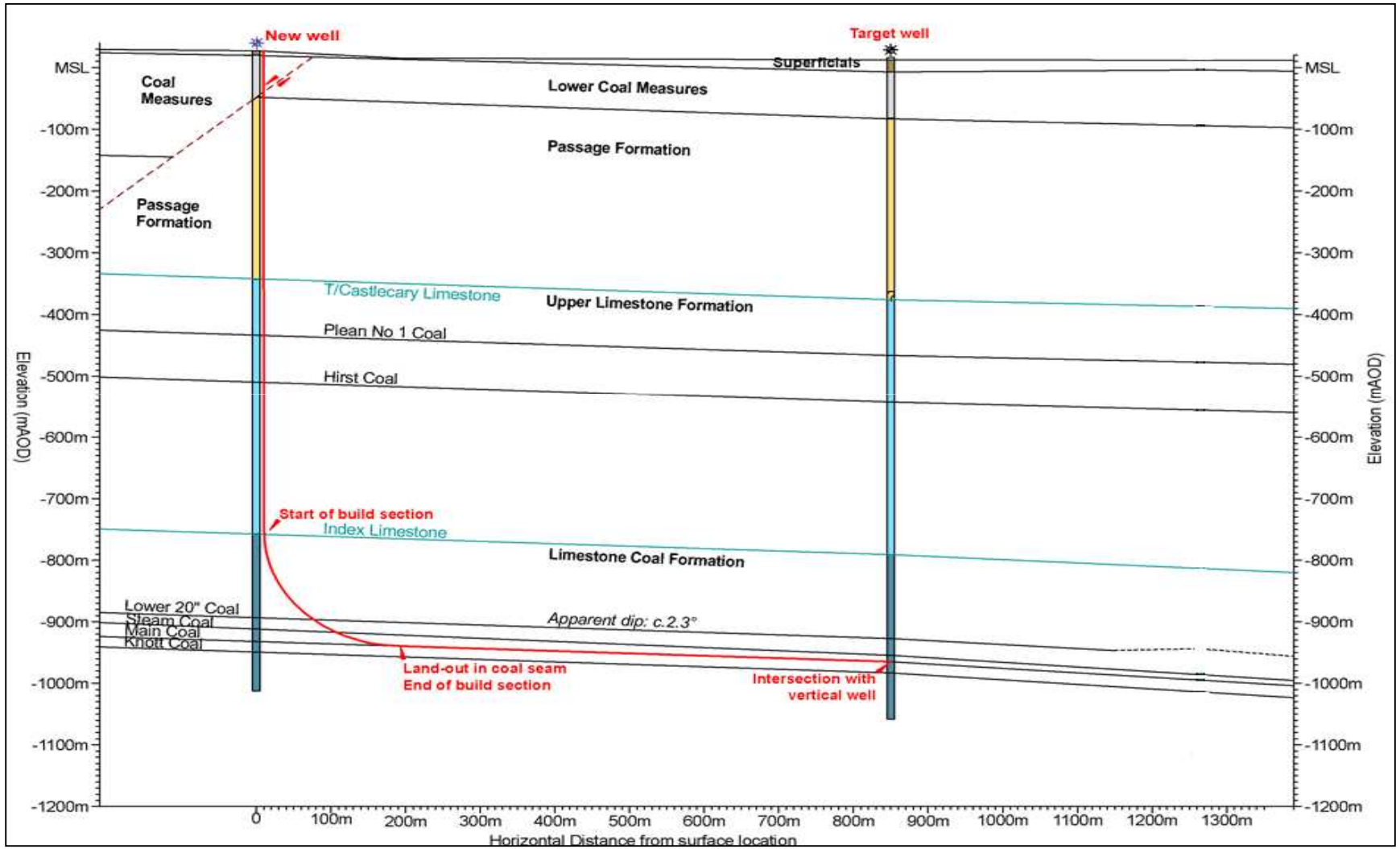


Abandoned mine workings 2km to W

24

Early Well Designs

Toe Intersection



