Optimizing CBM Development in Indonesia
Novel Approach for accessing CBM

Norbert Heitmann
Stimulation Domain Mgr.
Schlumberger

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CBM Current & Past Experience

**Australia**
- Reservoir depths: 400~1000 m
- Multi layers with 3 to 10 coal seams
- Wells are vertical / slightly deviated
- Combination of frac types (Xlinked to slickwater frac for low perm zone and some N2 StableFoam job)

**Rocky Mountains**
- Reservoir depths: < 350 m
- Multi layers with 1 – 8 coal seams
- Wells are vertical / slightly deviated
- Frac process evolved from X-link to SW to FoamFRAC.
- Current practice includes CBMA.

Main CBM activities
**General CBM Reservoir Characteristics**

**Coals are complex reservoirs:**
- Naturally fractured / dual-porosity behavior
- Gas is absorbed instead of compressed
- Two-phase flow in fracture/cleat system
- Fracture/cleat systems are highly variable

**Parameters controlling productivity:**
- Permeability (fracture/cleat system)
  - Permeable coals are more friable
- Well spacing
- Initial gas/water saturation
- Gas production is a function of lowering the reservoir pressure causing the methane to desorb.

**Most coals are shallow:**
- *Complex* fracture geometry
- High treating pressures
Coal Beds: Dual Porosity System

Case 2: Maximum stress at an angle to face cleats (causes tortuous fractures)

Face Cleat (primary flow)

Butt Cleat (secondary flow)

Desorption from internal coal surfaces

Diffusion through matrix and micropores

Fluid flow into natural fracture network
Permeability in Coal

- Due to Cleats (natural fractures)

- Cleat System
  - Face cleat: more dominant & continuous
  - Butt cleat: less dominant & perpendicular to Face cleats

- Face cleat orientation related to tectonic forces

- Cleat spacing ranges from 1/10 to several inches
Fastest Dewatering Requires Optimized Completions

- Optimized perforation density, size and orientation
- Prevention of proppant flowback
- Optimized fracture conductivity ($C_{fD}$)
- Efficient lift methods to keep fluid level at or below the perforations
- Produce water to lower reservoir pressure, lower $S_w$ in order to increase effective $k_g$
- Evaluate Re-fracturing after dewatering phase

Optimization Process:
- Develop comprehensive reservoir description
- Integrated and process-optimized fracture stimulation delivery
- Implement proper quality control and treatment diagnostics
Innovative Approach Integrates entire Upstream Cycle

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| Increase % of clusters contributing to production
Maximize fractured reservoir volume contributing to production to cater for fracture - reservoir reality | Optimize hydraulic fracture system performance based on cleats, rock & stress characteristics.
Innovative in-situ fracture fluid diversion to maximize reservoir contact and proppant placement | Dedicated Coiled Tubing with fit-for-purpose downhole BHA – allowing faster, optimized and continuous work
Micro-Seismic to monitor fracture placement | Pad Drilling
Simultaneous, continuous and integrated work - from drilling to completion.
Multiple frac equipment set-ups on multiple Pads to establish factory process |
Thickness, Depth and Number of Coal Seams

**Depth:**
Stress field affects the type of fracturing that will result

**Thickness:**
More complicated fracturing in thin seams

**Number of Seams:**
Governed by the number of stages for carrying out the treatment
Fracture Treatment Design Considerations

Main goal is *to connect* the matrix with the butt & cleat systems

- Create large effective wellbore radius (length and conductivity)
- Increase “pressure sink” into the reservoir *to maximize dewatering rate* and drainage area

Create highly conductive fracture

- Necessary to produce large volumes of water
- Needed to eliminate pressure drop in the fracture which allows the maximum pressure drawdown to be applied to the reservoir

Control fluid loss

- Minimize formation damage by controlling loss of frac fluid to the cleat system
  - Innovative frac fluid systems (VES) and smart deployment strategies to be pursued
- Helps maintain maximum hydraulic fracture width while pumping which improves proppant placement and fracture conductivity
Poor Fractured Well Performance - Why?

Hydraulic Fracture does not intersect sufficiently face cleats
- better frac placement and in-situ frac diversion needed
- more effective and efficient frac fluids to be deployed

- Well productivity is controlled by discontinuous and less permeable butt cleats

maximum horizontal stress direction

multiple & combination fractures

Face Cleat (primary flow)

Butt Cleat (secondary flow)
Cementing Considerations & Requirements

- Formation damage from the cement slurry can be more damaging than drilling
- This impairment can be minimized with properly designed light weight systems
- Traditional solution is the application of low density cement systems to reduce the hydrostatic pressure of the cement column
- Requirements of the slurry are more than just density reduction:
  - Slurry must create seal to prevent annular flow of fluids (low permeability).
  - Slurry must have adequate compressive strength to maintain bond integrity

- Whole slurry loss into the cleat structure must be minimized
Thin Section of Single Cleat

Analysis of a single face cleat shows restrictions where fines are able to bridge and restrict fluid flow.

