

Mamm Creek Field – Dynamic Modeling Update

Jim Gilman, Huabing Wang and Reinaldo Michelena

iReservoir.com, Inc.

April 21st, 2011

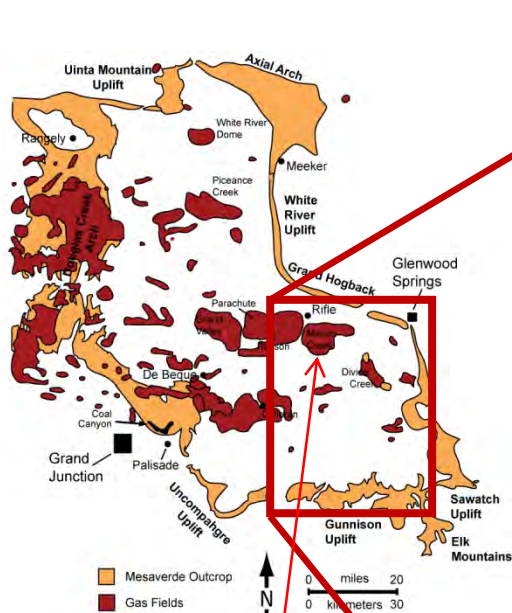
Objective

- The overall objective is to understand the reservoir connectivity and volumetrics
 - Use integrated approach to create a 3D dynamic simulation model based on detailed static geologic and petrophysical models.
 - Incorporate and calibrate hydraulic fracture properties at each well to approximate initial productivity.
 - Simulate long-term dynamic flow to investigate volume influence of wells and the impact of geologic uncertainty on early and long-time performance.

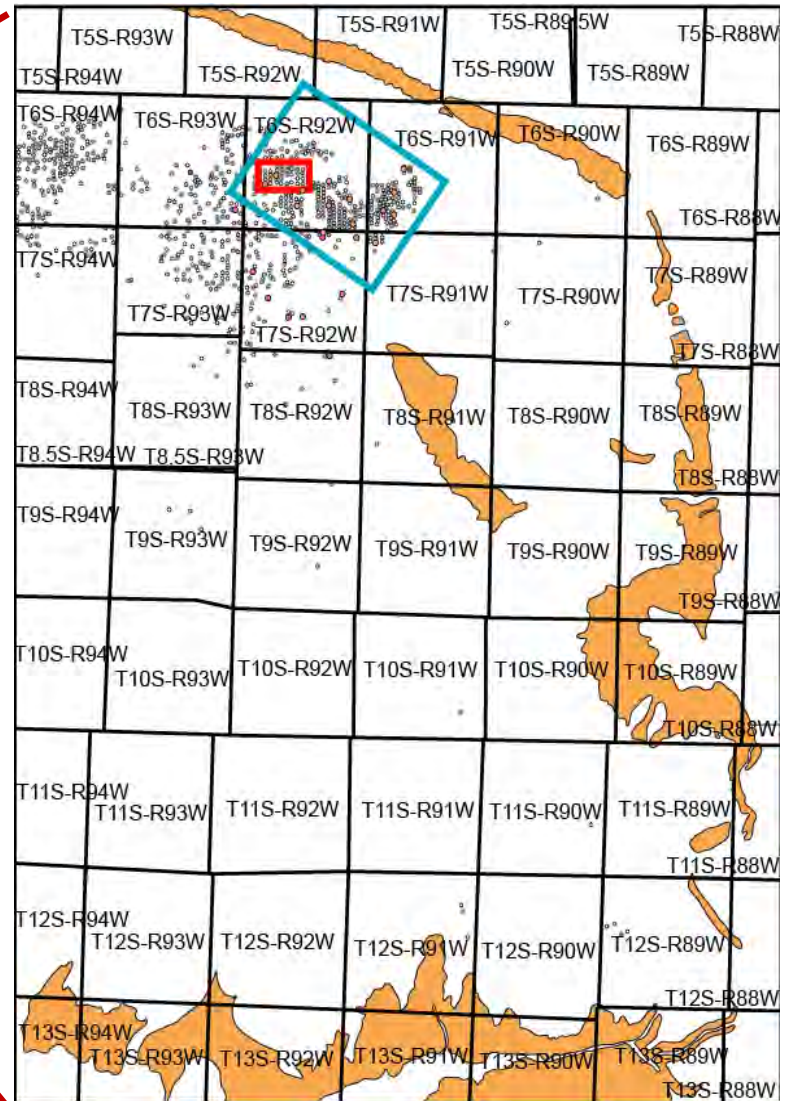
Dynamic Simulation Workflow

- Geologic Model Choices
 - Distribution methods, (e.g. Objects), seismic constraints
- Seismic Constraints
 - Sand probability distributions
- Petrophysical Constraints
 - net pay, BVW, permeability, overburden impacts
- Initial Pressure Distribution
 - representation of overpressure
- Hydraulic Fracture Representation
 - Propped length, height, orientation and conductivity
- Dynamic Model Calibration
- Forecasts of Long-Term Performance

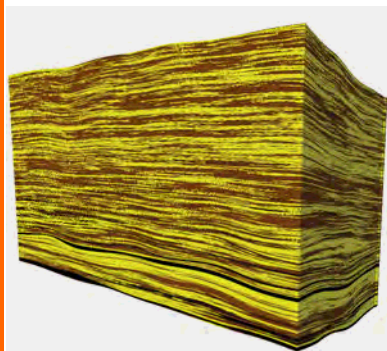
Location of Mamm Creek field



Mamm Creek

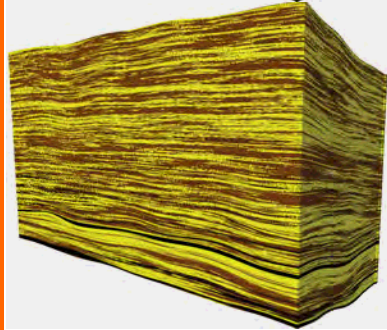


Geologic Model Choices (CU-Boulder)



