Resource Investment
Strategy Consultants

SPE Applied Technology Workshop

Petroleum Reserves & Resources Estimation – PRMS CBM Applications

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Agenda

- CBM: Definition and Comparison with Conventional Gas
- Discovery Transition Criteria
- CBM Resource Classification and Categorisation
  - Current Practice
  - Issues
- Conclusions
- A Solution

What is Coal Bed Methane?

- Natural gas formed in the coalification process and trapped within and adsorbed to the coal
  - Definition from Society of Petroleum Engineers (SPE)
- Coal Seam Gases can contain
  - Hydrocarbons – predominantly methane (CH_4), but may also contain trace amounts of ethane, propane and butane. They do not contain hydrocarbon liquids
  - Carbon Dioxide (CO_2), Nitrogen (N_2) and other non-hydrocarbon gases
- The gases may be biogenic or thermogenic in origin, depending on the depth of burial and temperature history of the coal
- Target depths for commercial extraction are typically 200-1000m below ground level

Common Abbreviations

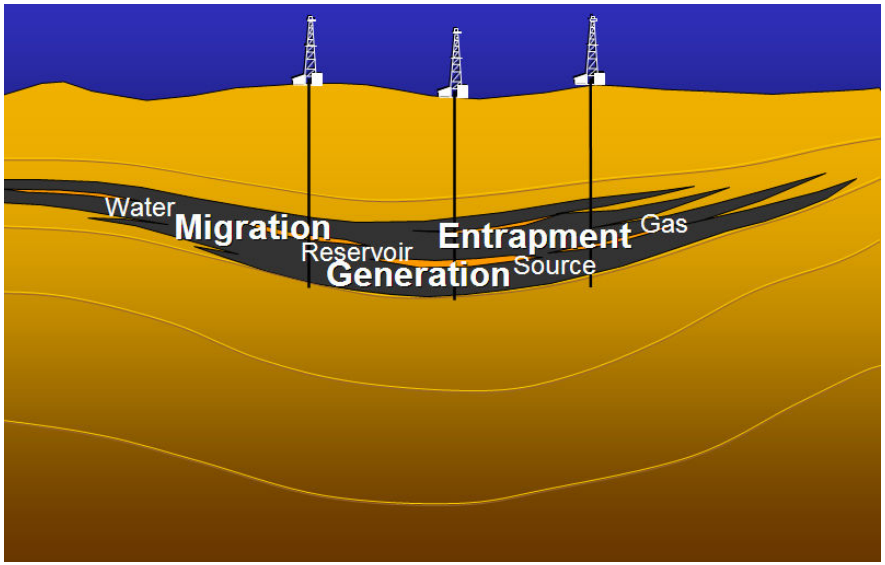
- CSG – Coal Seam Gas (all gases)
- CSM – Coal Seam Methane
- CBM – Coal Bed Methane
- CMM – Coal Mine Methane (may contain lots of air!!)

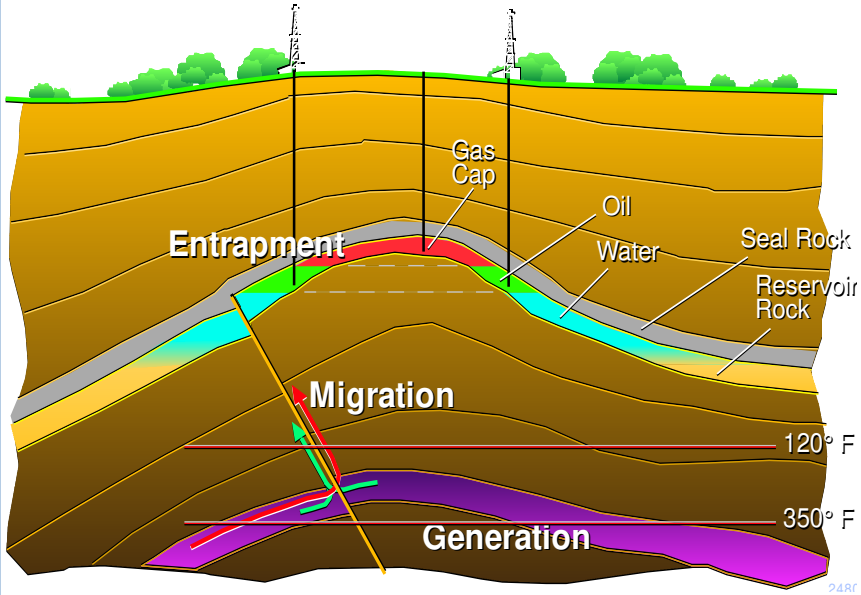
CBM Generation and Entrapment – Comparison with Conventional Hydrocarbons

Coal Reservoir vs Conventional Petroleum Traps

CBM:

- Laterally extensive coal seams
- Gas adsorbed onto coal surfaces
- Limited communication between wells
- Water usually fills pore/fracture space
- Water production then gas

