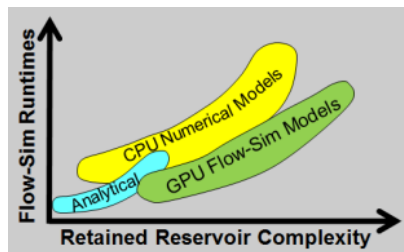


### Large Flow-Sim Model Questions

- Unconventional multi well PAD interference models for vertical and area well spacing questions
- Retain geomodel complexity with millions of cells
- Multiple flow-sim realizations for dynamic ranking
- Fast what-if HM parameter testing cases

Model Runtime vs. Reservoir Complexity



### GPU Flow-Sim Solutions

Echelon is new GPU software for large scale high performance reservoir simulation. It was developed from inception for fine-grained parallelism targeting GPUs. It is exceptionally fast, typically achieving between 10x to 20x faster runtimes than leading commercial simulators and has demonstrated scaling to very large systems with 100 million flow-sim cells, in some cases without upscaling.

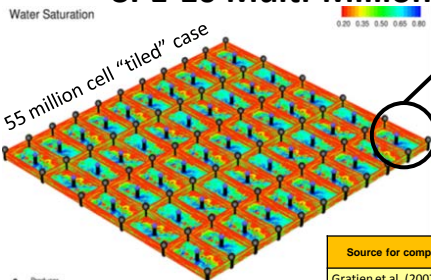
**GPU server with 8 x Tesla K40 GPUs**

**CPU Multiple Cores**

**GPU: Thousands of Cores**

STONE RIDGE TECHNOLOGY

### SPE-10 Multi-Million Cell Test Case



	1 Million Cell (1 GPU)	(2 GPUs)
Time steps	68	68
Newton iterations	418	417
Linear iterations	1678	1617
Solver setup time	31 s	20 s
Solver solve time	53 s	40 s
Jacobian time	8 s	4 s
Initialization time	7 s	7 s
Total wall time	103 s	75 s

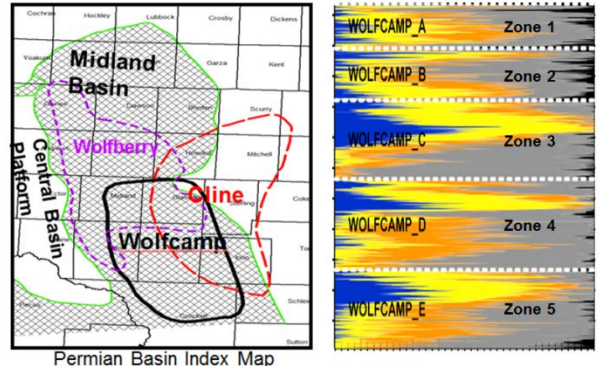
Source for comparison	Method	Hardware	Time
Gratien et al. (2007)	FI with CPR-AMG	64 CPUs	620 s
Fung and Dogru (2008)	FI with CPR-LSPS	64 CPUs	490 s

Gratien, J.M. et al. [2007] Scalability and load balancing problems in parallel reservoir simulation. SPE Reservoir Simulation Symposium, SPE-106023-MS  
 Fung, L.S. and Dogru, A.H. [2008] Parallel unstructured-solver methods for simulation of complex giant reservoirs. SPE Journal, 13 (04), 440-446.

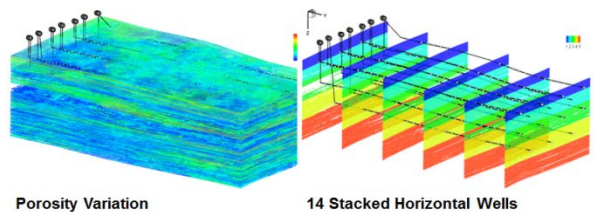
### 25 to 100 Million Cell Geomodel GPU Input Cases

