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Supermodels, bugs and gas-a retrospective

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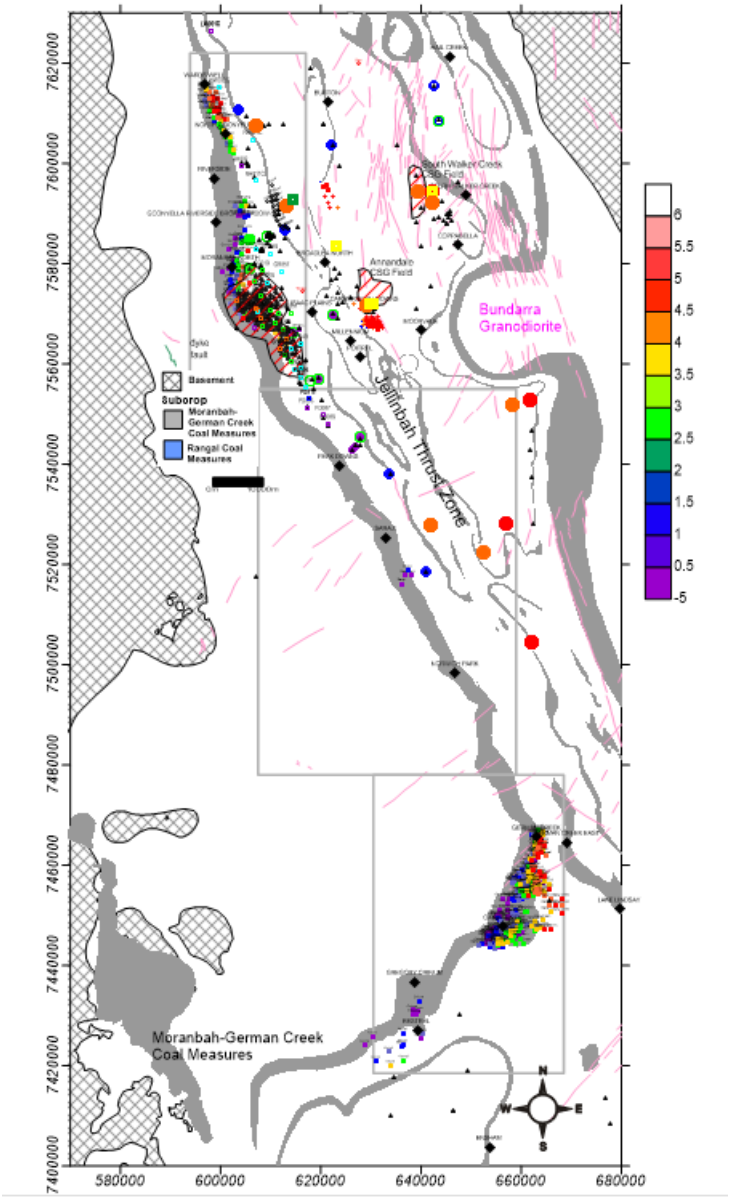
What is a Supermodel?

- An integrated approach to data compilation and analysis to develop a spatially consistent **model** of the geology that underpins coal resource assessment, mineability, quality and **gas resource distribution**

- Gas resource models assist **CSG** exploration and production prediction, underground **mine drainage**, and fugitive **emissions** estimation

- **Data** is contributed from coal companies (proprietary) and coal seam gas companies (proprietary and open file), government agencies and universities

- A collegiate a approach to knowledge sharing across the sectors



Example of data sharing from Bowen Basin

The mineable subcrop coal outlines the geological basin

The coloured dots represent a CSG saturation index (gas/100m depth of cover) using data from different sources

- operating gas fields,
- coal mines collecting for mine gas drainage or
- fugitive emissions accounting

Igneous intrusions (dykes) are shown in pink

Structural faults not shown

What makes a good coal seam gas reservoir?

Resource

Gas content – high gas but thin coal, or low gas but thick coal?

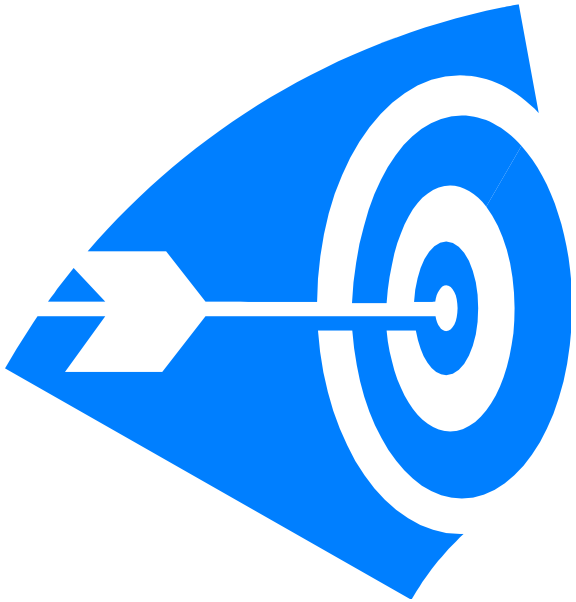
Gas composition – methane >98%

- Thermogenic or biogenic no problem

Coal net thickness – as much as possible

Coal seam lateral continuity – predictable

- thickness, splitting, quality, faulting, intrusives



Deliverability

Gas Saturation – high

Permeability – yes please

- Cleat density and orientation, mineralisation, stress
- Depth, stress magnitude and stress orientation

Matching the well completion techniques to the geology, is the only thing one can control. The rest is set from Mother Nature.

Gas Saturation

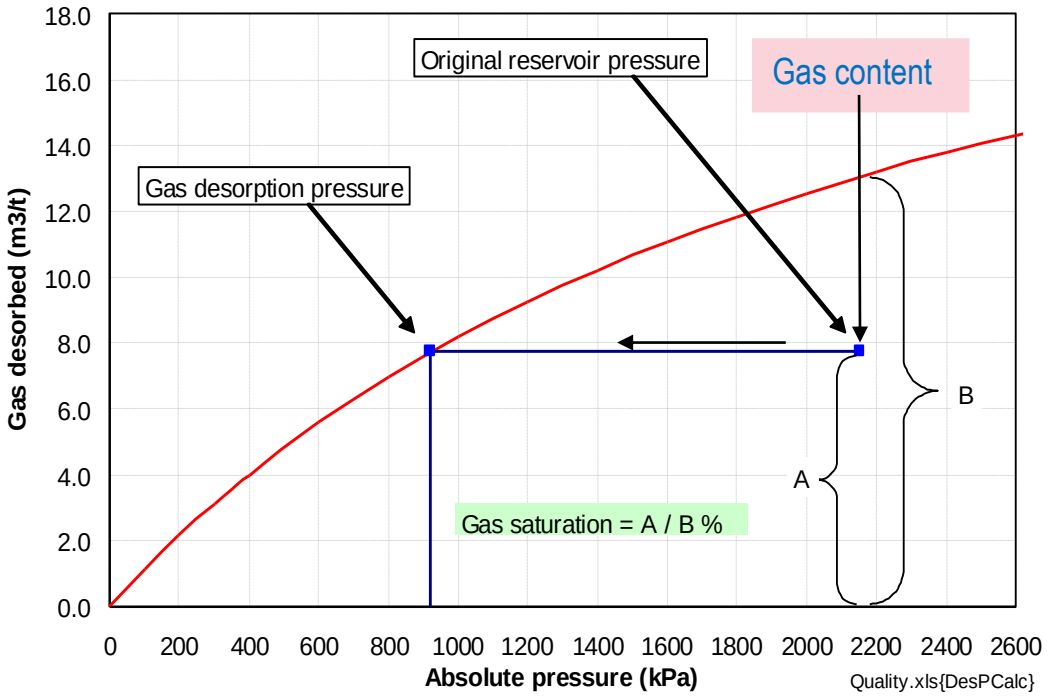
Similar to a promise, is the reservoir half empty ?

