PANEL SESSION:
Unconventional Reserves – Making the ‘New Standards’ Work in Practice

Unconventional Reserves & Resources Estimates
A Square Peg in a Round Hole?

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Outline

• Background

• Conventional vs. Unconventional Reservoirs

• Prospective Resources

• Discovery Test

• Reserves Definition

• Other Issues

• The Way Forward?
2007: SPE/WPC/AAPG/SPEE Petroleum Resources Management System (PRMS)

2011: SPE/WPC/AAPG/SPEE/SEG Guidelines for Application of PRMS
Background

2007: SPE/WPC/AAPG/SPEE Petroleum Resources Management System (PRMS)

2011: SPE/WPC/AAPG/SPEE/SEG Guidelines for Application of PRMS

- 2011 is subordinate to and does not replace 2007 document

- PRMS system was developed for conventional reservoirs
  - Although it is intended for use in unconventional reservoirs as well

- Unconventional reservoirs are fundamentally different in many key aspects

- Principles of PRMS are problematic to apply to unconventional reservoirs

- PRMS guidelines for unconventional reservoirs need more detail and rigour?

- Unconventional development has occurred rapidly and resources estimation techniques have struggled to keep up and been to date largely based on North American practice
  - Are the North American practices appropriate elsewhere?
  - How is rapid technology development accounted for?
Resources Classification Framework

- **PRODUCTION**
  - **RESERVES**
    - On Production
    - Approved for Development
    - Justified for Development
  - **CONTINGENT RESOURCES**
    - Development Pending
    - Development Unclarified or On Hold
    - Development not Viable
- **PROSPECTIVE RESOURCES**
  - Prospect
  - Lead
  - Play

Range of Uncertainty: Increasing Chance of Commerciality

Not to scale
Conventional vs. Unconventional

Hydrodynamic emplacement and trapping
- Trapping not hydrodynamic

Controlled by local structure and stratigraphy
- Well defined limits (e.g. seal and fluid contact)
- Discrete fields

Controlled by regional stratigraphy
- Poorly defined limits
- “Continuous” or “Dispersed” Accumulations

Un-stimulated Production
- Requires stimulation / de-watering

These key differences cause the most of the difficulties applying PRMS to unconventional reservoirs

Modified from Elliott
How to define a Prospect in a continuous unconventional accumulation?

**By Basin**
- Have seen this done, but basins can cover 100s sq. km?
- Basin Resource Potential? TRR?
- Should clearly identify maturity (Play / Lead / Prospect)

**By Licence Block / Tenement / Sub-Block**
- Provides granularity and is often level at which development decisions are made
- How big is a block?

**By Geological “Domain”**
- Various combinations e.g. depth, thickness, gas content, mineralogy, facies, thermal maturity, structural style, stress regime etc.

**By Concentric Well Spacing**
- i.e. same methodology as used for Reserves?

**By Combinations / Others**
- Combinations of the above
Geological Chance of Success

- Hydrocarbons in unconventional reservoirs are not trapped by conventional hydrodynamic forces and have not undergone the source-migration-trap history so conventional risking methodology does not apply
- Risk factors different for different types of unconventional resources?
  - CSG/CBM, Shale Gas, Tight Gas
- PRMS provides no guidance on this, intentionally
  - Individual companies typically come up with their own schemes, but for conventional hydrocarbons, the science is well-established

<table>
<thead>
<tr>
<th>Coal Bed Methane</th>
<th>Shale Gas</th>
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<tbody>
<tr>
<td>Coal Thickness (coals present with sufficient thickness)</td>
<td>Basin Character (stable deposition with suitable depth, thickness, continuity)</td>
</tr>
<tr>
<td>Gas generation (has gas been generated that is stored in the coals)</td>
<td>Burial History (HC generation likely to have occurred)</td>
</tr>
<tr>
<td>Permeability (sufficient permeability in the play)</td>
<td>Organic Content (sufficient TOC in basin)</td>
</tr>
<tr>
<td>Is the coal sufficiently gas saturated that dewatering will produce significant amounts of gas?</td>
<td>Geochemical (Kerogen type, TOC, HI)</td>
</tr>
<tr>
<td>Fractures/Cleating (is there sufficient fracturing to allow gas flow?)</td>
<td>Mechanical (is there sufficient brittleness to allow effective hydraulic fracturing?)</td>
</tr>
<tr>
<td>Stress Regime (is the local stress regime favourably oriented?)</td>
<td>Continuity (is there sufficient continuity and thickness to allow a potential development, horizontal wells)</td>
</tr>
<tr>
<td>Development suitability (is the coal suitable for a particular type of development?)</td>
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Discovery Test

“A discovery is one petroleum accumulation, or several petroleum accumulations collectively, for which one or several exploratory wells have established through testing, sampling, and/or logging the existence of a significant quantity of potentially moveable hydrocarbons”

Conventional
- Deliberately does not require a flow test to establish a discovery
- “In this context, ‘significant’ implies that there is evidence of a sufficient quantity of petroleum to justify estimating the in-place volume demonstrated by the well(s) and for evaluating the potential for economic recovery”

Unconventional (Same principles)
- Generally harder
- Differs between Shale Gas/CSG/Tight Gas?
- For CSG, how much de-watering is required? Single well or pilot?
- For Shale Gas/Tight Gas, can you have a discovery without fraccing? e.g. through analogues?
- ‘Scoresheet’ approach may be useful if includes key features such well testing, gas contents, coal thickness etc., but will still need to make a call one way or other
- Discovery test for unconventionals should be easier?; commerciality is the hard part?