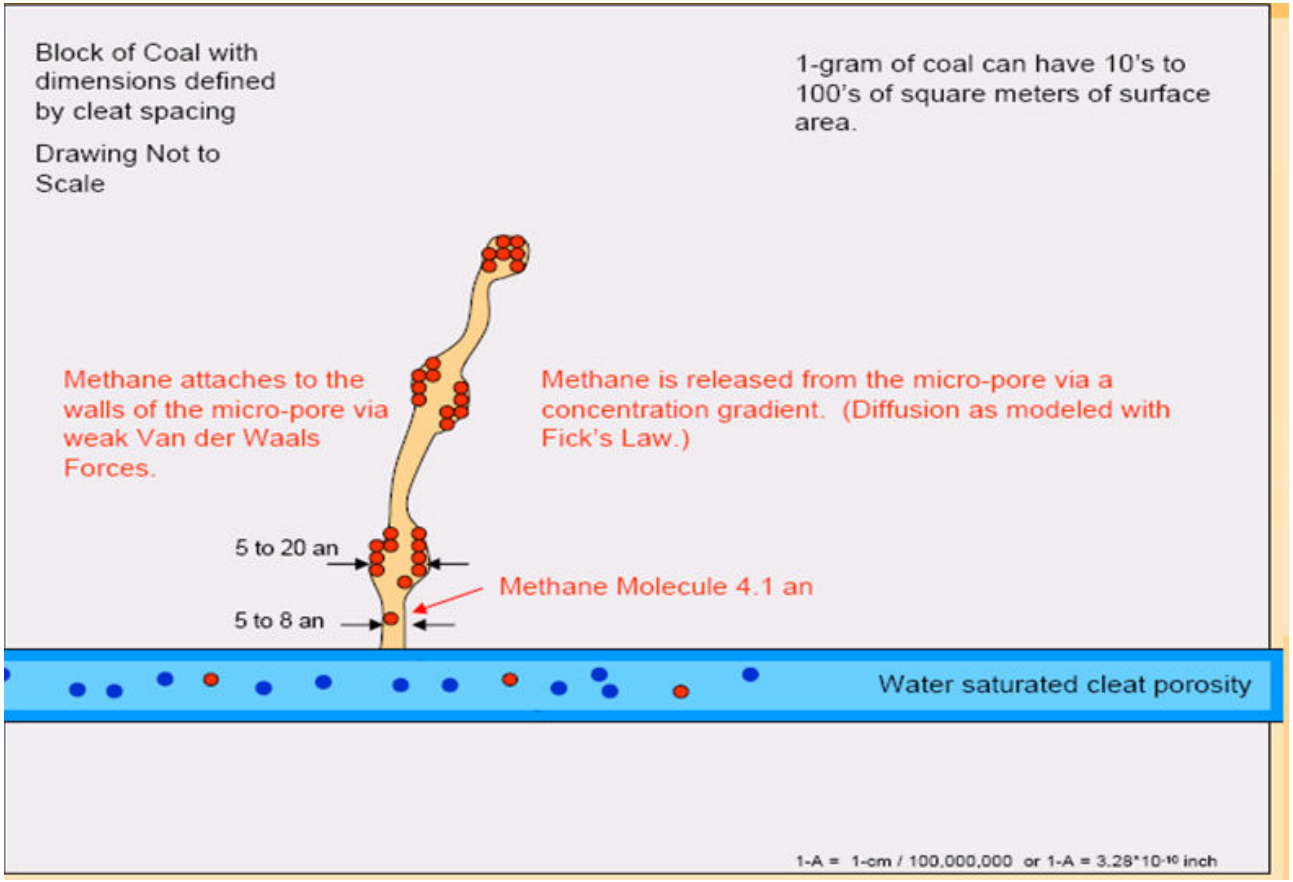




Conventional:

- Structurally trapped by seal
- Hydrocarbon presence due to buoyancy
- Gas compressed into pore space
- 1 well may drain entire trap
- Gas then perhaps water
- Possible condensate