Gas Saturation and Sorption

Basic concepts

- Gas adsorption increases with pressure at a given temperature, but CH4 behaves differently to CO2, and in many cases varies with coal rank, grade and type;
- To drain or produce the gas, pressure is lowered through pumping water out, which depends on permeability (and stress and fracture networks);
- Over geologic time, any change in pressure or temperature, will cause the gas to desorb, migrate and/or re-adsorb into the reservoir;
- Methane can also be generated secondarily through biogenic pathways, at any geological stage- this really bugs me!

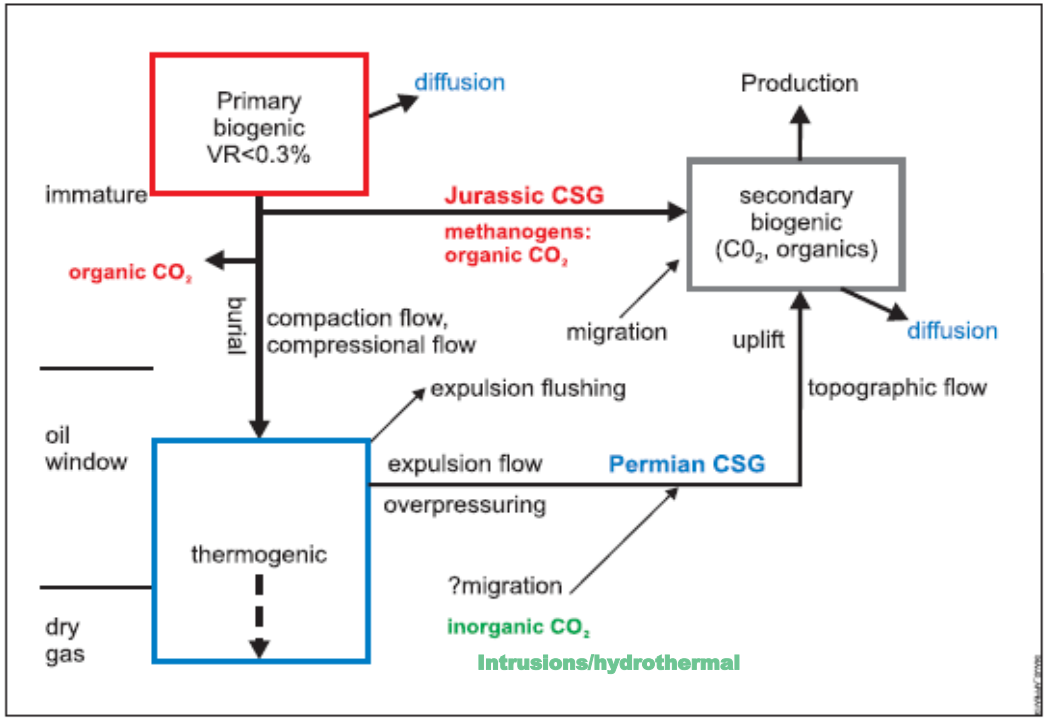
Undersaturated example



From Ray Williams et al, 1999

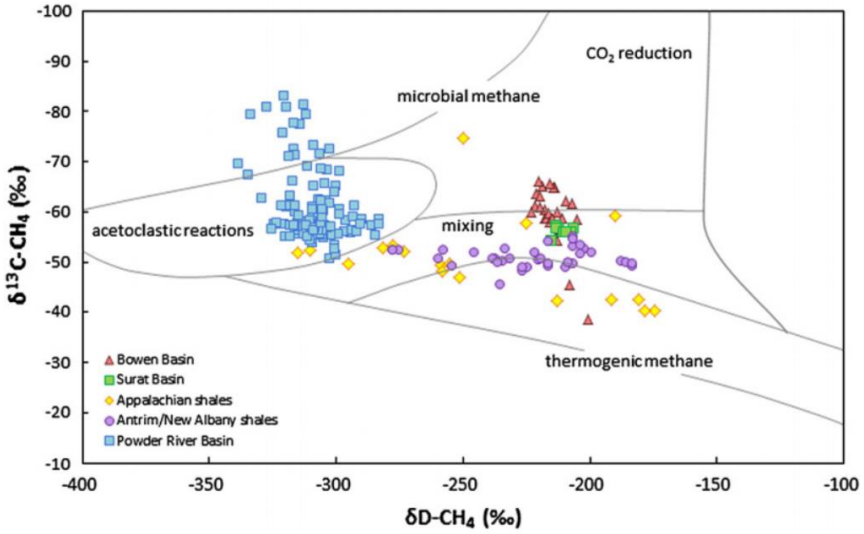
Models for Gas Generation and "re" Cycling by Microbes in Australian Permian and Jurassic CSG reservoirs

Conceptual diagram of gas generation where older Permian reservoirs have more complex geological history than Jurassic



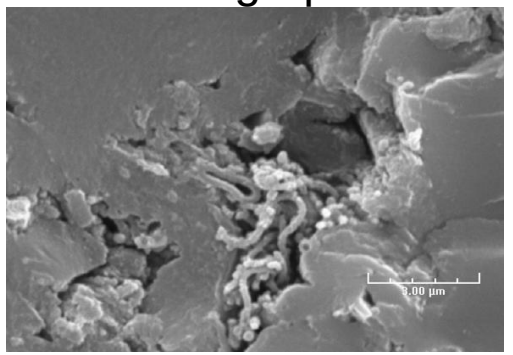
Draper and Boreham, 2006

Isotopic evidence for methane origins



Golding et al, 2015

Photomicrograph of microbes



http://www.lucatechnologies.com/content/index.cfm?fuseaction=showContent&contentID=62&navID=58