#### Wolfcamp Geomodel

SPE 173246

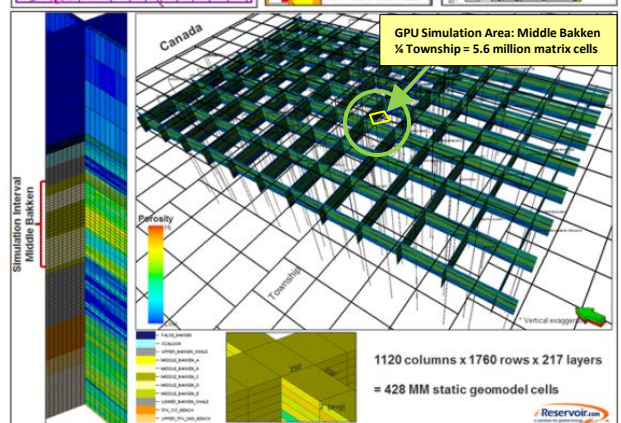
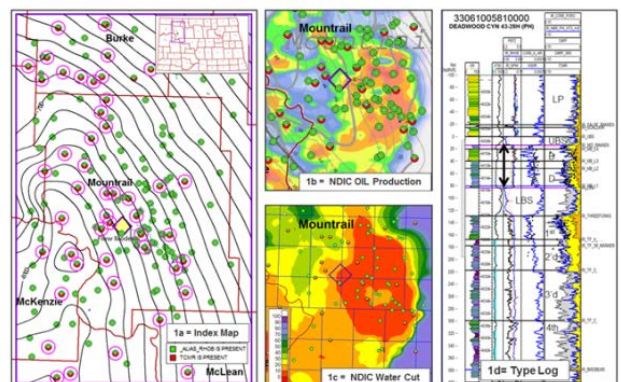


5 zones, 14 staggered wells,  
30 stages/well, 16 million cells



#### Bakken/TF Geomodel

URTEC 2153938



### Wolfcamp GPU Flow-Sim

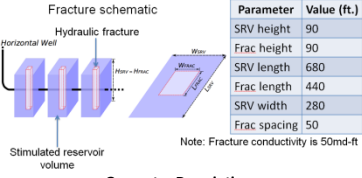
SPE 173246

### Initialization

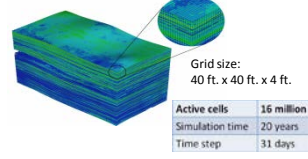
### Bakken GPU Flow-Sim

URTEC 2153938

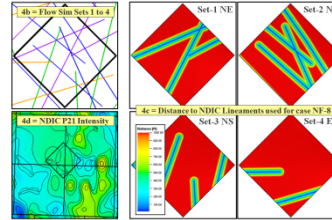
#### SRV and Hydraulic Fracture Description



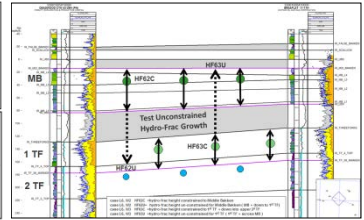
#### Porosity Variation



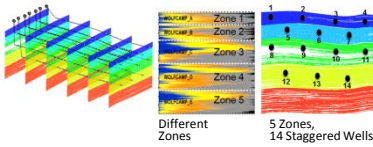
#### Natural Fracture Distribution Cases