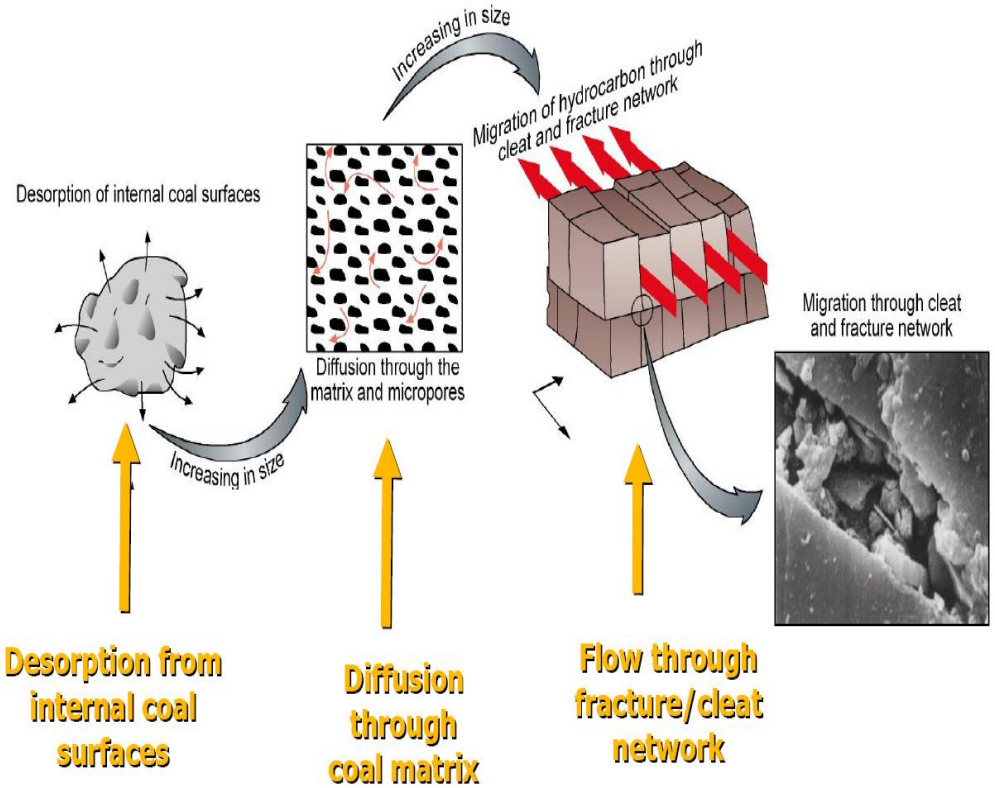
How is gas stored in coal?



Gas is adsorbed onto the surface of micropores within the coal

It is held in place by molecular attraction (Van Der Waal's forces)

How is gas produced from coal?

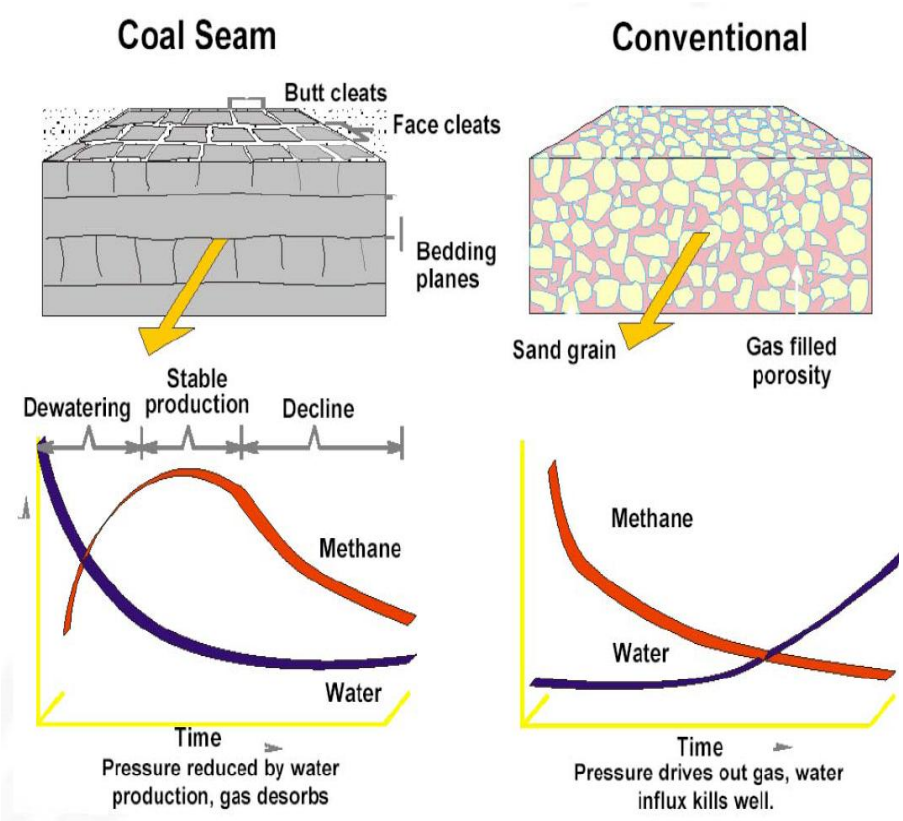


Depressuring the coal by producing water is required to desorb gas from the coal matrix. Gas then flows into the cleat system where it can be produced by wells