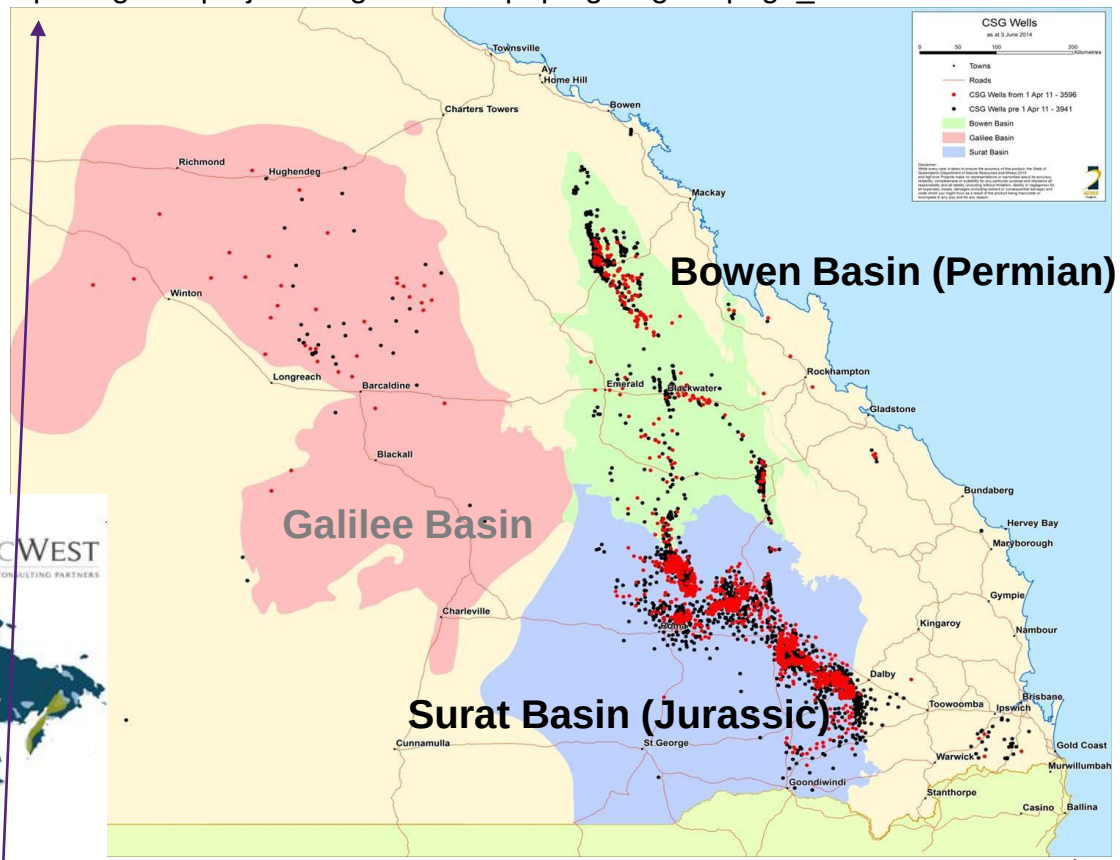
Permian and Jurassic Coal Seam Gas Plays in Queensland, Australia