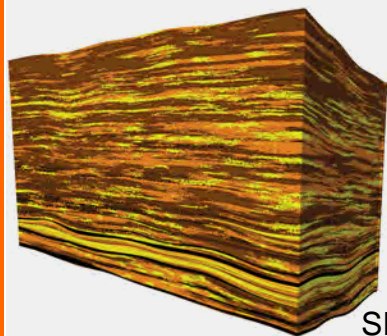
Case A

- SIS
- basic lithology
- no seismic constraint



Case B

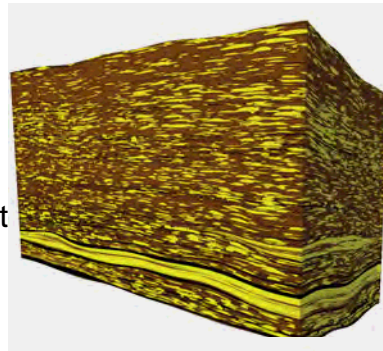
- SIS
- basic lithology
- constrained to seismic



Case C

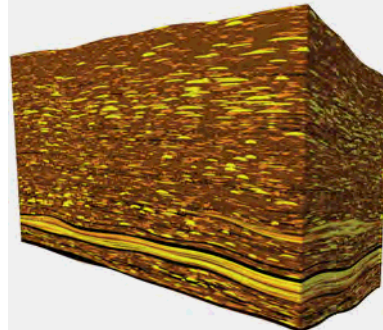
- SIS
- refined lithology

SIS: Sequential-indicator simulation
OBS: object-based simulation



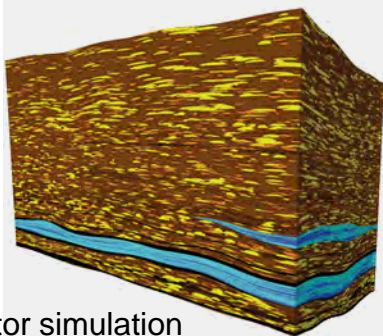
Case D

- OBS
- basic lithology



Case E

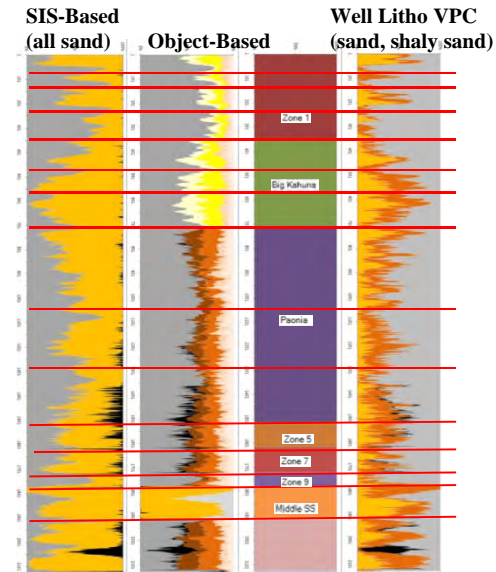
- OBS
- refined lithology



Case F

- OBS
- architectural elements

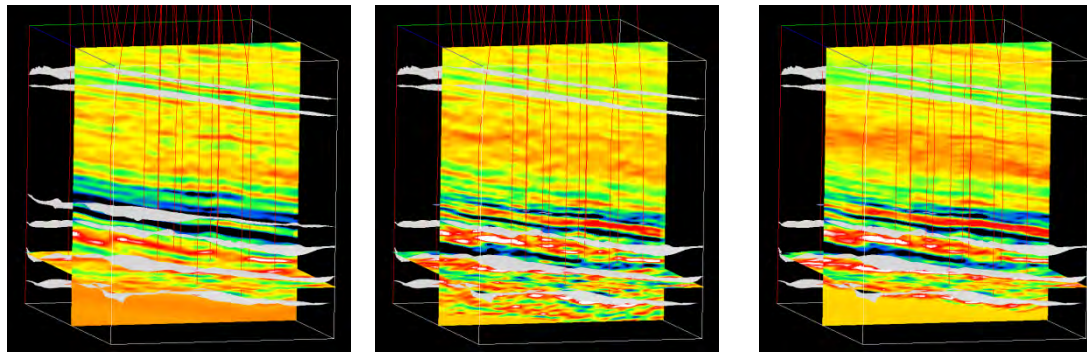
Facies Proportions



- Facies9: MarineShale
- Facies8: MarineSands
- Facies7: CrevasseSplayB
- Facies6: CrevasseSplayA
- Facies5: ChannelBarB
- Facies4: ChannelBarA
- Facies3: PointBarB
- Facies2: PointBarA
- Facies1: Coal

Pranter, M. J., *A. C. Hewlett, R. D. Cole, H. Wang, and J. R. Gilman, in review, Fluvial architecture and connectivity of the Williams Fork Formation: use of outcrop analogues for stratigraphic characterisation and reservoir modelling, in T. Good, J. Howell, A. W. Martinus, eds., Sediment body geometry and heterogeneity: analogue studies for modelling the subsurface, The Geological Society of London, Special Publication.

