Modelling Unconventional Oil & Gas Reservoirs

Industry’s Go-To
Unconventional Resources
Modelling Workflows
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Modelling Unconventionals with CMG

Agenda

• Why use Reservoir Simulation?
• Top 10 Reasons why CMG is the preferred technology for modelling unconventionals
• Workflows for Modelling only Production
• Workflows for Modelling Injection (Fracking) & Production
• Large Model Example
• Who is using CMG for Modelling Unconventionals
Why Use Reservoir Simulation?

For Physics-based EUR’s & Well/Cluster Spacing Optimization

- Very long times to boundary-dominated flow (between perf clusters, stages & wells)
- Multi-phase Flow (dropping below bubble or dew point pressures in matrix)
- Non-Darcy Flow (turbulent & slip)
- Multi-Component Phase Behavior, Adsorption & Diffusion
- Compaction of Induced & Natural Fractures (propped & unpropped)
- Heterogeneous Rock Properties (fluid flow & geomechanical)
- Heterogeneous Well Completions (SRV geometry & extent)
- Geomechanics (modelling stress changes during hydraulic fracturing & production)
- Geochemistry (modelling interaction between injected fluids and insitu minerals & fluids)
Why Use Reservoir Simulation?

To Accommodate Current Development Practices

• Analysis & Forecasting of multi-well pad models exhibiting interference
• Modelling of Re-Fracs & Infill Drilling (time-dependent fracs, compaction & rock-physics)
• Interpreting Production Surveillance Data (DTS, Production logs, tracers, etc.)
• Accounting for many uncertain parameters simultaneously

Deep Parameterization
Top 10 Reasons
to Use CMG for Modelling Unconventional Reservoirs
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<th>Options in CMG</th>
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<td>Black Oil &amp; EOS</td>
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<td>Function of <strong>pressure</strong> (Dilation/Compaction tables) or <strong>stress</strong> (3D geomechanics) During Injection and/or Production</td>
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<td>Flow in Wells</td>
<td>Steady-state, homogenous flow &amp; transient, segregated flow</td>
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Easy Creation of Hydraulic Fractures in Reservoir Models

Planar Fractures

Complex Fractures
Easy Import of 3rd Party Fracture Designs

GOHFER, StimPlan, FracProPT, FracPredictor, FieldPro & MFrac

Pressure Distribution: 3D

Pressure Distribution: 2D

Non-Uniform Conductivity

Asymmetric Fractures with Non-uniform Conductivity Distribution
Iteratively Coupled 3D Geomechanics

- Compaction/Rebound/Dilation/Recompaction/Subsidence
- Elastic/Plastic Deformation
- 2D & 3D Geomechanical formulation
- Stress effects on porosity & permeability
- Geomechanics in naturally fractured models
- Geomechanical grid independent of flow grid
- Hydraulic Fracture initiation & growth
6
Practical for Both Single Well & Full-Field Multi-Well Simulation

SPE 171611 Patrick Kam, Encana (multi-well)
SPE 171671 Blair, Crescent Point Energy (multi-well)
Modelling of EOR for Unconventionals

Substantial increases in recovery factor predicted

Recovery Factor CO2 vs CH4

7%
4 Fast, Automated Workflows

HM a well in no more than One Day!

“I can do it Faster in CMG than I can using RTA”
Satisfied Customer
Best Support in the Industry

- 93% Customer Satisfaction, Support Query
- <24-hours Response Time
- 1175 Training Courses
- 9246 Trained Engineers

“...we received extraordinary support across multiple regions in order to complete our project on time...”
Baker Hughes 2016

“Great balance between focus on theory and practical use of the software”
Shale Class Student 2015

“The CMG team is far more responsive to issues that arise vs. their competitors”
IRT newsletter 2011
REMOVED CUSTOMER LIST FOR PDF DISTRIBUTION
It’s What your Peers Use!

Rapidly Optimize Recovery & Returns of Unconventional Reservoirs…TODAY!