- CSG wells 2011-2014
- CSG wells pre 2011

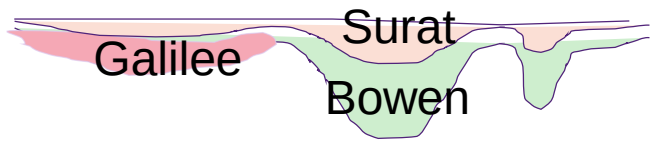
World map of unconventional gas

Queensland map of sedimentary basins and CSG wells

https://agforceprojects.org.au/index.php?tgtPage=&page_id=172



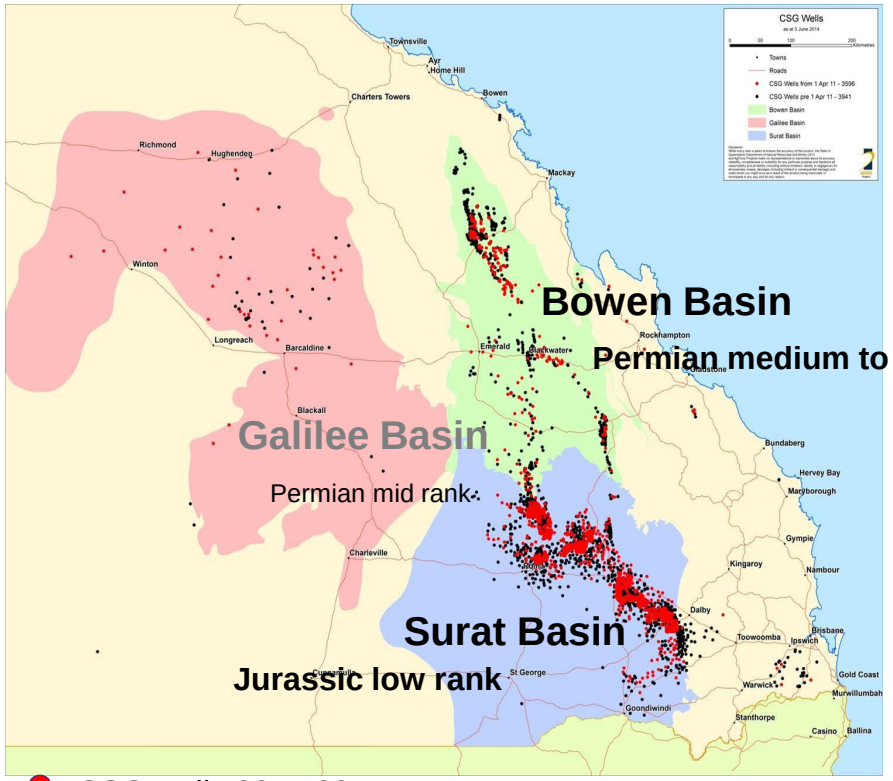
Cartoon cross section of the basins



Trends in gas content with depth for different basins

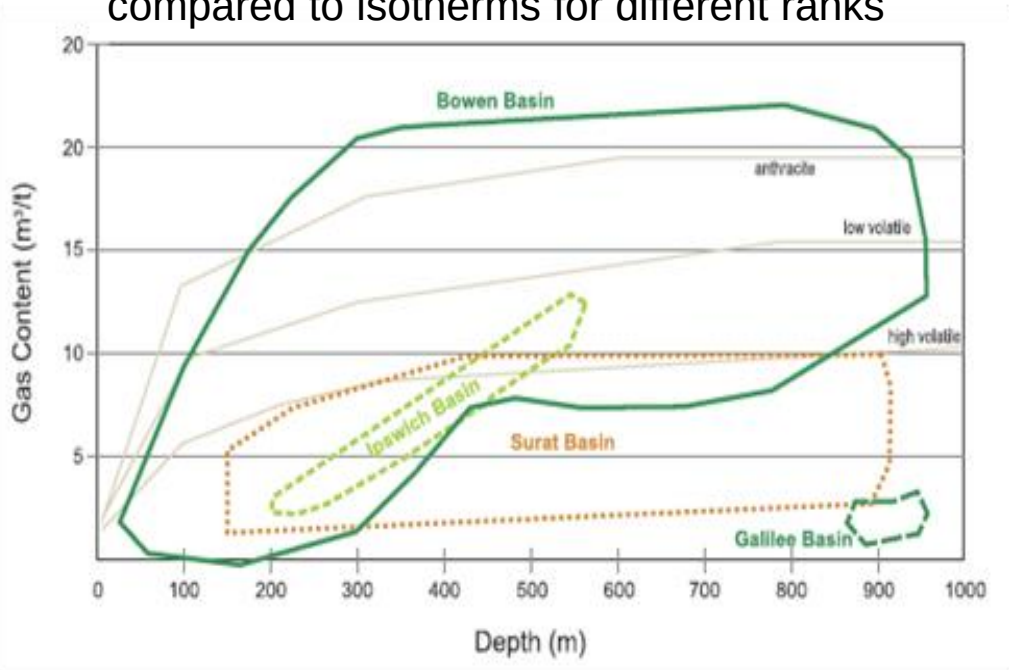
Queensland map of sedimentary basins and CSG wells

https://agforceprojects.org.au/index.php?tgtPage=&page_id=172



- CSG wells 2011-2014
- CSG wells pre 2011

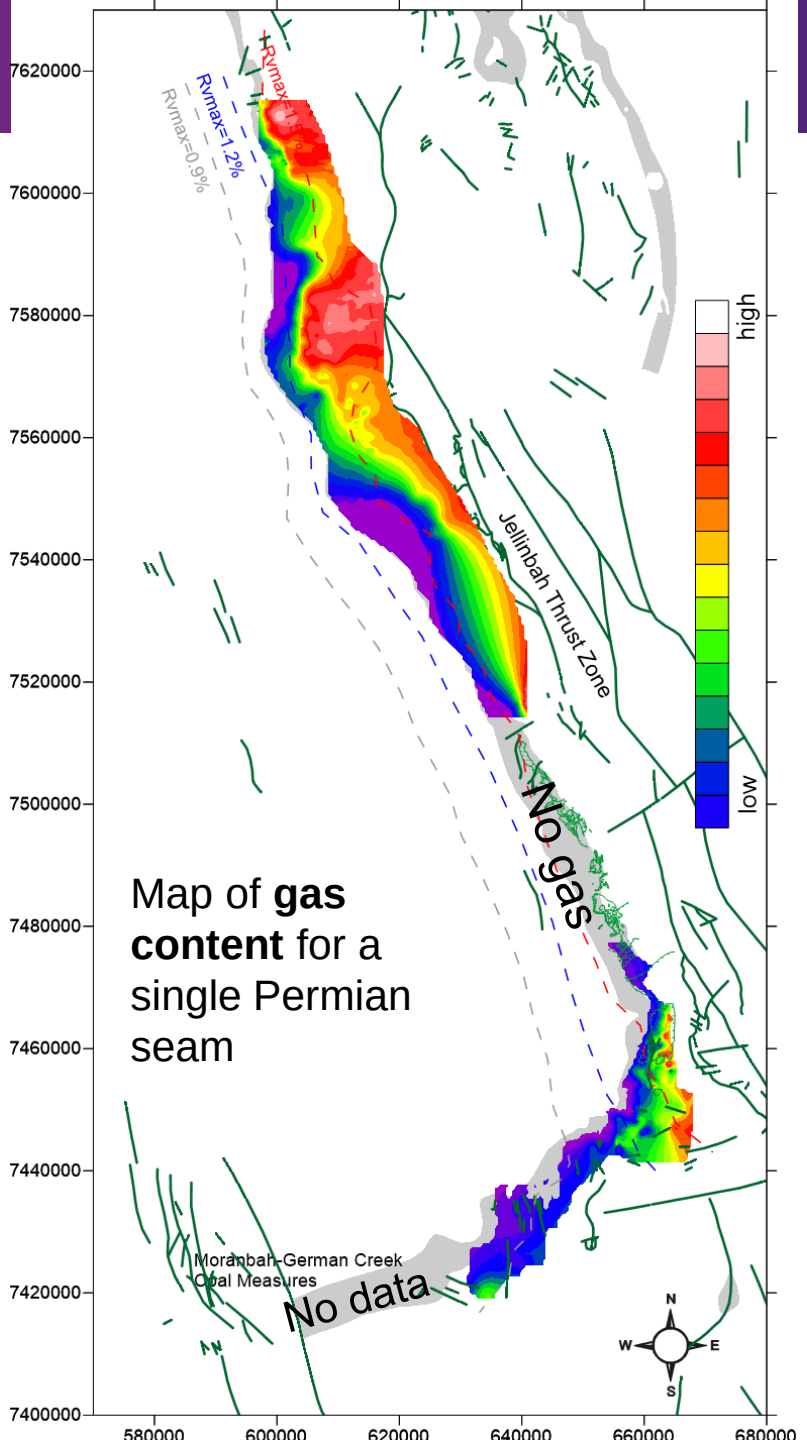
Gas content vs Depth for different age coals compared to isotherms for different ranks