Integrated Seismic Constraints

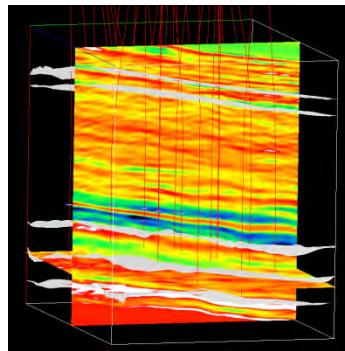


RHO

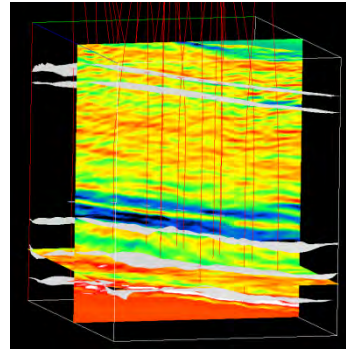
Vp

Vs

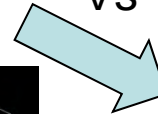
high
low



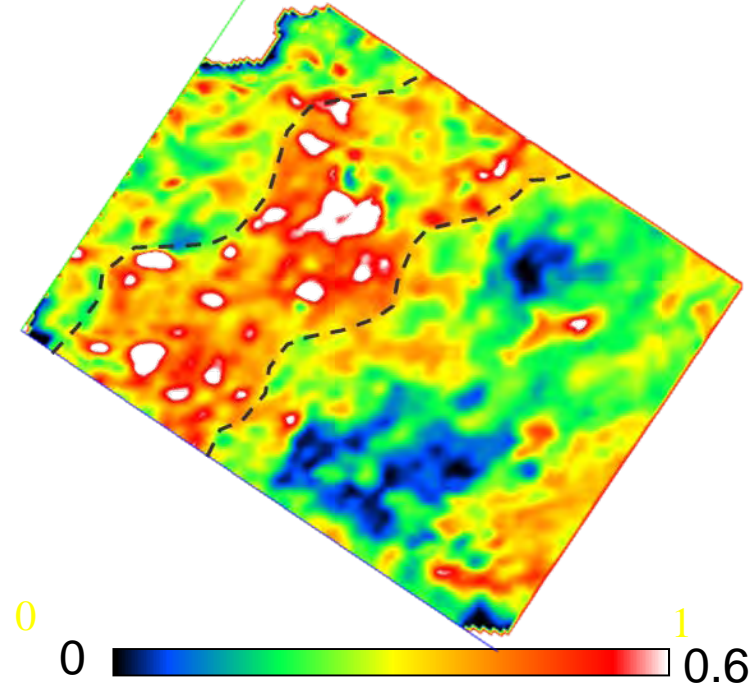
pSI_fast



pSI_slow

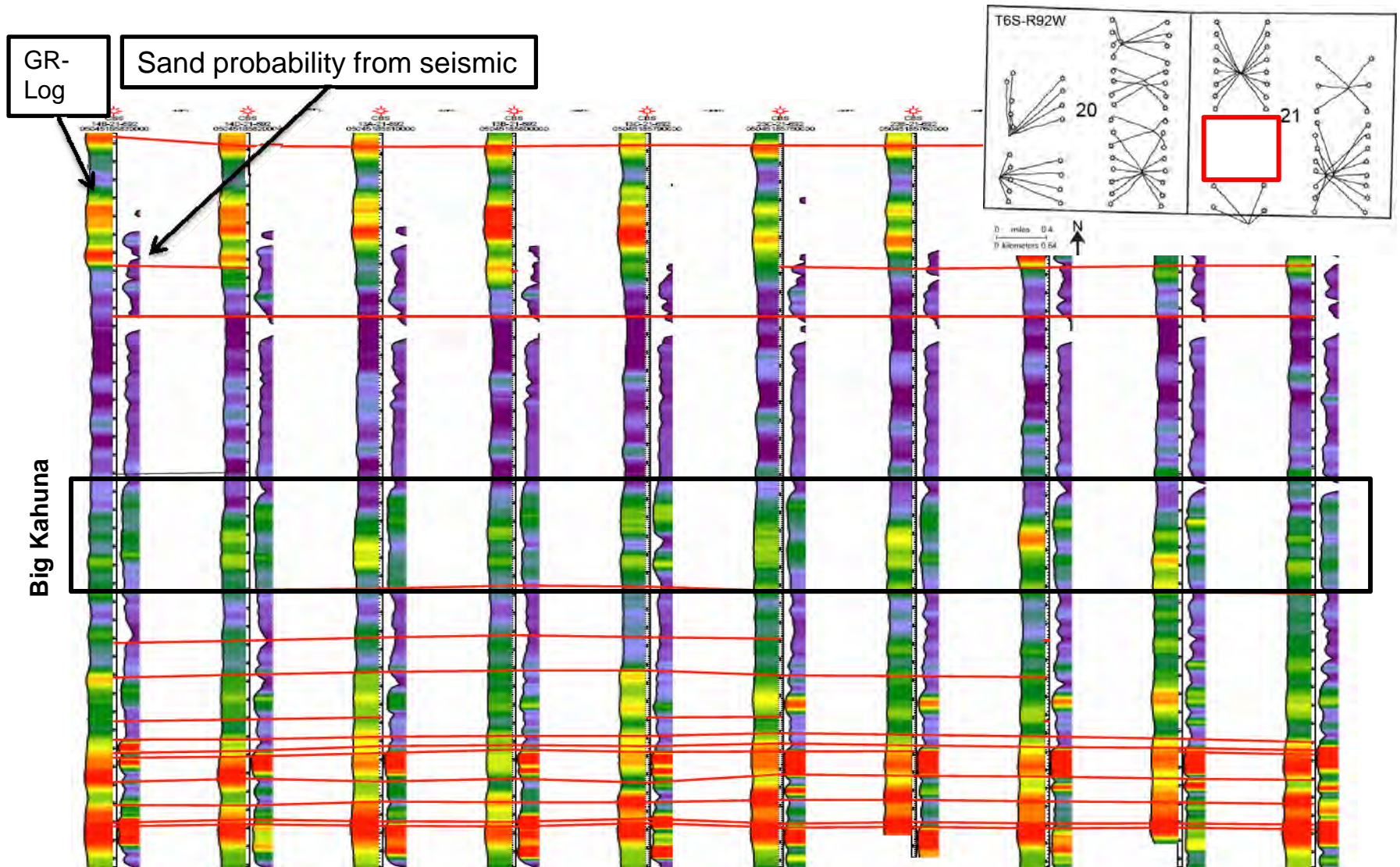


Thick Sand Probability



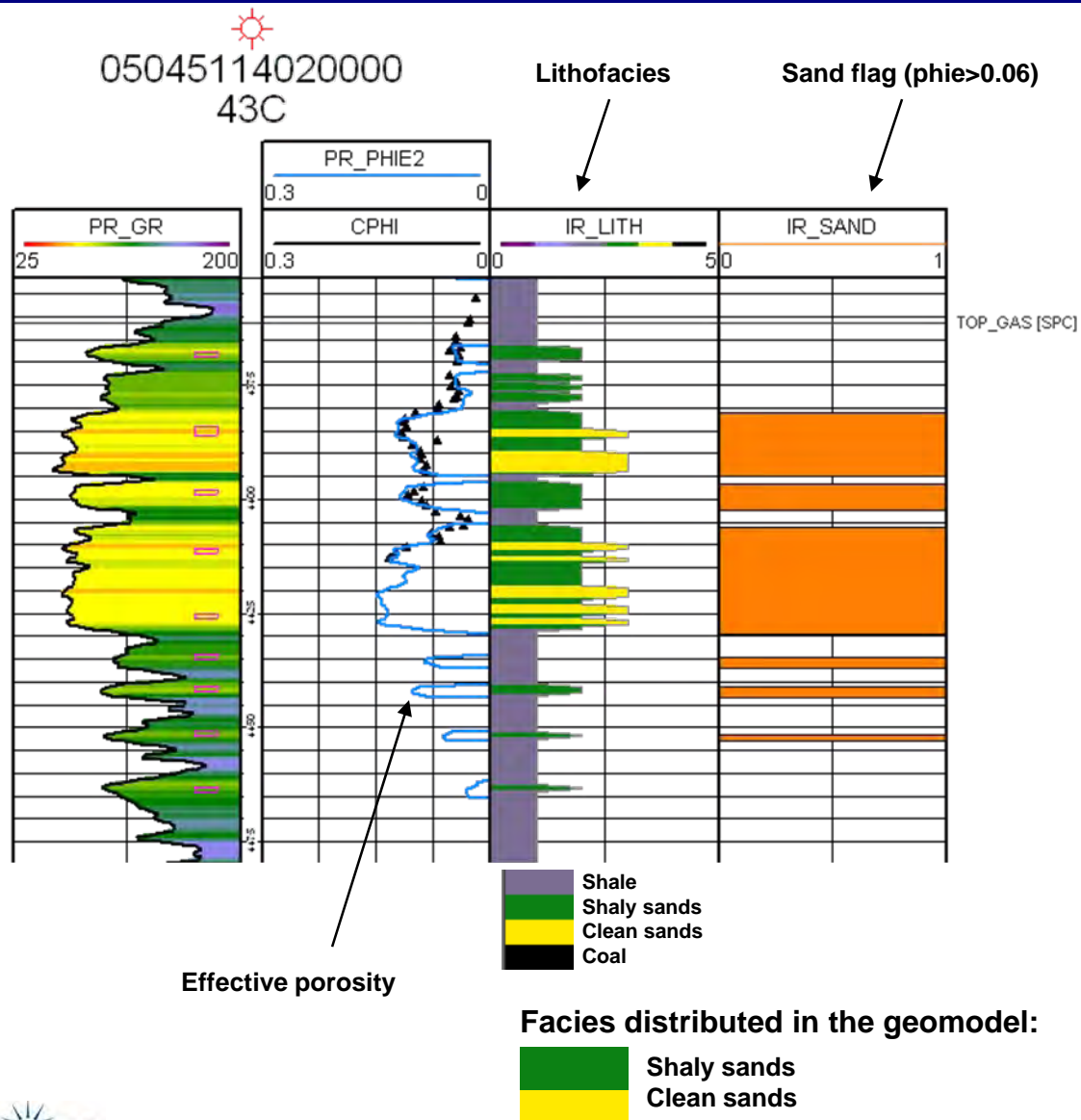
Facies probabilities from multidimensional crossplots of seismic attributes
Reinaldo J. Michelena, Kevin S. Godbey, and Patricia E. Rodrigues