86 North American E&P Operators use CMG For Unconventional Modelling

Modelling in Real time, not Geologic time
CMG’s Unconventional Reservoir Production Modelling Workflow

- Bi-Wing Planar Fractures
- Complex Fractures Via Micro Seismic
- Third Party Import
Parameterizing Propped Frac Properties & Sizes with CMOST AI

Propped Frac Properties:
- Half-length
- Width
- Perm
- Spacing
- Height
- Perm Gradient

Stimulated Natural Frac Properties:
- Width
- Perm

SRV Size & Shape:
- # MS events per gridblock
- MS Moment Magnitude
- MS Confidence Value
Sensitivity Analysis

- **Maximum**
  - Matrix_Permeability (1E-05, 0.001)
  - Propped_Frac_Spacing (100, 400)
  - XF (50, 400)
  - Propped_Frac_Permeability (1000, 30000)
  - SW_Nat_Frac (0.15, 0.45)
  - Rock_Compaction ("c-type1.inc", "c-type4.inc")

- **Target**
  - 7.756E+04

- **Minimum**
  - 1.09E+04

- **Parameters**
  - Cum_Oil (Linear) (bbl)
  - Values: 3.614E+04, 3.289E+04, 1.766E+04, 1.566E+04, 7362, 3567, 2662
Assisted History Matching
Bayesian History Matching

Differential Evolution Method

CMG Bayesian Engine
Probabilistic Forecasting

Deterministic forecasts may be misleading:
• Only provides one solution
• Ignores Uncertainty

Probabilistic forecasts are preferred:
• Range of Possibilities
• Quantification of risk
Optimization

Cum Oil & NPV after 30 years vs # of Wells

- Cumulative Oil SC (bbl)
- NPV, MMUSD

Time (date)

# of Wells
Engineer only has to build base reservoir simulation model, then decide which parameters to be varied. CMOST does the rest!
CMG’s Unconventional Reservoir Injection (Fracking) & Production Modelling Workflow

CMG’s Reservoir Simulation Workflow

- **CMG’s Reservoir Simulation Workflow**
- **CMOSTAI**
- **IMEX**
- **GEM**

**Builder**

- **Pressure-dependent Dilation/Compaction Tables**
- **Stress-dependent Natural Fracture Dilation/Compaction BARTON-BANDIS**
- **Stress-dependent Hydraulic Fracturing via HYDROFRAC**
Pressure-Dependent Compaction/Dilation Tables

- Propped Region
- Unstimulated Region
- Stimulated Region
- Elastic/Unstimulated Region

Graph showing the log of transmissibility vs. pressure in psi with different regions marked.
Stress-Dependent Natural Fracture Dilation/Compaction

Barton-Bandis Feature in Geomechanics

- Block Considered “Fractured” if: Effective Stress < Tensile Failure
- Permeability mapped back to natural fractures
- During injection permeability is a step function change
- During production permeability follows the curve described by the Barton-Bandis Model
Stress-Dependent Hydraulic Fracture Initiation & Propagation

HYDROFAC feature in Geomechanics:

- Rigorously estimate fracture permeability
- Compute fracture geometry (width, length, & height) in 3D
- Fractures cause discontinuous finite elements to occur

Pressurization

SPE Paper: 167123-MS
Large Model Example:
Run Time Comparison, GPU vs CPU
Large Model Example

- 6.6 million active cells without fractures
- 32 wells
- Nano Darcy perm
- Over-pressured
- Highly under-saturated
Large Model Example

• Added 1,253 planar fracs
  – 39 stages per well
• Increased cell count to 8.73 million
• Ran 10-year forecast at constant BHP
GPU vs CPU Run Time Comparison

GPU Vs. CPU Runtime

GPU cost $163,592

CPU cost $17,912

Broadwell: Dell PowerEdge Xeon E7 4800 Quad Socket
CMG’s Vision: To be the leading developer and supplier of dynamic reservoir technologies in the WORLD