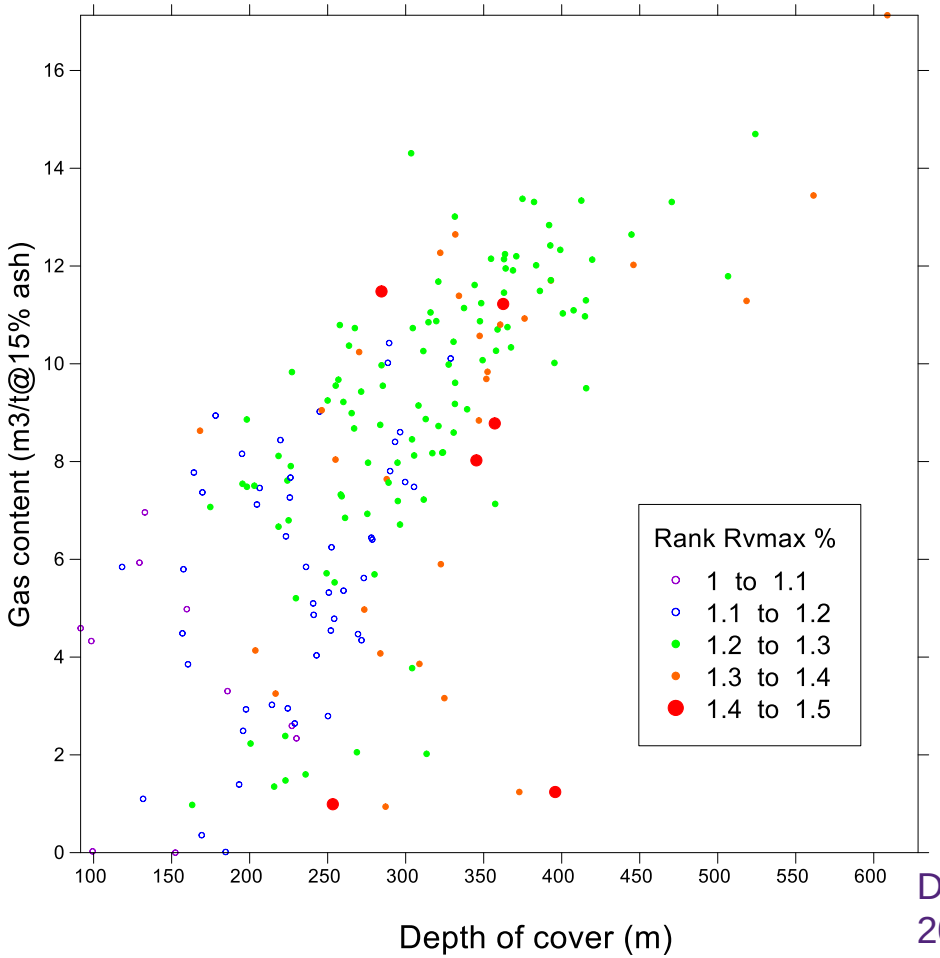
Draper and Boreham, 2006

Prospective CSG can occur across a range of basins and coal ranks

Supermodel Western limb of the central Bowen Basin

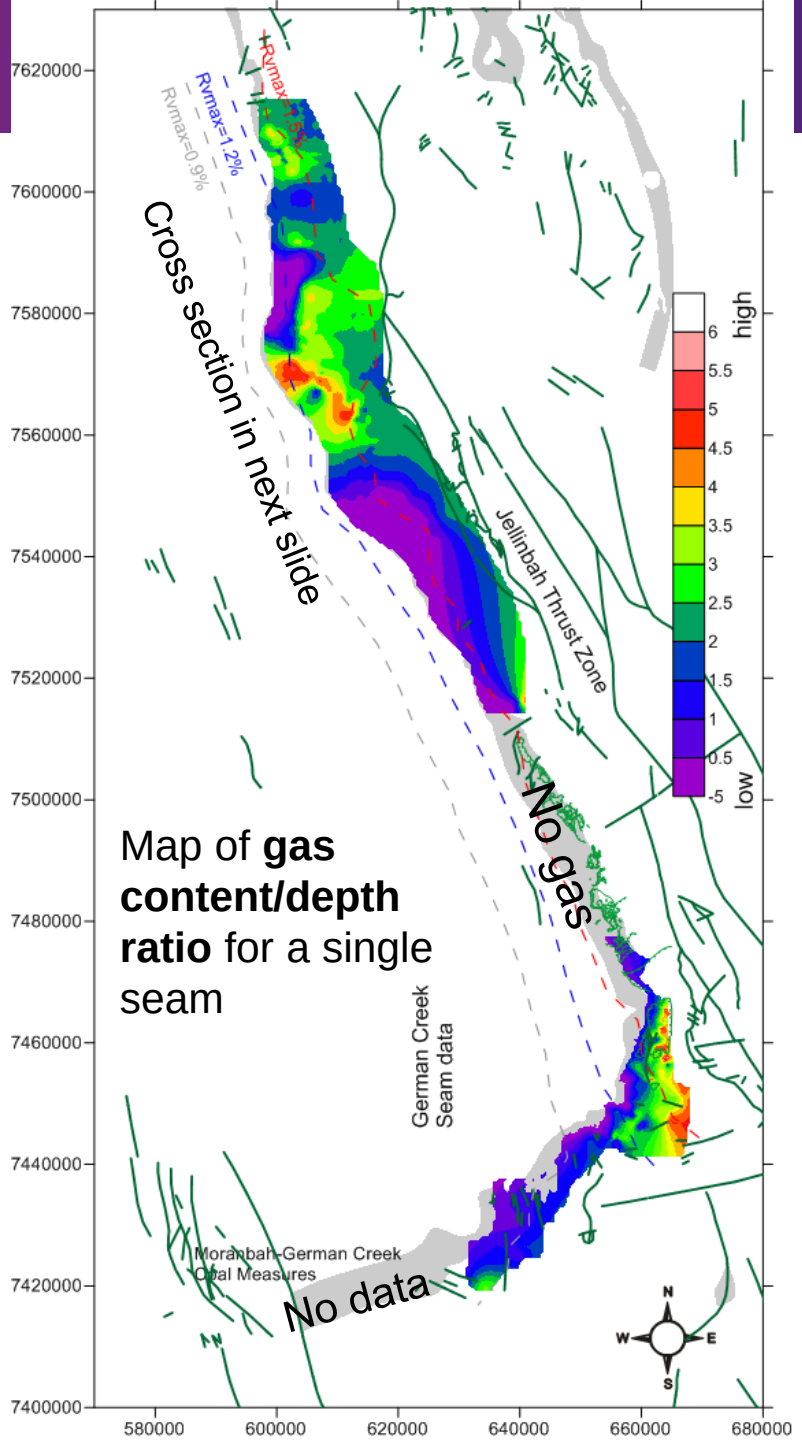


- >1000 boreholes with gas content data for a given coal seam (minesite + CSG company data)
- Gas content low to high, and generally increases with depth, but not at same rate and independent of coal rank