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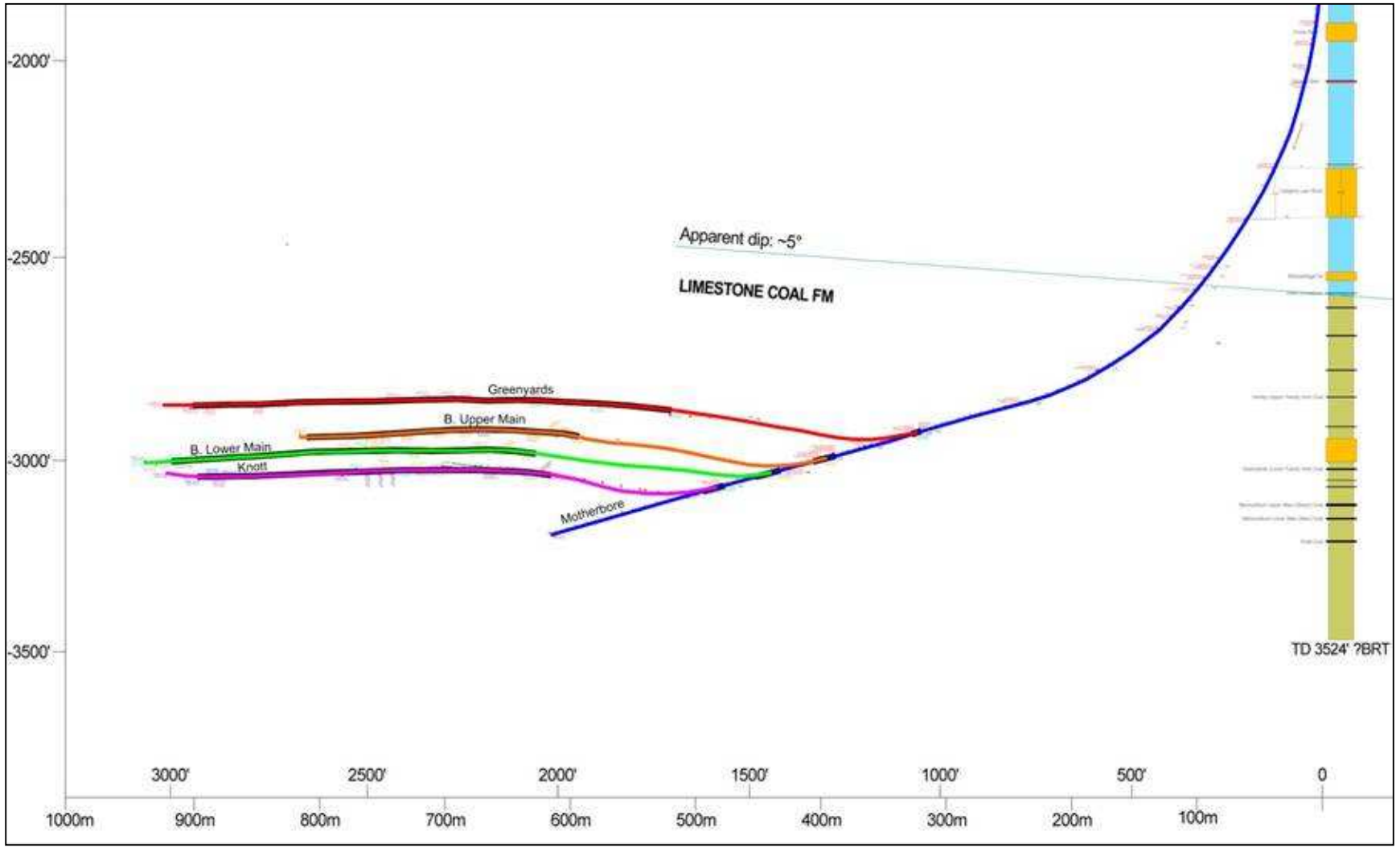
Early Well Designs