Plugged cleats limit water production and back-pressure the reservoir, which prevents methane desorption.

**New integrated perforating strategies to be deployed**
Coal Bed Methane Additive: CBMA™

Designed specifically for the unique properties of coal reservoirs

- Non-ionic surfactant solution adsorbs on coal surfaces
- Lowers surface tension of the water around the coal surfaces
- Maintain the natural wettability of the coal surface
- Enhance the ability of the coal to dewater – increases permeability of coal to water
- Minimize fines movement through the cleat system. Repels water from fines
- Operationally easy as add to frac fluid
- Economical
Inefficient Complex Fracturing

Fracture follows Cleat or zigzags

Solution:
Temporary In-situ fracture diversion

Butt Cleat (secondary flow)
Face Cleat (primary flow)

Maximum horizontal stress direction
Inefficient Complex Fracturing

Maximum horizontal stress direction

Multiple & Combination fractures

Face Cleat (primary flow)

Butt Cleat (secondary flow)
Fracture Geometry in Coal

- It is difficult to generate long fracture half-length in coal seam reservoirs
- Single, vertical fractures intersecting multiple coal seams
- Single, vertical fracture contained in a single coal seam (common in thicker coal seams (>20 ft)).

- **Innovation:**
- Fracture intercepts seams from near-by wells (vertical and horizontal wells)
Innovative Coal Fracture Geometry

• Key is to avoid inefficient Coal Initiated Fractures

Solution: Initiate fractures in the lower stress clastic rock allow fracs to grow into coal seams

High vertical permeability in coal, enables efficient drainage through indirect fracture

High Leakoff in coals, will assure proppant connectivity to coal seams
Advantages of Indirect Vertical Fracture Completions (IVFC)

- Significantly more efficient fracture length propagation
- Reduction in near wellbore friction effects & screenouts
- Reduced proppant and formation flowback
- Enables the application of less damaging fracturing fluids
New: Complex Fracture Modeling

- Wire-mesh Model
  - Semi-analytical
  - Elliptical equivalent porous media
  - Two orthogonal sets of fractures
  - Can work with limited input dataset

- Unconventional Fracture Model (UFM)
  - Gridded numerical, rigorous model
  - Explicit modeling of HF-NF interaction
  - Links rock fabric with fracture geometry
  - Unique fully coupled solution
Innovative Fluid: VES – Visco-elastic polymer-free

Polymer Fluids

True VES Fluids
Temporary in-situ Fracture Diversion

- Large particles are intercepted at fracture entrance. Smaller particles reduce permeability and deliver temporary isolation.
- Fibers ensure integrity of the blend from surface to near-wellbore area and enhance the bridging mechanism.
- Particles and fibers degradation is triggered by BHST.
- Reliable isolation with small volume of materials (< 20 bbl of composite fluid with < 150 lbm of solids per operation).
- Degradation without residue. No interventions required.
Be Ready to Think Big

More Planning Less Footprint

- Drilling pads
- Longer laterals
- Reduce traffic
- Evaluate reservoir quality
- Favorable reservoir 'sweet spots'
- Pad well design
- Long term cost
- Pad placement
- Favorable reservoir and pad location

The 7th International Indonesia Gas Conference & Exhibition

“Gas for Sustainable Economic Development”

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Options for Coiled Tubing Assisted Fracturing

CoilFRAC:
- All target Zones perforated with WL in advance
- Straddle cup packer
- Frac pumped down the CT
- Each Zone fracked independently

AbrasiFRAC:
- Perforations cut with AbrasiJET nozzles
- Frac Pumped down the CT/CSG Annulus
- Isolation between zones with sand plugs
- Frac pumped down the CT/CSG Annulus
- Each zone fracked independently

Hybrid Frac:
- Same as AbrasiFRAC
- Isolation between Zones with Packer
CT Hybrid Frac Performance in Australia

6 Frac Stages Performed in 12 hours in one trip

Client decreased completion time from 6 to 3 days and experienced a cost savings of ~40%
Conclusions & Outlook

- Functional business model needed to get it going & to get it right

- Commitment and partnering-up among all players

- Factory Drilling and Hydraulic Fracturing to optimize & maximize production

- New innovative and fully integrated Coiled Tubing assisted fracturing is a viable option for development of CBM

- The success of a project of this magnitude will be depend on the efficiency of the overall process and a commercial model that promotes a sustainable scenario for the operators and the service provider.

- Fit for purpose equipment, fluids and techniques will bring success