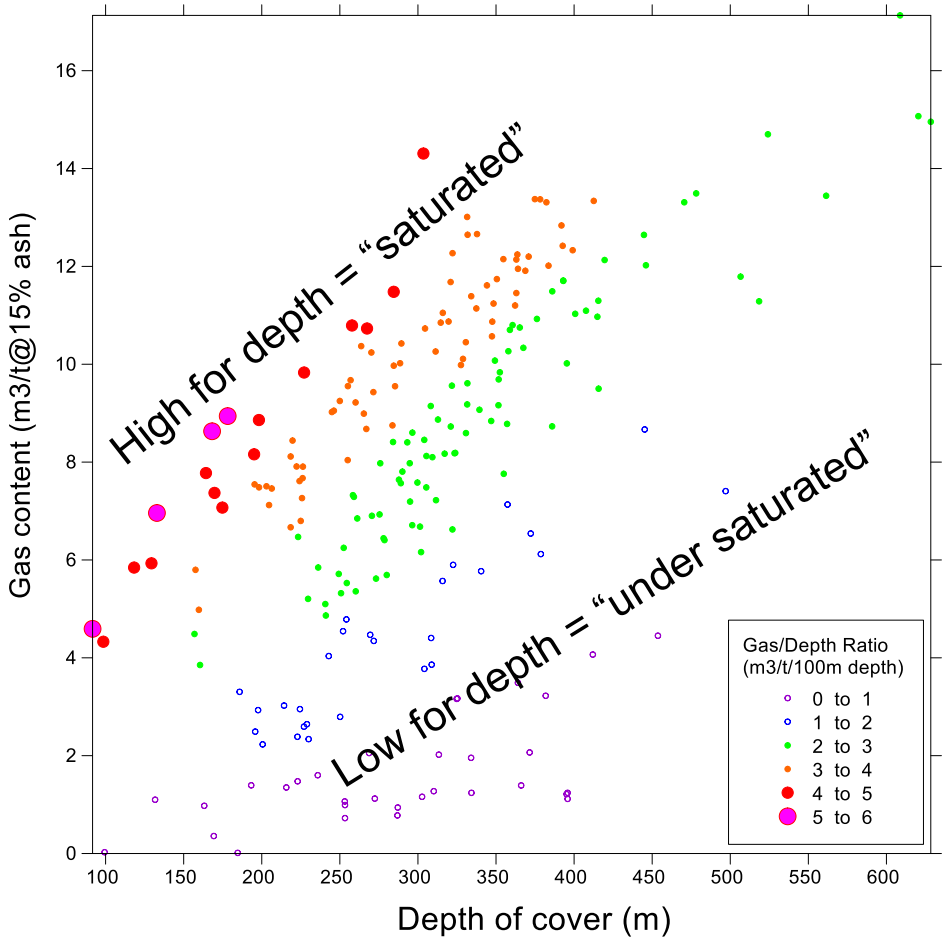
Data Esterle et al, 2002 and 2006
From coal mines

Supermodel Western limb of the central Bowen Basin



Map of **gas content/depth ratio** for a single seam

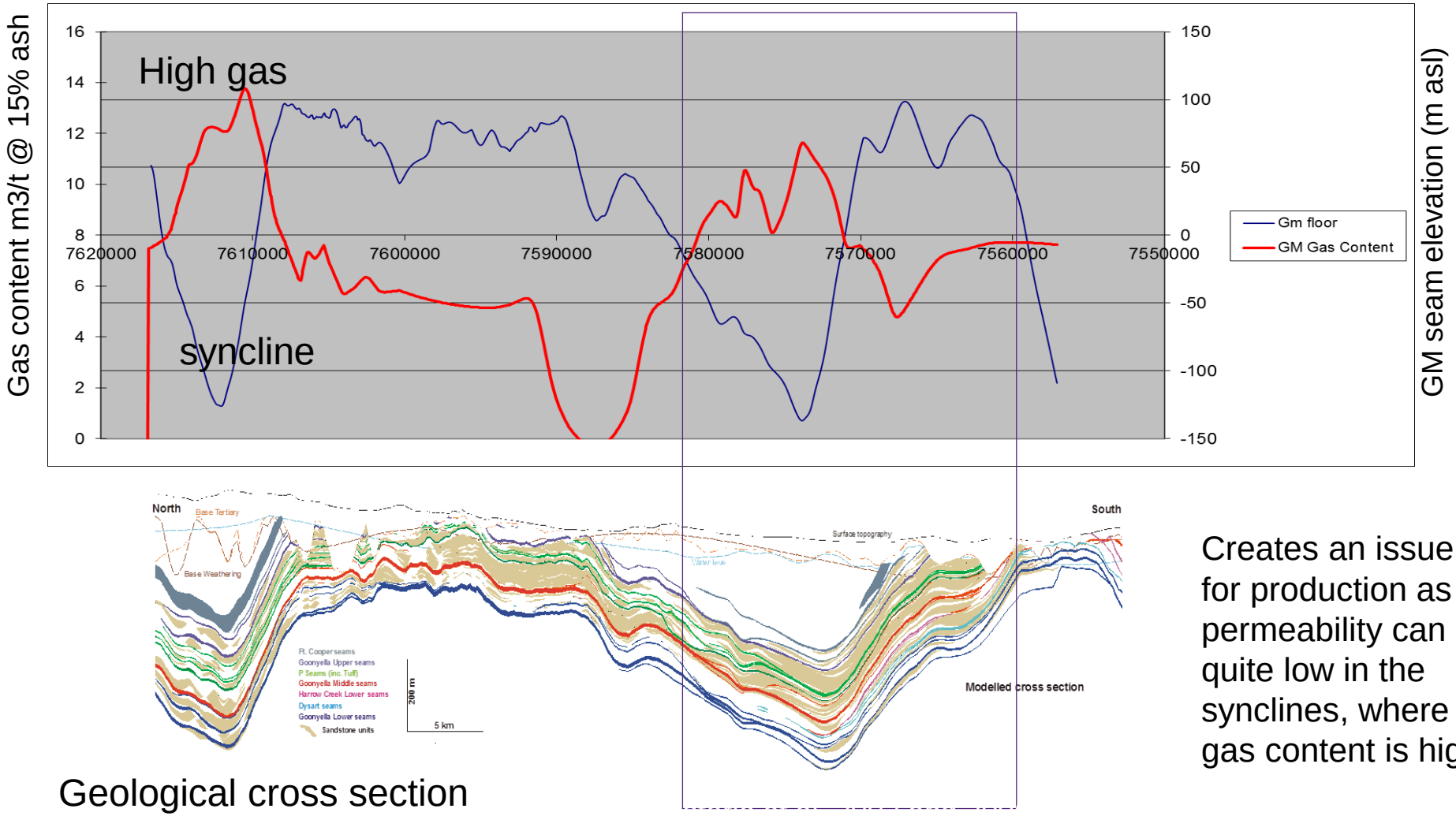
A ratio of gas content/depth can signal areas of good gas **saturation** (domains)



Data Esterle et al, 2002 and 2006
From coal mines
Gas/depth concept from Ray Williams, GeoGAS