Up-Dip Well – Airth 10



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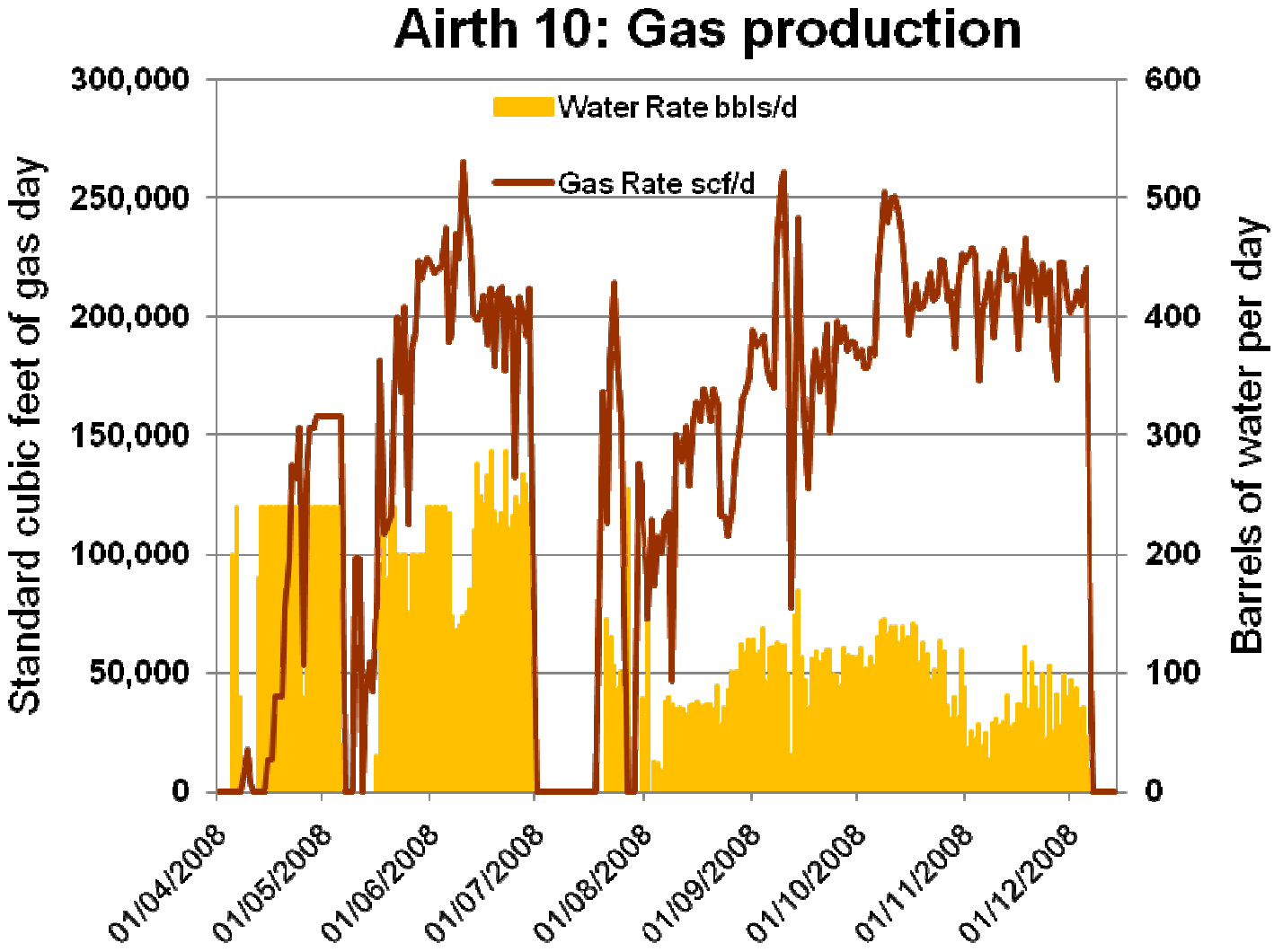
Airth 10 Production Success



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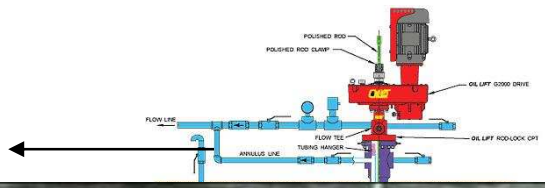
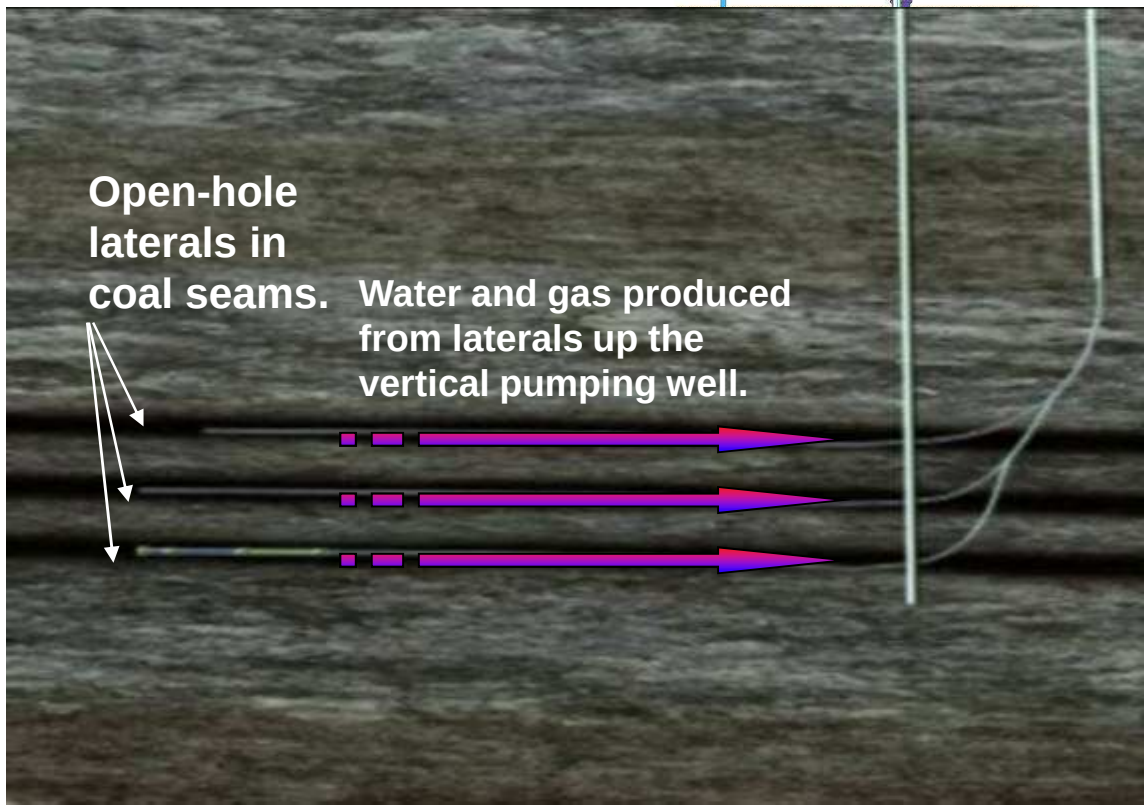
New Well Design