CBM vs Conventional Gas Production Characteristics

CBM

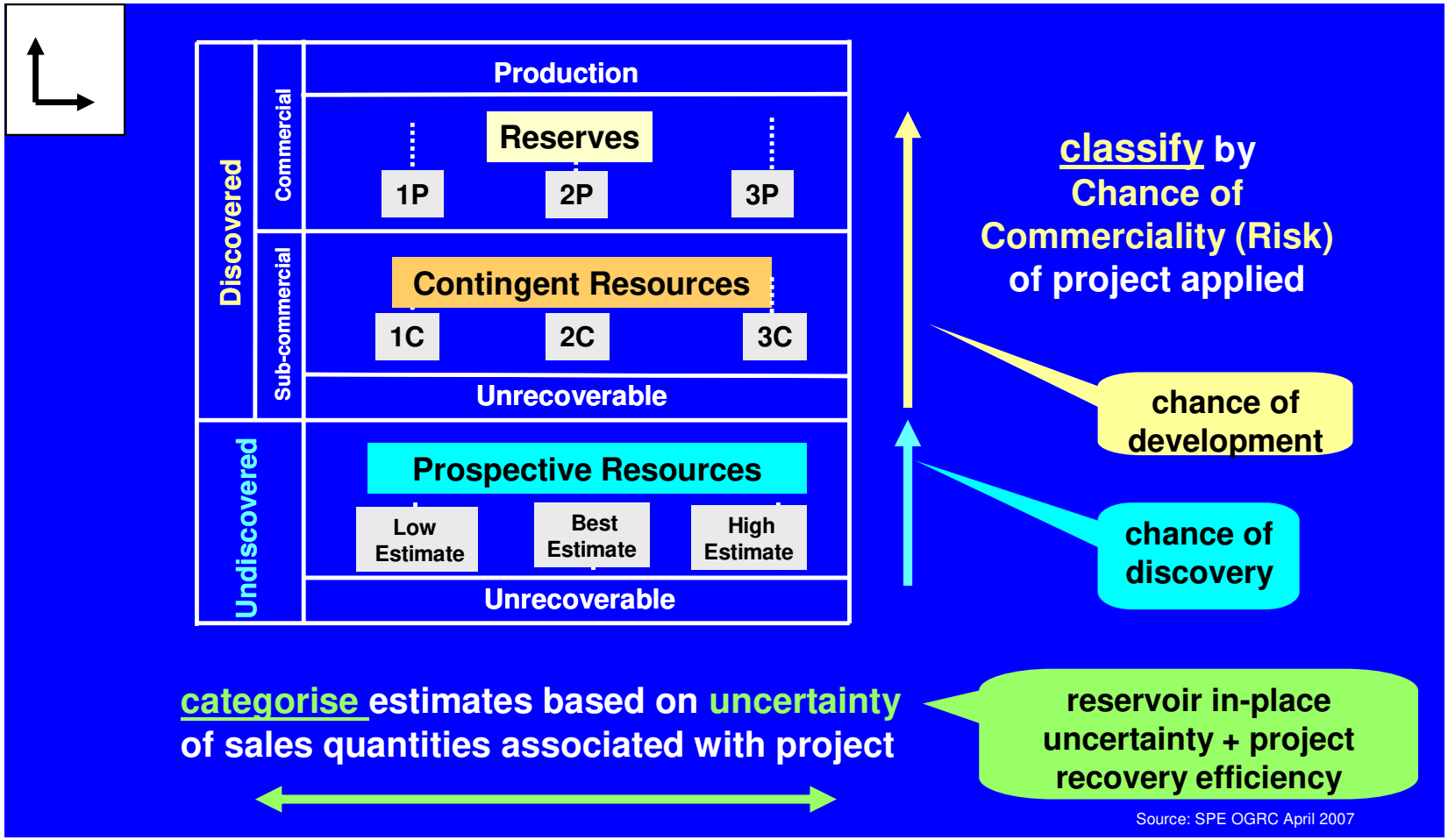
- During the initial phase of dewatering, gas rates are typically low and pumping is required
- As the pressure declines, gas desorbs and migrates into the cleat system and then to wells
- Gas production increases before entering decline



Conventional Gas

- The maximum rate is at the start of production when the pressure is highest
- The rate declines as pressure declines
- Late in life, water may be produced which inhibits production

PRMS Separate Classification & Categorisation



Six things to remember about the PRMS that also apply to CBM

- Project maturity and recovery uncertainty are evaluated separately
- Projects are “classified” based on their chance of commerciality (the vertical axis)
- Estimates of recoverable and marketable quantities associated with each project are “categorized” to reflect uncertainty (the horizontal axis).