SEG Expanded Abstracts 29, 1377-1381 (2010).

Predicted sand probabilities in newer wells

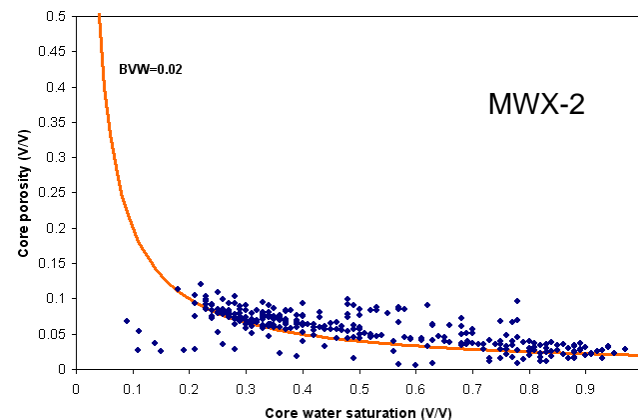


(Figure courtesy Steve Cumella from Bill Barrett Corp.)

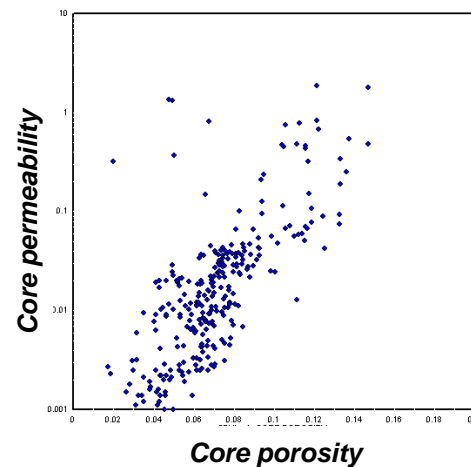
Petrophysical Calibration



Irreducible water saturation estimation using Bulk Volume Water (BVW)

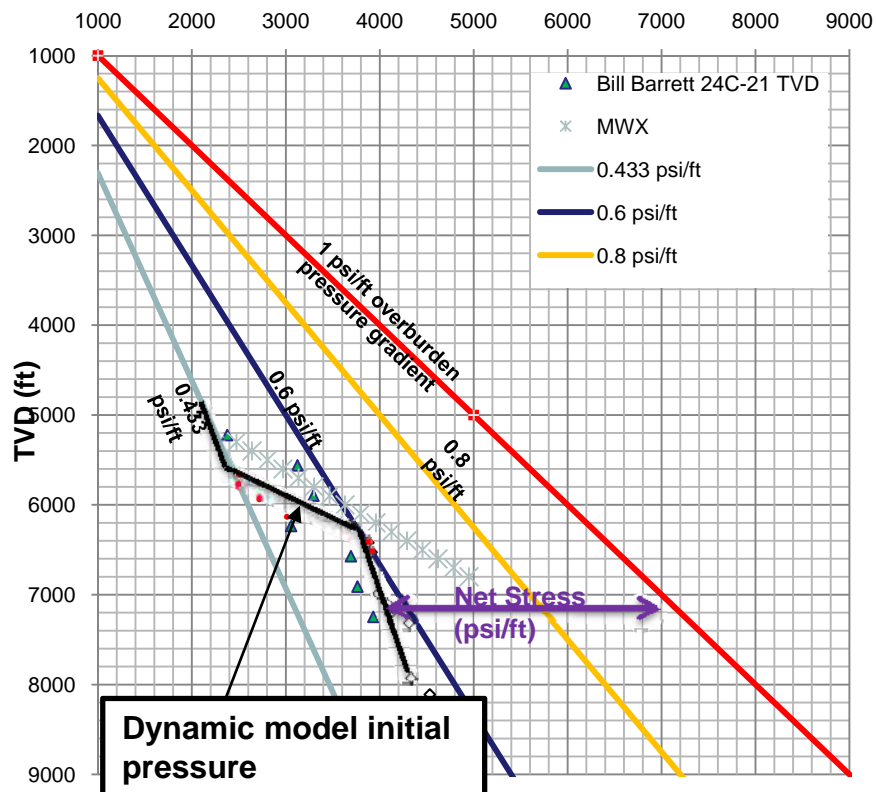


Permeability distribution using Phi-K cloud transform (or other)