Is discovery test different based on local conditions?
- Does significance vary?
- What is potential for economic recovery?
How far does a discovery extend?

Similar issues as for “what is a Prospect”

- In a single unit, formation?
- Across a lease?
- Limited by what?
  - Geology, size, lease, depth, thickness, gas content, development criteria………
- Maximum Size
- Is it all CR?(or PR)
- How to define 1C, 2C, 3C?
- Does concentric rings incremental method predetermine 1C, 2C, 3C ratios?
- Should there be more use of technical uncertainty (gas content, permeability …)?
- Tendency to develop only sweet spots?
- Combinations are likely appropriate depending on local circumstances
Reserves

“RESERVES are those quantities of petroleum anticipated to be commercially recoverable by application of development projects to known accumulations from a given date forward under defined conditions”

- PRMS states clear linkage between Reserves and Development Projects
- Definition of a “development project” may be difficult in unconventional reservoirs, especially for large scale LNG export projects, sub-projects etc.
- PRMS intention is that this is done at the level at which decisions are made
  - Differs from company to company?
  - In North America, this might be a single well, or group of wells
  - Or could this be a 2 year drilling plan approval, individual compressor stations, entire CSG-LNG project?
- PRMS uses the term “firm intention to proceed” and requires appropriate evidence to support this (timing, commerciality, markets, approvals, facilities)
• Reserves keep going up as more wells are drilled and larger areas are joined up as 2P

• What is linkage to development plans and decisions, FID, GSA, LNG contracts etc.?

• What is uncertainty range based on?

• Reserves jump up (conversion from CR) as “firm intent to proceed” is achieved when all criteria or contingencies for Reserves are met

• For large projects e.g. CSG-LNG, should this happen in phases?

• Appropriate definition of a Project? Sub-Projects, Phase
  ➢ Depends on decision making?
Queensland 2P Reserves

Queensland Coal Seam Gas 2P* Reserves

Australia consumed about 1082 PJ gas in 2010-11

Queensland consumed about 239 PJ gas in 2011
Source: DomGas Alliance, July 2012

Based on Operators submissions

FID of 3 main CSG-LNG projects

Comments on “Traditional” Method

- Traditional method is an incremental, well spacing based approach
- Derived from North American practice, where infrastructure is readily accessible
- It is a simple, easy to understand and implement, consistent system

However it has several issues:
- Some authors and resources assessors feel that it mixes the PRMS axes, i.e. does not separate risk from uncertainty
- Not necessarily linked to development decisions; Not project-based
- Technical uncertainty plays a minor role i.e. well spacing areas dominates the Reserves range
- Are locations close to existing wells really more certain, given well high degree of heterogeneity in small areas and adjacent wells? Spatial Correlation?

- Alternative approaches have been proposed e.g. SPE 117124 which proposes the project area as fixed (based on development plan), then assign technical uncertainties to 1P, 2P, 3P
- Still requires link to development plan, gas sales, LNG sales, approvals etc.

More work required in this area!
Performance Variability

Well productivity can vary greatly in a small area

Variation in production rates over a small area, Powder River Basin

- CSG development involves a close well spacing e.g. 750m
- Well performance varies greatly from well to well

Other Issues related to Unconventional Reserves

- Volumes associated with a large project may not be classified as Reserves until successive commitments are reached e.g. for large LNG projects, gas volumes, compressor stations are staged
  - Project definition? Sub-projects? Timing?
  - Some volumes may remain as Contingent Resources
  - Poor quality areas may be “subsidised” by high quality areas such that the project as a whole is economic (project definition)
- Reserves dependent on Price; Reserves may be much larger at higher prices
- Local vs. International Pricing
- Availability and Cost of Services (Rigs, Fracture Crews etc.)
- Gas Sales Agreement may be tied to an IOC’s global portfolio, or other assets, not to a specific development
- 1P vs. 2P based lending
- Very little long term historical data to validate forecasts
- Application of new technology to predictions, well spacing etc.
  - e.g. micro-seismic as basis for Stimulated Rock Volume
Conclusions

- Applying PRMS to Unconventional Reservoirs is challenging!
  - Fundamental differences between conventional and unconventional reservoirs and developments are responsible
  - Issues occur throughout the project lifecycle
  - Definition of a ‘Project’ is a key issue, which may vary between companies, and geographies
  - Judgement and justification are required even more
  - Greater use of sub-classes

- PRMS can, and will, provide more guidance in this area
- PRMS is a Principles-Based System, that applies globally, to all situations, and is not a ‘cook-book’
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