- and

- The PRMS is a project based system
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PRMS Reserves & Resources: Risk vs. Uncertainty

- Under the PRMS, risk and uncertainty are treated separately
- Risk applies to the **commercial maturity** of a project hence:

  Exploration (Prospective Resource):
  => Chance of Discovery (risk of dry hole)

  Discovery (Contingent Resource):
  => Chance of Development (risk of non-commercial discovery)

- Uncertainty is considered in **recovery** for a given project hence:

  High Confidence => Proved Reserves (1P or P90)
  Best Estimate => Proved+Probable Reserves (2P or P50)
  Low Confidence => Proved+Probable+Possible Reserves (3P or P10)

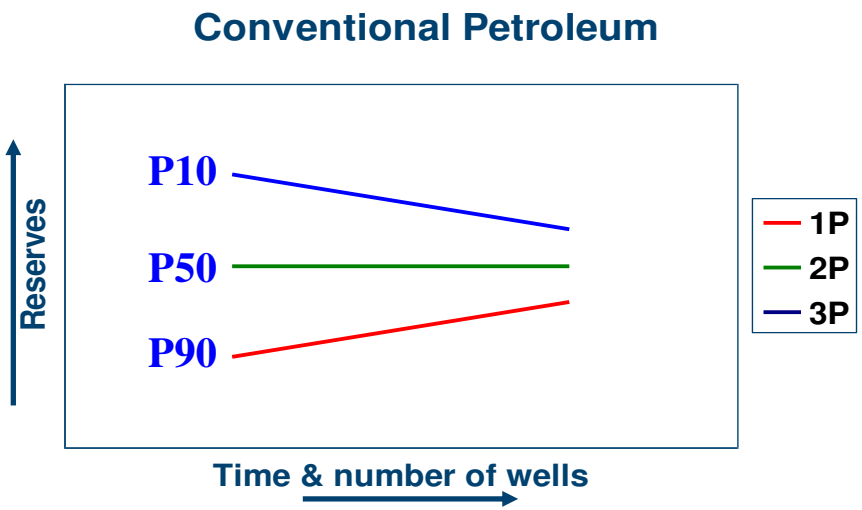
PRMS Resource Category Transition Criteria

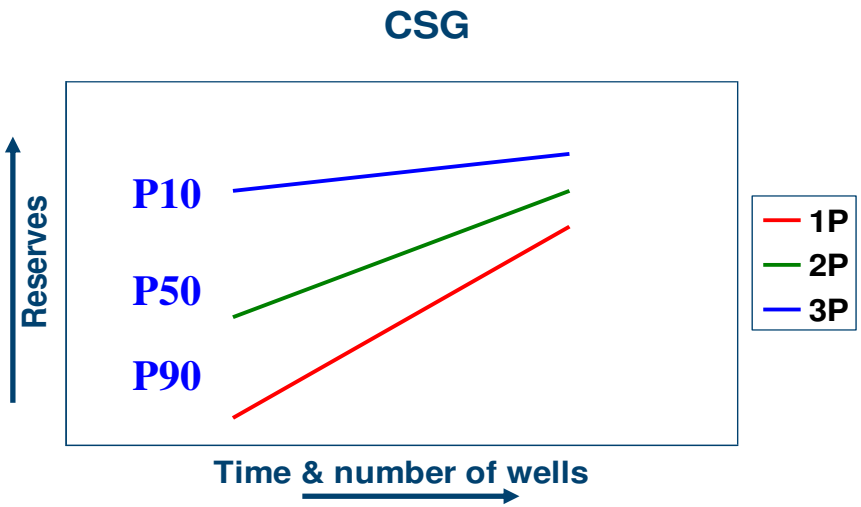
	PROSPECTIVE RESOURCES	CONTINGENT RESOURCES	RESERVES
DEFINITION	Petroleum .... potentially recoverable from undiscovered accumulations	Potentially recoverable from known accumulations .... not currently considered to be commercially recoverable	Petroleum ... commercially recoverable by application of development projects to known accumulations
TRANSITION CRITERIA		**Must be discovered:** ...exploratory wells have established through testing, sampling, and/or logging the existence of a significant quantity of potentially moveable hydrocarbons	**Must be discovered and commercial:** • Reasonable timetable for development. •Economic and market exists • Facilities can be made available: •Reasonable expectation of approvals • High confidence in the commercial producibility

Prospective to Contingent Resource Category Transition Criteria – Application to CBM

- Demonstrated by drilling, testing, sampling and/or logging:
  - Hydrocarbon gas content (e.g., coal sample or gas flow)
  - Coal thickness sufficient to establish the existence of a significant quantity of potentially moveable hydrocarbons
  - There should be data indicating sufficient permeability for flow within the coal seam
- Gas rates may as yet be undemonstrated or uneconomic
- Gas composition may or may not support marketability
- Location may be significant distance from existing well locations that have demonstrated commercial potential
- May be outside coal fairway or acceptable depth limits (typically 200 to 1000 m)
- May require as yet unproven well technology, (e.g., untried stimulation techniques or horizontal/multilateral wells)
- May be outside areas that can be accessed legally (e.g., protected land)
- Development plan immature or subeconomic
- Market not assured
- May require approvals.