Distribution of gas relative to structure- in this part of the basin

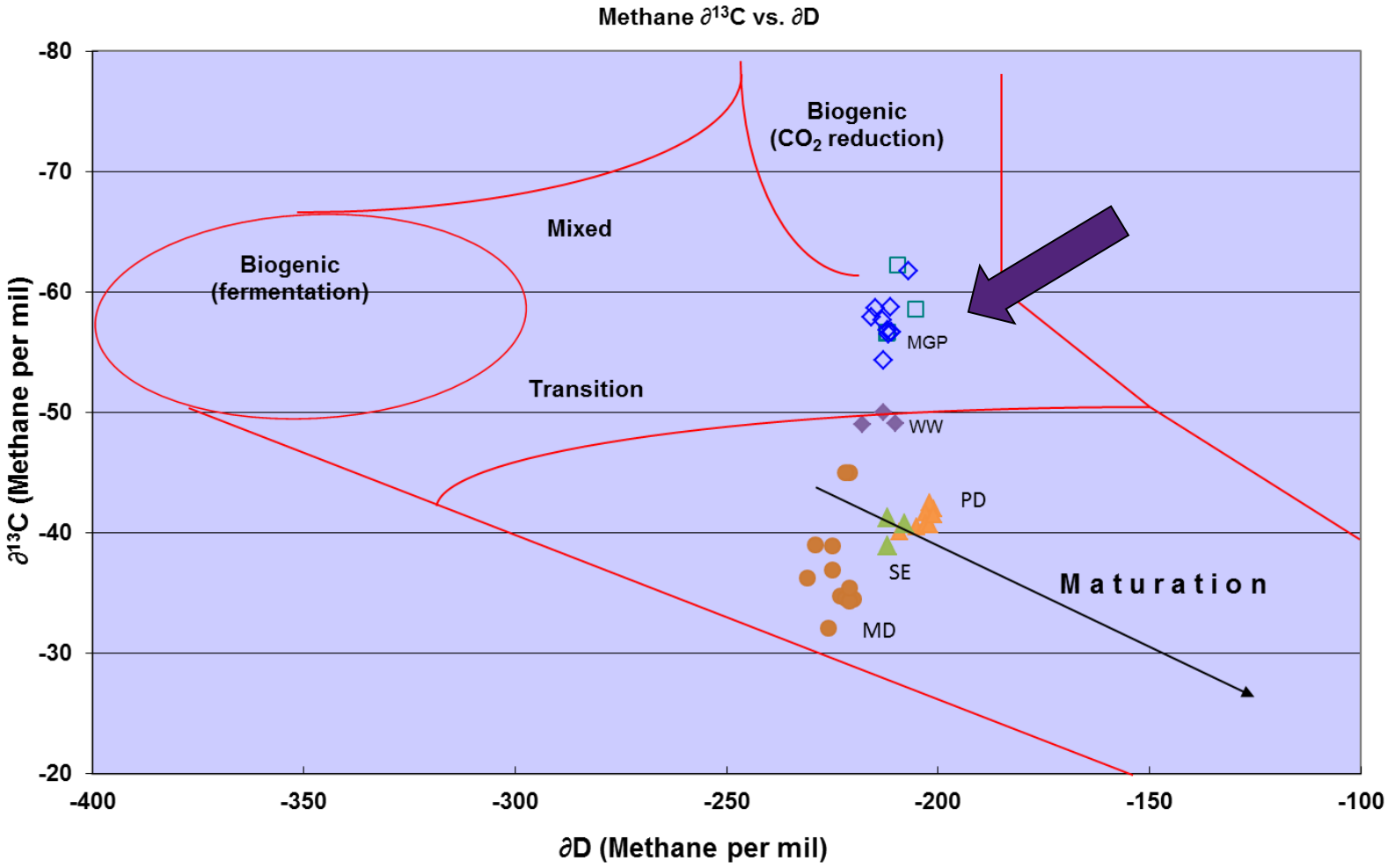
Gas is “retained” in the synclines where hydrostatic pressures are higher, but higher stress and lower permeability



Geological cross section
Supermodel 2000, Esterle et al, 2002

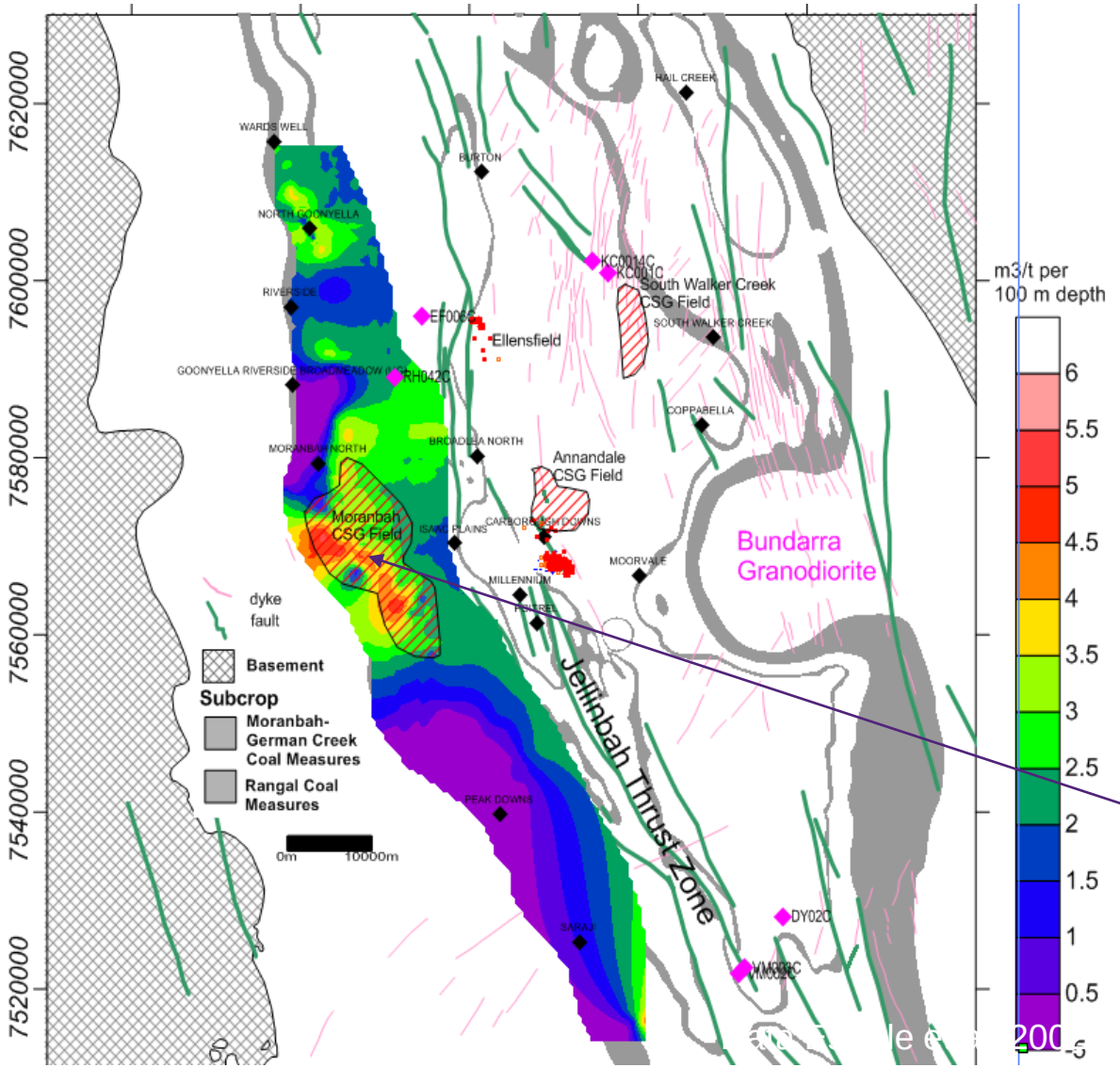
Creates an issue for production as permeability can be quite low in the synclines, where gas content is high