Produced water and gas to separator and wellhead compressor.



Wellhead with pumping unit



Development wells consist of two wellbores:

- **A vertical well used for pumping produced water and producing gas up the annulus.**
- **A directional well offset from the vertical from which open-hole laterals (4) are drilled to intersect the vertical well.**

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Drilling Operations

G55 and HH102 Hydraulic Top Drive Rigs

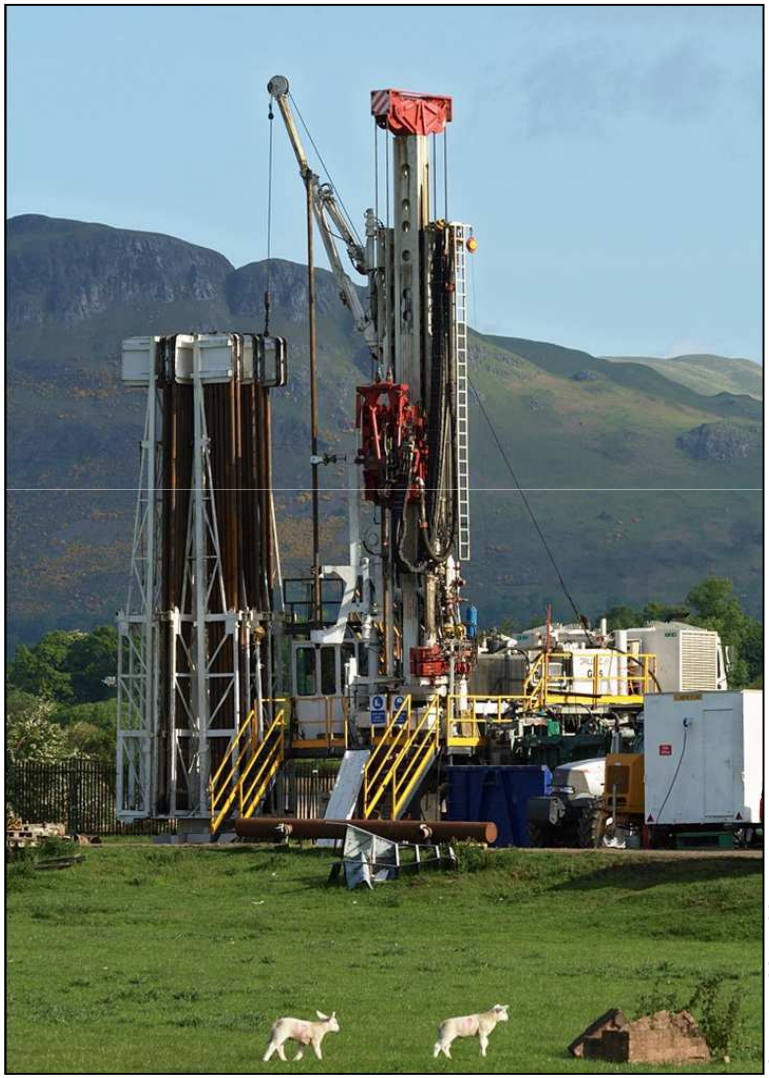

Photo: David Goold