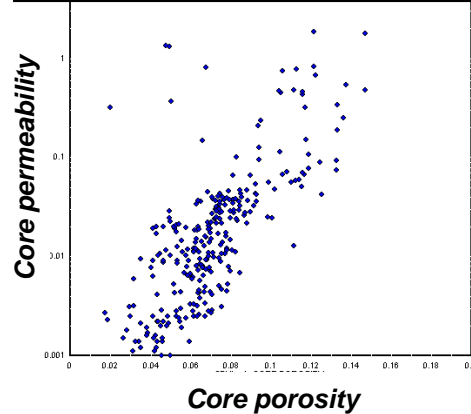
Initial Pressure, Overburden and Permeability Correction

Stress/Pressure

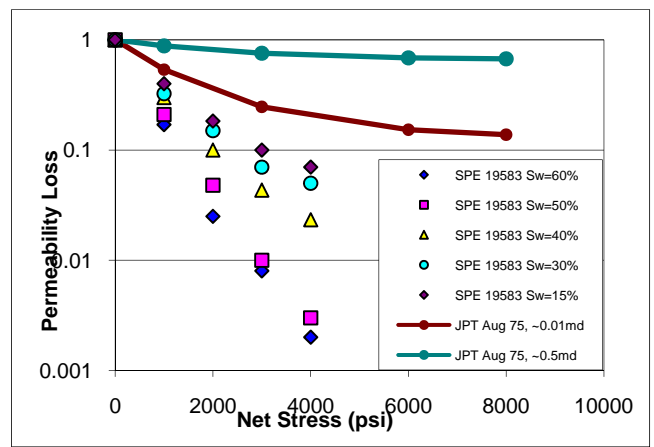


Dynamic model initial pressure

Phi-k from Core. Permeability distributed in geomodel is air perm at low NCS. Need to correct for reservoir initial conditions. (Net Stress, water presence, Klinkenberg k)

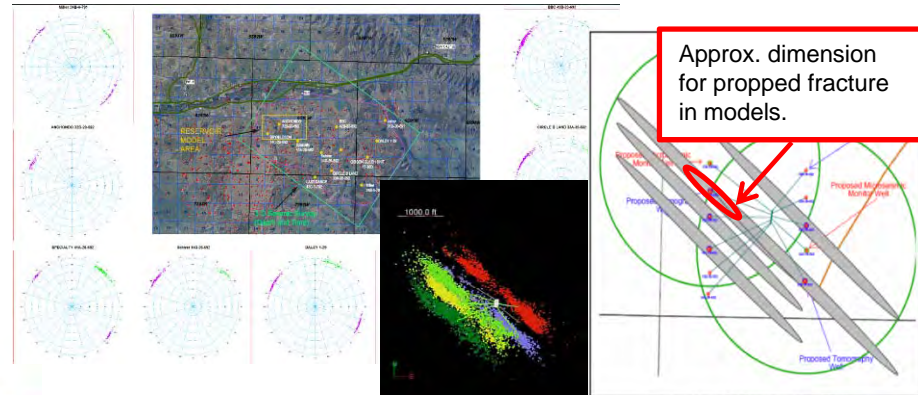


$$\phi, k_g = f(\text{NetStress})$$



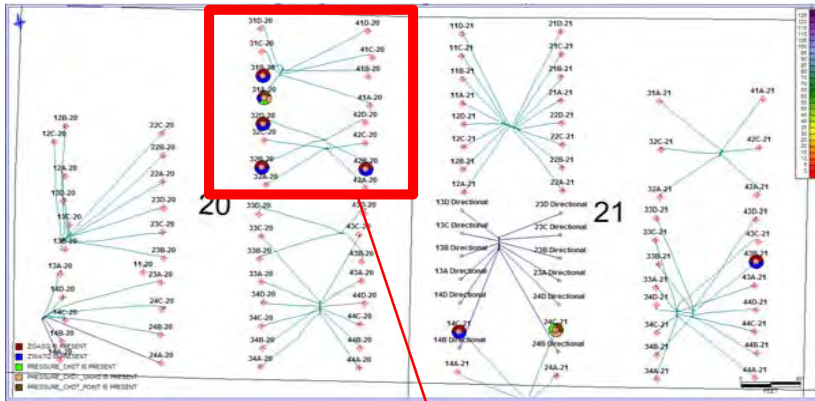
Model Area and Hydraulic Fracture Representation

Area Borehole Breakout (Sait Baytok) & nearby micro seismic (L. Weijers et. al.)

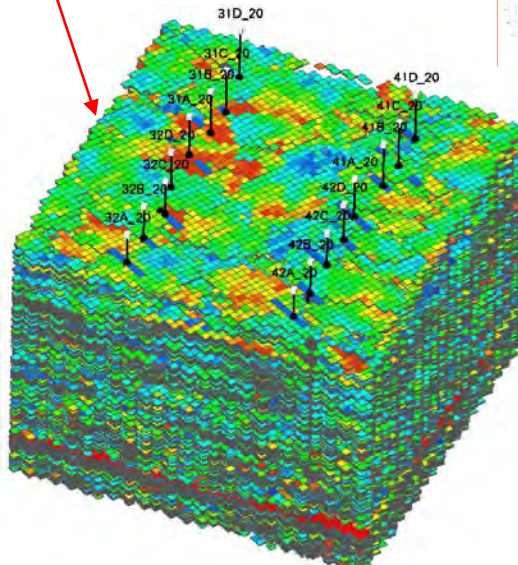
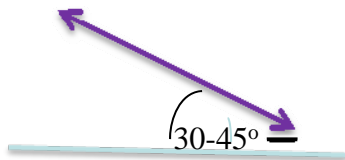


Approx. dimension for propped fracture in models.

Figure 1. Gibson Gulch fracture mapping project setup.