CBM Reserves Growth Paradox





- Trends towards 2P
- Makes sense if 2P is roughly a P50 or 'equally likely" value

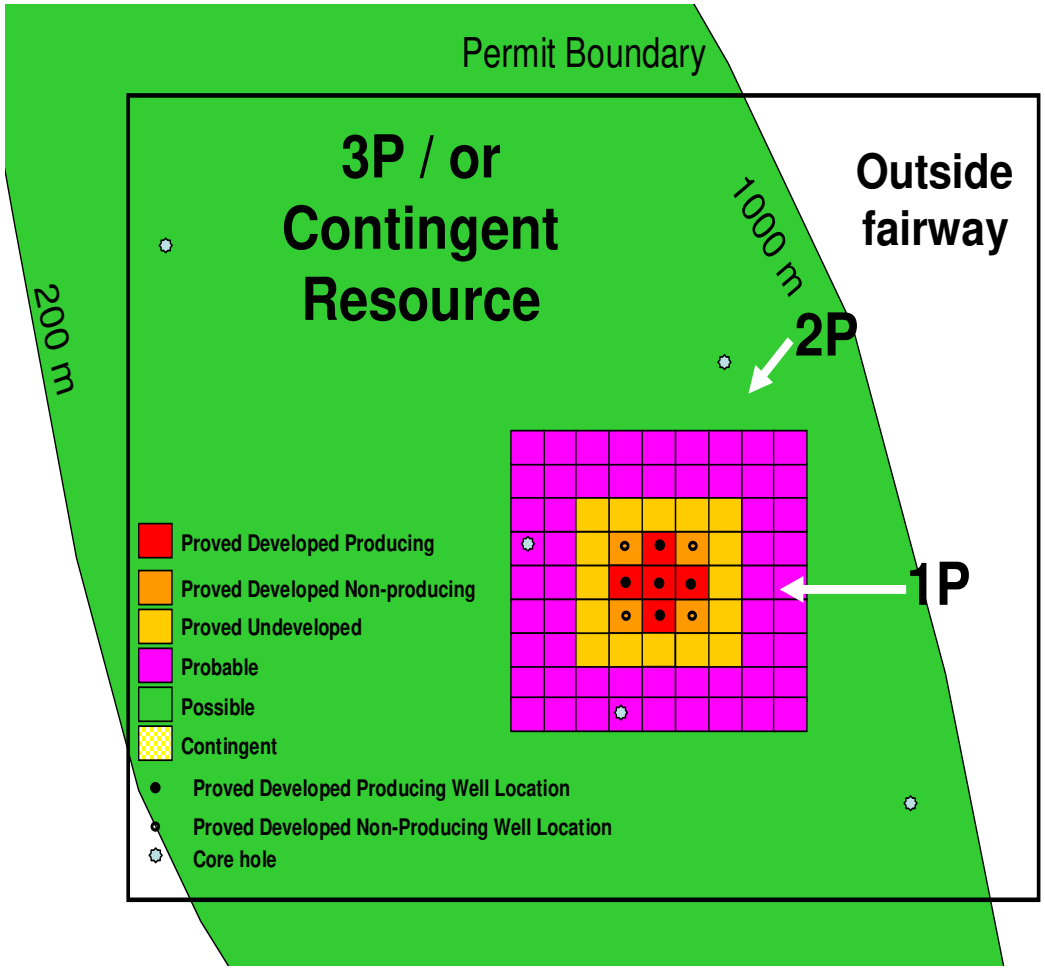
- Trends towards 3P value which may also experience growth in immature areas
- Inconsistent with "equally likely" principle
- Why? – the 2P as stated is <u>not</u> "equally likely" and the 3P is <u>**not**</u> low probability outcome!!!

Why is CBM 3P (so far) not a low probability?

- Areal extent of coals generally much greater than permit area => resource limited by permit area
- Deterministic incremental approach used where the only developed reserves are proved. Probable and possible are undeveloped
- Questionable application of SPE PRMS – even by independent reserves certifiers!!!
  - Examples observed of non-compliance in relation to the "defined project"
- Full life of permit vision may not always be disclosed
- "Low" probability 3P may in fact include "higher" probability 2C Contingent Resources

How are CSG Reserves booked now?