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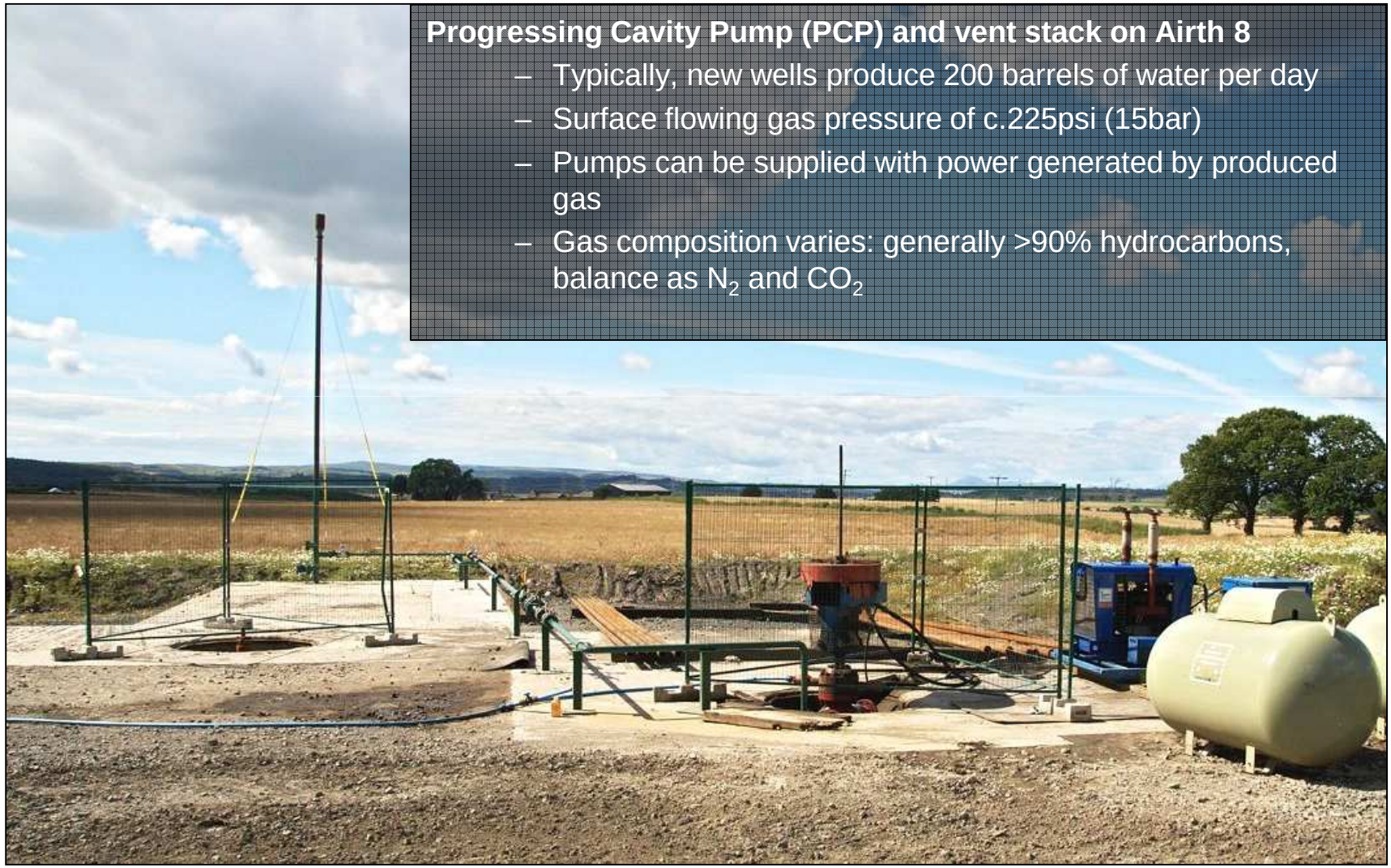
Airth CBM Production Site



Progressing Cavity Pump (PCP) and vent stack on Airth 8

- Typically, new wells produce 200 barrels of water per day
- Surface flowing gas pressure of c.225psi (15bar)
- Pumps can be supplied with power generated by produced gas
- Gas composition varies: generally >90% hydrocarbons, balance as N_2 and CO_2

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Pilot Production Facilities

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