Evidence for biogenic recharge in areas of "higher" gas gradients

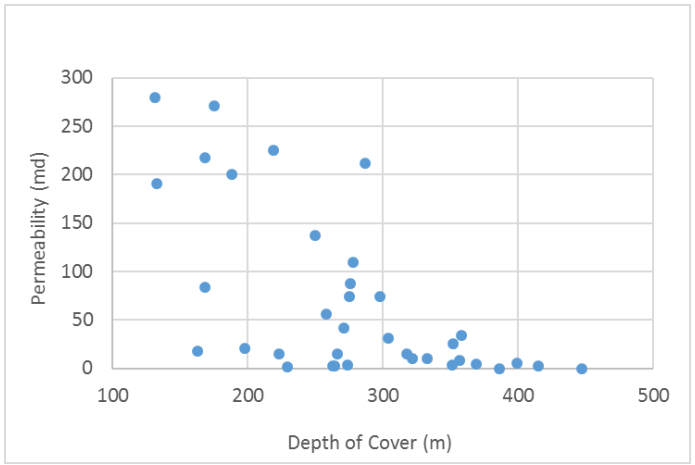


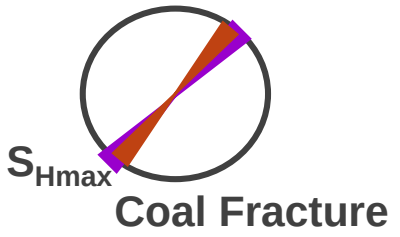
Data courtesy of Arrow Energy and Golding et al, 2015

Gas content/depth ratio as a saturation targeting tool



Maps out areas of relative saturation, and because higher than expected for a given depth, potentially areas of better permeability, and fracture is **open** parallel to stress



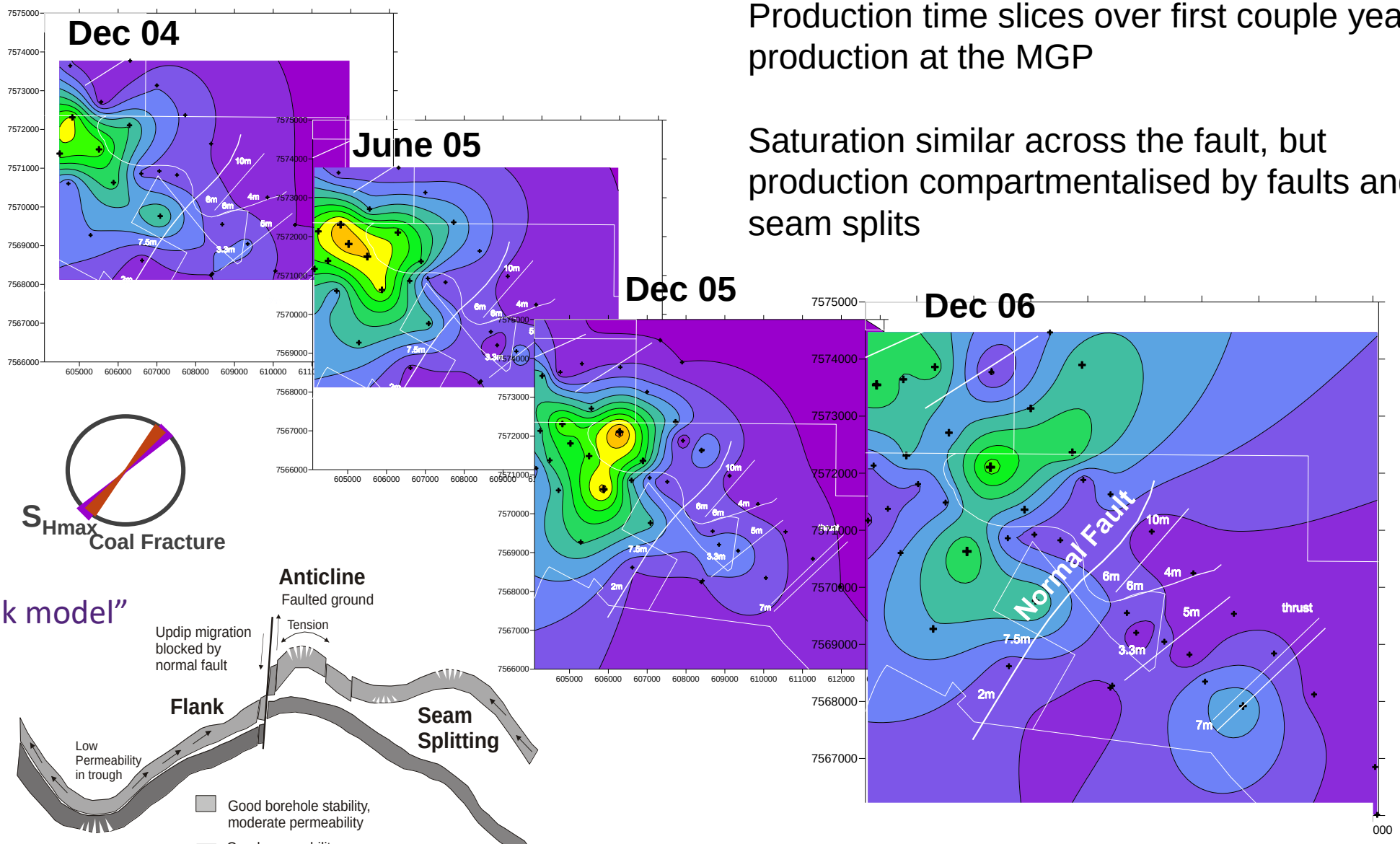


Coal Fracture

Esterle et al, 2002

Production time slices over first couple years of production at the MGP

Saturation similar across the fault, but production compartmentalised by faults and seam splits



"flank model"

Kinnon and Esterle, 2007

Conclusions

- Data sharing and integration across different commodities and lease boundaries improves understanding of spatial distribution of gas reservoir properties relative to geological structure
- Gas/depth gradients highlight areas of gas saturation and potentially better permeability where gas is higher than expected for a given depth
- Saturation at shallower depths is promoted by biogenic recharge
- Methanogenesis is linked to meteoric recharge, coal seam permeability and cleat development
- At the field scale, the directional permeability influences production domains
- **It really doesn’t bug me so much, because the bugs seem to do a good job.**

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Thank you

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