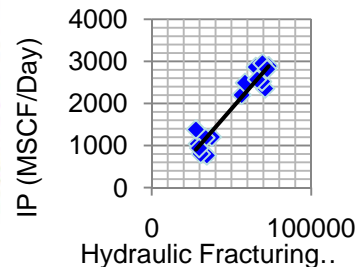
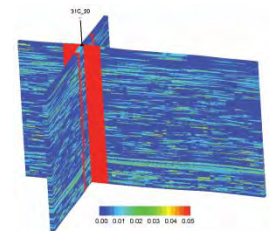
Simulation Grid Rotation for Hydraulic fracture representation



Simulated Hydraulic Fracture (Red = hydraulic fracture)

Actual Well IP

An "Ideal" Frac?
 1,500,000 lbs sand →
 ~15,000 ft³ →
 Height=2000ft
 Length=400ft
 Width=0.225inches



SPE 116304: "Effective propped half-lengths are significantly shorter than measured hydraulic half-lengths."

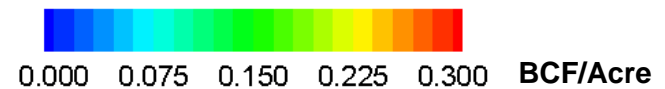
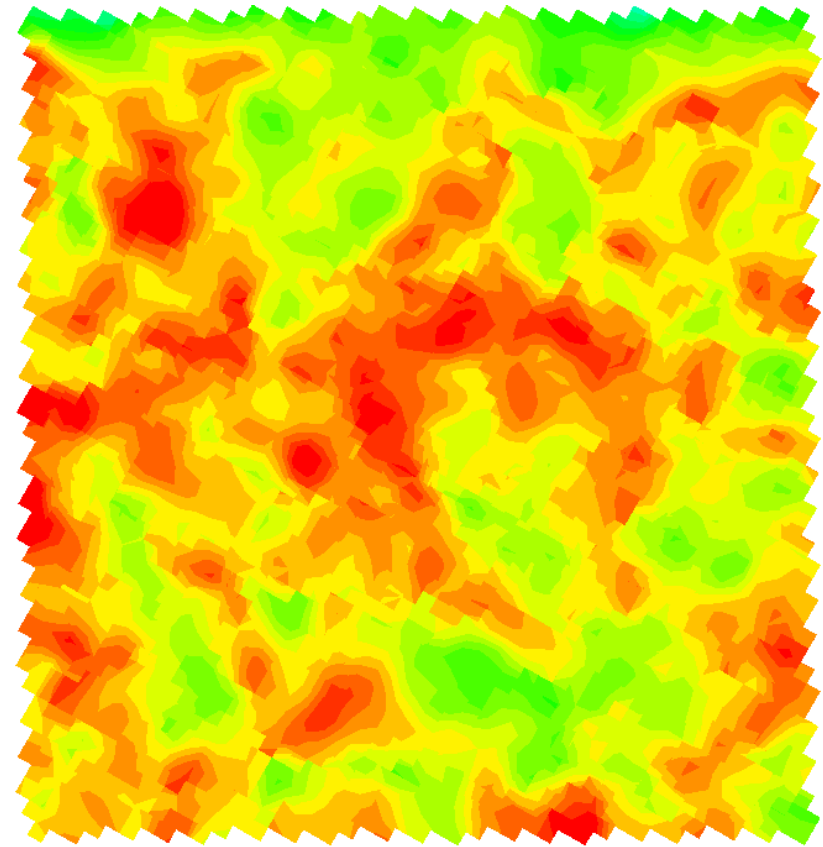
- Near well perm boost for hydraulic fracture conductivity. Initial fracture conductivity ~ 75 md-ft, $x_f \sim 248\text{ft}$ → $Fcd \sim 200$. Minimal permeability & porosity reduction with pressure depletion

Initial Gas-In-Place, BCF/Acre

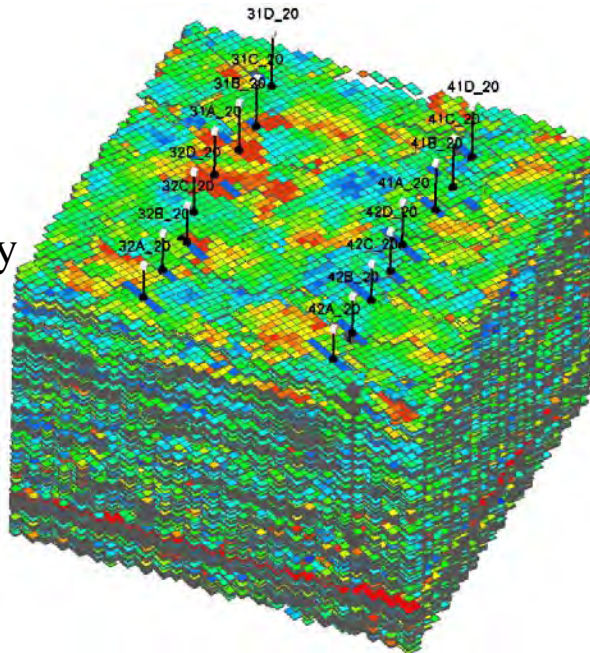
Model Average Values

Area, acres	183
Net Pay Thickness, ft	570
Avg. Sg*Poro, %	4.97%
Net-Phih*Sg, ft	28.31
Avg. kx(air), md	0.0101
Avg. kx(mod), md	0.0011
Avg BG, RB/MSCF	0.9475
GIP, BCF	42
BCF/640 acres	148