- Deterministic incremental approach where the only developed reserves are proved. Probable and possible are undeveloped
- **Proved developed**: Nominal drainage area of a well, depends on coal properties and geology, typically 40-320 acres
- **Proved undeveloped**: within 1 drainage radii from productive well, up to 2 in high permeability areas with good continuity
- **Probable**: typically 2 drainage radii away from Proved, could be extended in high permeability areas with good continuity
- **Possible:** 2 drainage radii away from Probable – or greater if data allows
- **"Bracketing" or "rubber-banding"** is also used to enable areas beyond normal well spacing conventions to be categorised in a higher confidence resource class/category

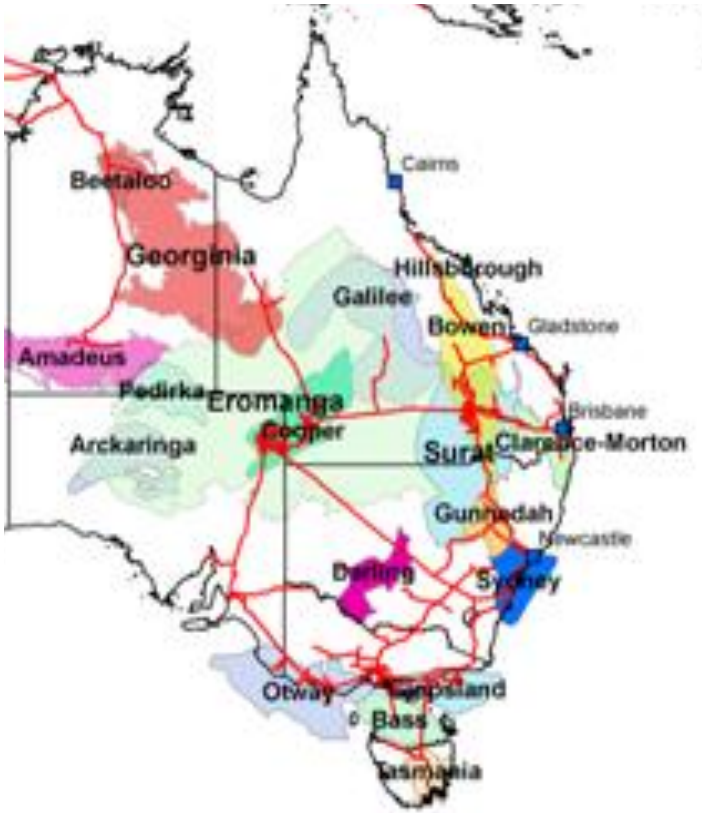


Comments on Current Practice

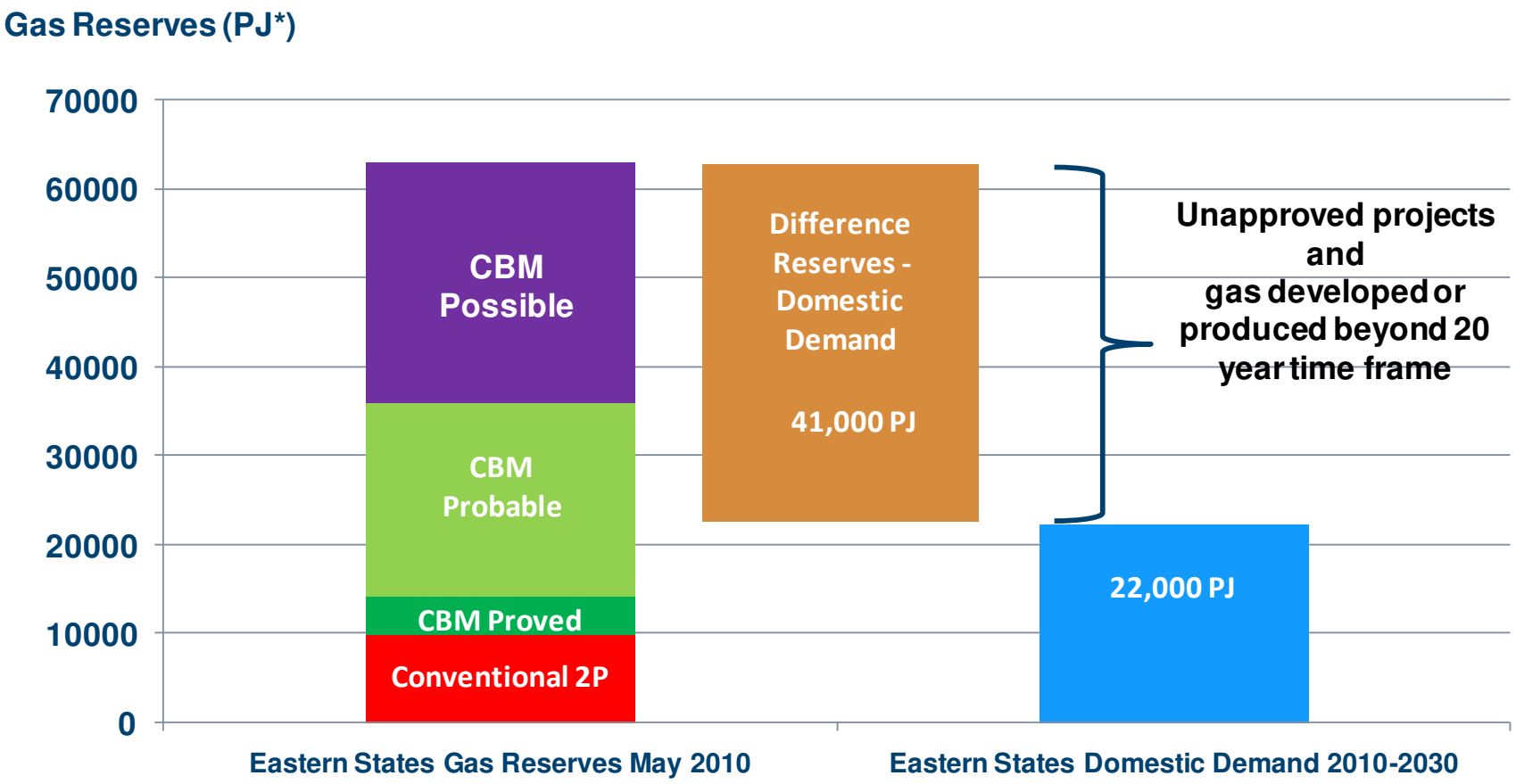
- May be no direct link between project and reserve
  - Often may have no link between reality of project scope in terms of well numbers / areas to be developed and reserve range quoted
  - can be 1-2 orders of magnitude difference between 1P and 3P reserves for a given property
  - Vastly different scale of development between 1P and 3P e.g. 10s to 1000s of wells
  - Vastly different market implied ie bcf/low Tcf to tens of Tcf
  - Vastly different scale of investment between 1P and 3P e.g. $10's of millions to $1000's of millions
- Current approach may confuse the risk of project being commercial and the uncertainty surrounding project recovery
- Does not recognise uncertainty in developed reserves
- Does not provide realistic assessment of project risks and uncertainties
  - Eg for typical offset well spacing rules, once 1/9 of the acreage has been drilled up on an evenly spaced, all of the acreage will be deemed proved
- There is an alternative: refer SPE 117124 Application of PRMS to Coal Seam Gas