#### HydroFrac Well Placement Cases



#### Geometry Description

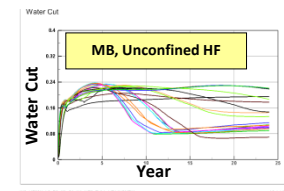
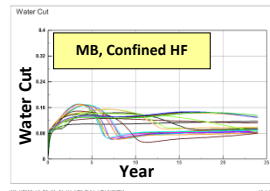
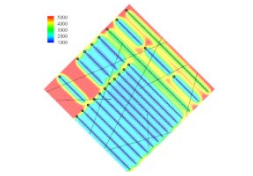
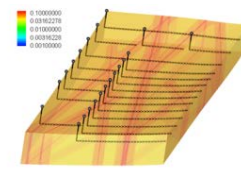
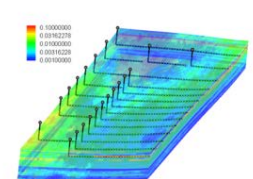
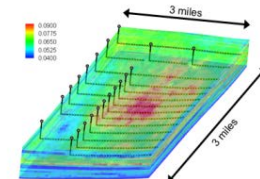
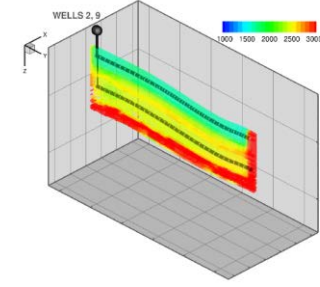
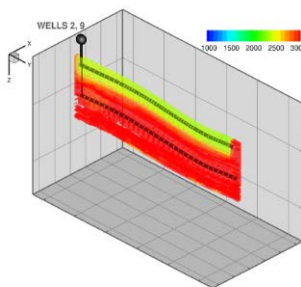
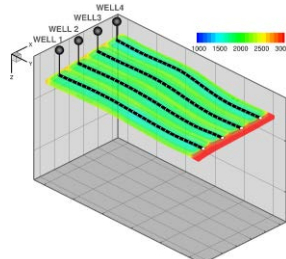
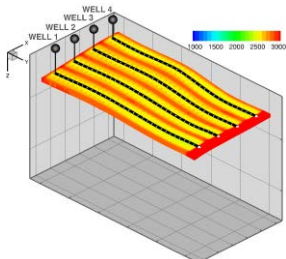


#### Multiple Realizations: Parameter Space

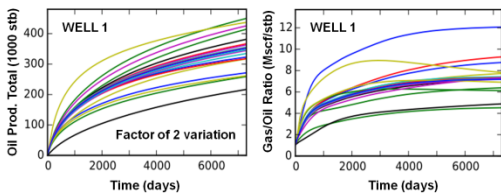
Parameter	Min.	Base	Max.
Initial gas saturation (multiplier)	0.8	0.8	1
Matrix porosity multiplier	0.9	1	1.1
Matrix perm multiplier	0.2	1	2
Matrix-fracture trans. multiplier	0.1	1	10
Natural frac. perm. multiplier	0.1	1	10
SRV permeability (mD)	0.05	0.1	0.2
SRV height (ft.)	56	90	122
SRV areal extent (ft.)	440	680	920
Fracture height (ft.)	56	90	122
Fracture areal extent (ft.)	280	440	600
Fracture conductivity (mD-ft)	10	50	250
Well interference	S-7, 12-14 Shut	All open	1-4, 8-11 Shut

Parameter	Min. Value	Max. Value	Avg. Value
P1 TCMB Porosity Fac.	0.0718	0.345	0.086
P2 TCMB Porosity Fac.	0.0711	0.117	0.058
P3 TCMB Porosity Fac.	0.068	0.052	0.059
P4 Regression Equation Permeability mD	0.0001	2.000	0.0075
P5 Core Fracture Permeability mD	0.0001	2.000	0.0001
P6 Fracture Permeability mD	0.0001	1.000	0.0001
P7 Fracture Permeability mD	0.0001	1.000	0.0001
P8 Fracture Permeability mD	0.0001	1.000	0.0001
P9 Fracture Permeability mD	0.0001	1.000	0.0001
P10 Fracture Permeability mD	0.0001	1.000	0.0001
P11 Fracture Permeability mD	0.0001	1.000	0.0001
P12 Fracture Permeability mD	0.0001	1.000	0.0001
P13 Fracture Permeability mD	0.0001	1.000	0.0001
P14 Fracture Permeability mD	0.0001	1.000	0.0001
P15 Fracture Permeability mD	0.0001	1.000	0.0001
P16 Fracture Permeability mD	0.0001	1.000	0.0001
P17 Fracture Permeability mD	0.0001	1.000	0.0001
P18 Fracture Permeability mD	0.0001	1.000	0.0001
P19 Fracture Permeability mD	0.0001	1.000	0.0001
P20 Fracture Permeability mD	0.0001	1.000	0.0001

### Well Interactions



### Simulation Results



2 jobs: 2U server, 8x K40  
4 jobs: 2U server, 8x K80

Model	Size	# of runs	Total time K40 [K80]	Avg. time/job
Dual Poro	16 M cells	100	13 hrs [7hrs]	16 mins.
Dual Perm	16 M cells	100	17 hrs [9hrs]	20 mins.