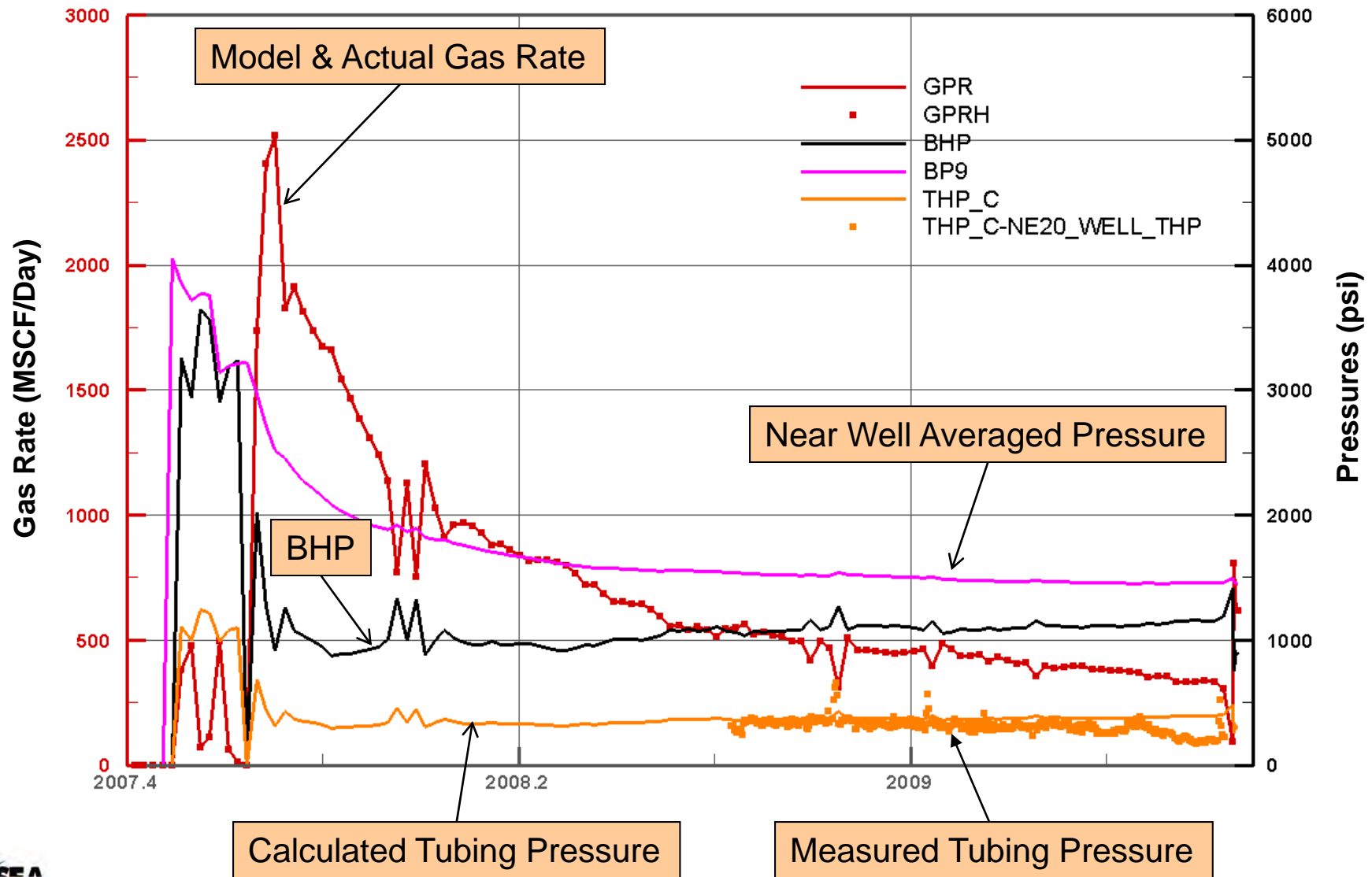
Vertical Summation, OGIP



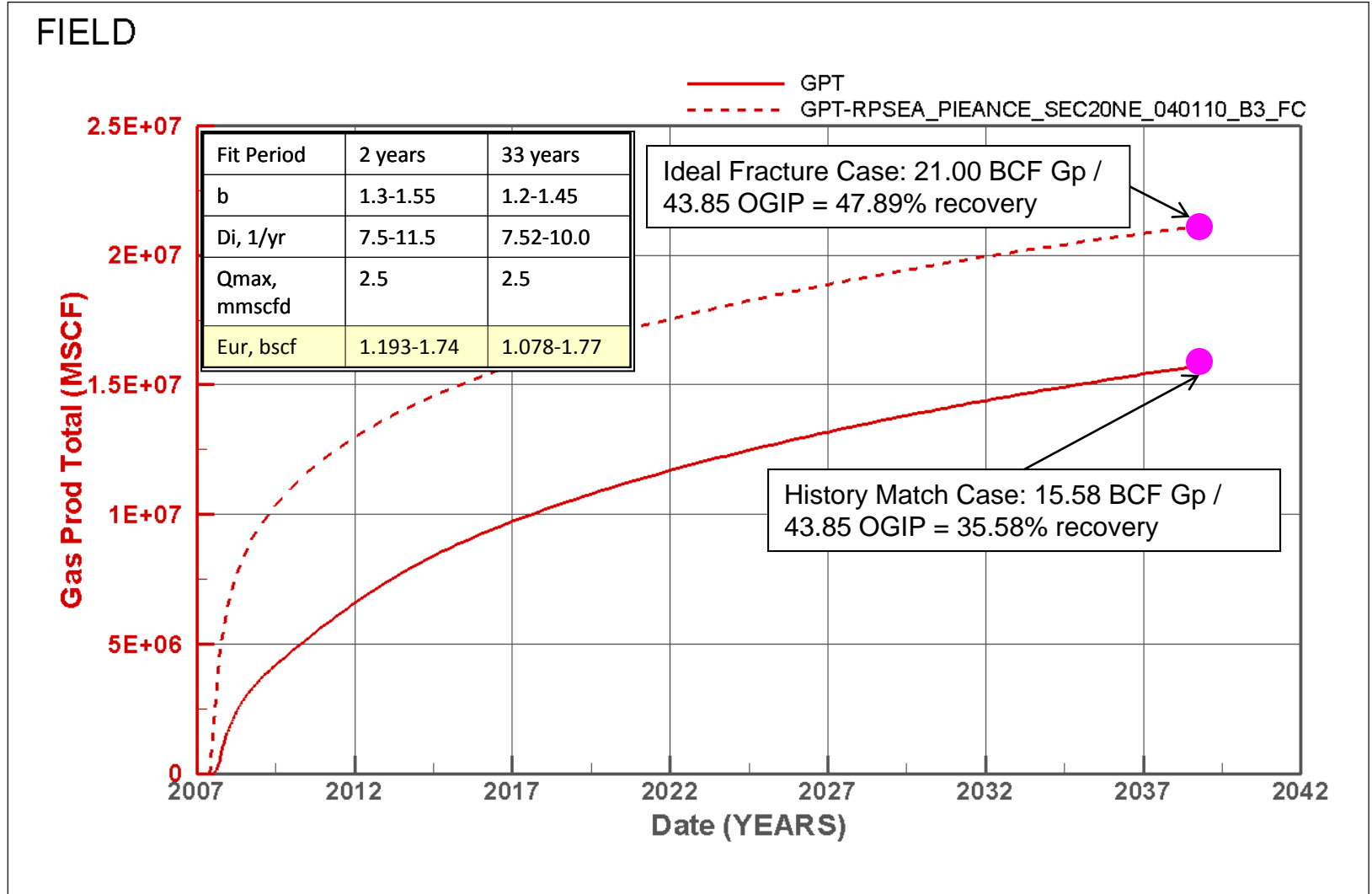
3D
Model
Gas
Porosity



Calibrating to Rate Performance



10 Acre Spacing: Long Term Recovery

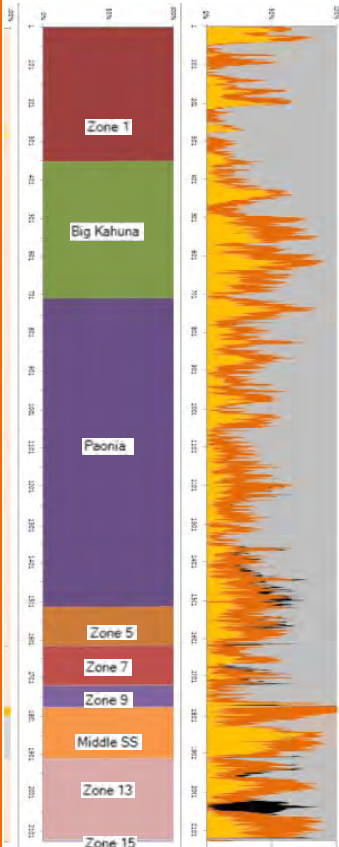


RPSEA_PIEANCE_SEC20NE_040110_A1_FC.UNSMRY

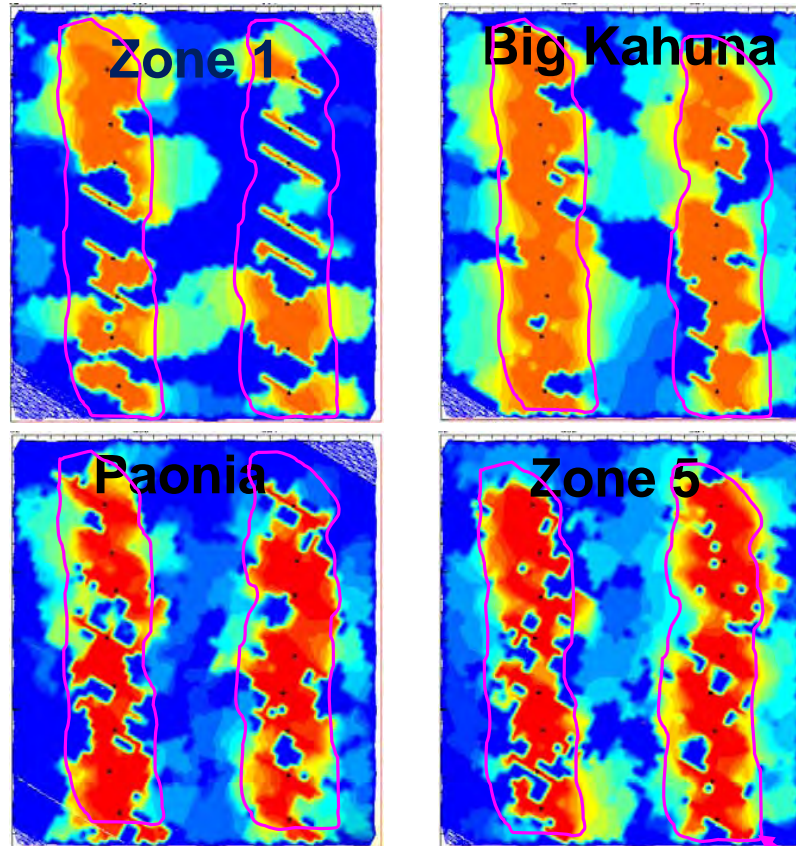
05 Apr 2010

30-Year Recovery for 25 ft Intervals

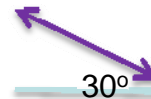
Facies Proportion



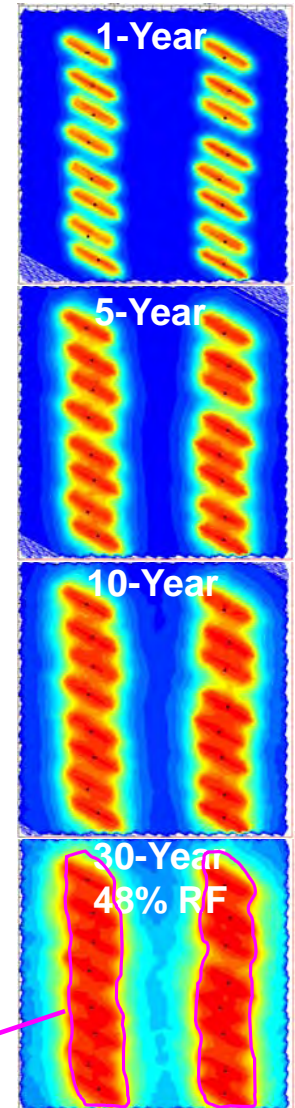
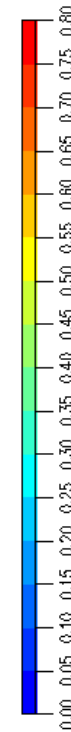
Recovery after 30 years, "optimal" hydraulic fractures, 25~30 ft thickness



Hydraulic Fracture Orientation:



Avg. all layers by year →



Approx 30-year high recovery area

Summary

- Geologic models created at Mamm Creek Field were the result of a complex workflow of known concepts and a careful data analysis and interpretation rather than a single algorithm that integrated all the data automatically
- This integrated approach to characterization and simulation allowed approximate matches to the character of pressure decline while still ensuring consistency with petrophysical, geological, geophysical, and engineering interpretations.
- The models are not overly simplistic allowing non-uniform distribution of pressure depletion as seen in the field and thus allowing more realistic assessment of infill well potential and long-term recovery as compared to other engineering methods.
- The integrated characterization and simulation approach shows the importance of geologic controls on long-term recovery, providing a data constrained methodology to assess optimal infill well spacing.

Acknowledgments

- **RPSEA** (Research Partnership to Secure Energy for America) for financial support
- **Bill Barrett Corporation** for providing much of the data and valuable insights
- **CU-Boulder** for geomodel and fracture analyses
- Other **iReservoir** and RPSEA team members for analyses and insights