Implications of Current Practice – Australian Example

- Following example is a snapshot of gas reserves reported as at Q1 2010 and booked by companies with gas attributed to the Australian Eastern States gas market and/or proposed CBM-LNG export projects
- In Eastern Australia, the gas market is largely contract based, with domestic gas contracts being based on 2P reserves
- However CBM 3P reserves were being routinely reported for both export and domestic projects.
- Since Q1 2010, there have been 3 CBM-LNG projects sanctioned: The first in October 2010



CSG Reserve Bookings and the Eastern Australian Gas Market – Q1 2010 Snapshot



Source: Company websites, ABARE 2010 and RISC Analysis

*1 PJ is approximately 0.95 bcf @ 1000 BTU/scf

Australian Eastern States Gas Reserves – Q1 2010 Snapshot

- In aggregate, reserves bookings were 2.8 times Eastern States 20 year gas demand
  - In Q1, 2010 no CBM-LNG projects had been sanctioned
  - Surplus of 41,000 PJ over 20 year demand
  - PRMS has "reasonable development timeframe" guideline (5-year recommended)
  - If not 5 years, how long is reasonable – 20, 50, why not 100 years?
- In Q1 2010 CBM unproved reserves/production ratios (R/P) were out of line with norms
  - CSG 1P R/P 25 years, 2P 149 years, 3P 305 years!!!
  - Conventional R/P 2P 13 years
- CBM measure of uncertainty ratios were out of line with norms
  - CSG 2P/1P 6.0, 3P/1P 12.3

- What are the defined "project or projects" that can sustain an order of magnitude difference between 1P and 3P reserves?

Conclusion? – 1P CBM quantities understated and/or some of the reserves were in fact contingent resources based on project maturity criteria

Conclusions and Issues

- Booking CBM reserves based on the traditional incremental "well spacing" approach has advantages - it is a predictable rules-based system, but there are issues
- Typically based on a "best estimate" outcome for wells in all reserves category and relies primarily on area to provide a range of uncertainty in the outcome.
- Does not recognise uncertainty in developed reserves
- The project required to develop the 1P, 2P, or 3P scenario may have a vastly different scale of investment and market requirements, which has implications for project approvals and the potential exists for noncompliance with the project-based principles within PRMS.
- The "defined project" will need to include development and appraisal of the Probable and Possible areas to define the ultimate project limits for Reserves to be claimed over these areas.
- If Reserves are claimed, they must have the necessary degree of operator commitment.
- The approach may not clearly separate risk (i.e., the likelihood of commercial production being realized from a given project) and uncertainty (i.e., the uncertainty in the amounts that will actually be recovered from the applied project)

A Solution

- An uncertainty-based cumulative approach could provide a better indication of the risks associated with successive expansion projects proceeding and the uncertainty associated with the recovery of each project.
- Another advantage of approaching the problem in this fashion is that the uncertainty analysis lends itself to probabilistic assessment should this be required, which may yield additional insight.
- Refer SPE 117124 Application of PRMS to Coal Seam Gas

THANKS

QUESTIONS?