PS Impact of Petrophysical Properties on Hydraulic Fracture Analysis*

Kelsey L. Seals[1]

Search and Discovery Article #80600 (2017)**
Posted June 12, 2017

*Adapted from poster presentation given at AAPG 2017 Annual Convention and Exhibition, Houston, Texas, April 2-5, 2017

[1]Department of Petroleum and Natural Gas Engineering, New Mexico Tech, Socorro, New Mexico, United States (kseals04@gmail.com)

Abstract

Hydraulic fracturing is the most common stimulation method used in medium- to low-permeability and unconventional reservoirs. Accurate hydraulic fracture modeling for lithologically complex reservoirs requires detailed knowledge of the reservoir rock, including permeability, porosity, and mechanical properties, and identification of water-productive zones and barriers. The objective of this work is to determine if using detailed petrophysical properties provides fracture design parameters that better represent actual fracture behavior and subsequent well performance by using an existing hydraulic fracture treatment to model fracture behavior using both detailed and averaged petrophysical properties. Fracpro© software was used for the analysis. The models were designed with both simplified and detailed input parameters and with varying layer thickness resolutions. Modeling was based on actual treatment data from the Nash Unit #23 well located in the northern Delaware Basin producing from the lower Brushy Canyon Formation (Guadalupian). The reservoir consists of multilayered sandstone reservoirs that include thin-bedded and micro-laminated siltstone. Hydrocarbon-producing layers are in close vertical proximity to water-productive zones. Single Lithology, 10-ft, 5-ft, 2-ft, and 1-ft layer thickness models were created. The Single Lithology model has low layer thickness resolution and averaged petrophysical values. The 1-ft model has high layer thickness resolution and uses detailed petrophysical values. Data was obtained from sonic logs, point load tests, core descriptions, core analysis, and other well logs. Resulting fracture behavior variables include average fracture width, fracture and propped half-length, and total fracture and propped height. Production history matching was conducted to validate the models using actual production data from Nash Unit #23. Results from fracture and production analysis indicate that using high layer resolutions and detailed petrophysical values (e.g. 1-ft Model) yields more accurate simulation results and better represent the actual hydraulic fracture behavior. Software-default petrophysical values and simplified reservoir layer models yielded significantly over- and under-estimated fracture behavior variables. Using detailed petrophysical data in hydraulic fracture treatment designs could provide a better understanding or prediction of fracture behavior and growth, and can reduce the likelihood of treating out of zone.

Reference Cited

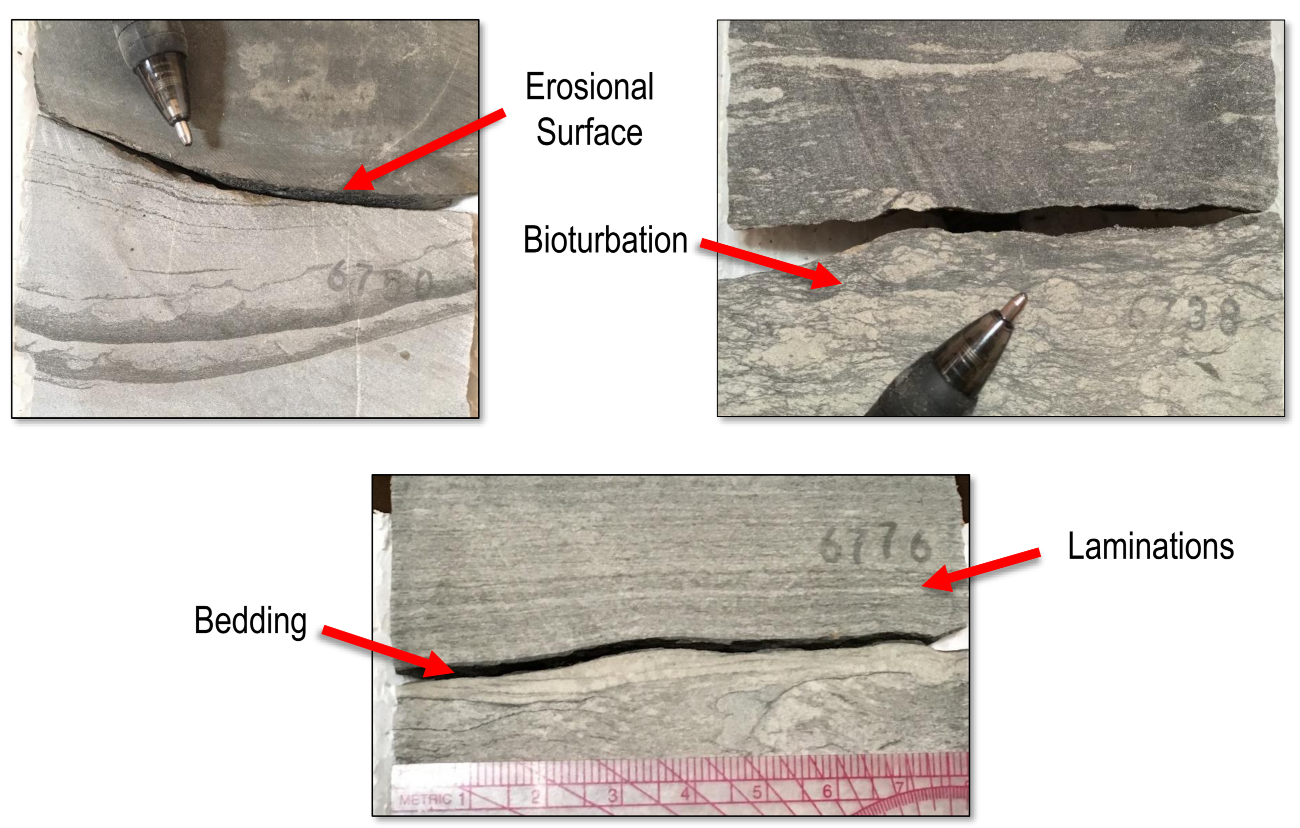
Scott, G.L., and A. Carrasco, 1996, Delaware Sandstone Reservoir Completions and Real-Time Monitoring of Hydraulic Fractures, *in* W.D. DeMis and A.G. Cole (eds.), The Brushy Canyon Play in Outcrop and Subsurface: Concepts and Examples: Permian Basin Section SEPM, Publication 96-38, p. 183-188.

Impact of Petrophysical Properties on Hydraulic Fracture Analysis

Kelsey L. Seals
kseals04@gmail.com
New Mexico Tech Department of Petroleum and Natural Gas Engineering, Socorro, New Mexico

Introduction

Accurate reservoir representation in hydraulic fracture modeling is a critical component for effective stimulations, yet complete and detailed input data is often limited in availability. Petrophysical parameter values, such as porosity, permeability, and mechanical properties, are often simplified or averaged. Modelers are often over-reliant on software-provided petrophysical values. The use of limited and simplified data for treatment designs could be inadequate for vertically complex, highly-laminated reservoirs such as the Brushy Canyon Formation (Guadalupian) in the Delaware (Permian) Basin. Vertical variations in porosity, permeability, lithologies, and layer thickness prove challenging for modeling fracture treatment designs. Many Delaware Basin fracturing treatments did not adequately account for the formation's laminated sand-silt sequences and variations in reservoir properties, and as a result, many wells are plagued with poor hydrocarbon recovery and high water production (Scott & Carrasco, 1996).



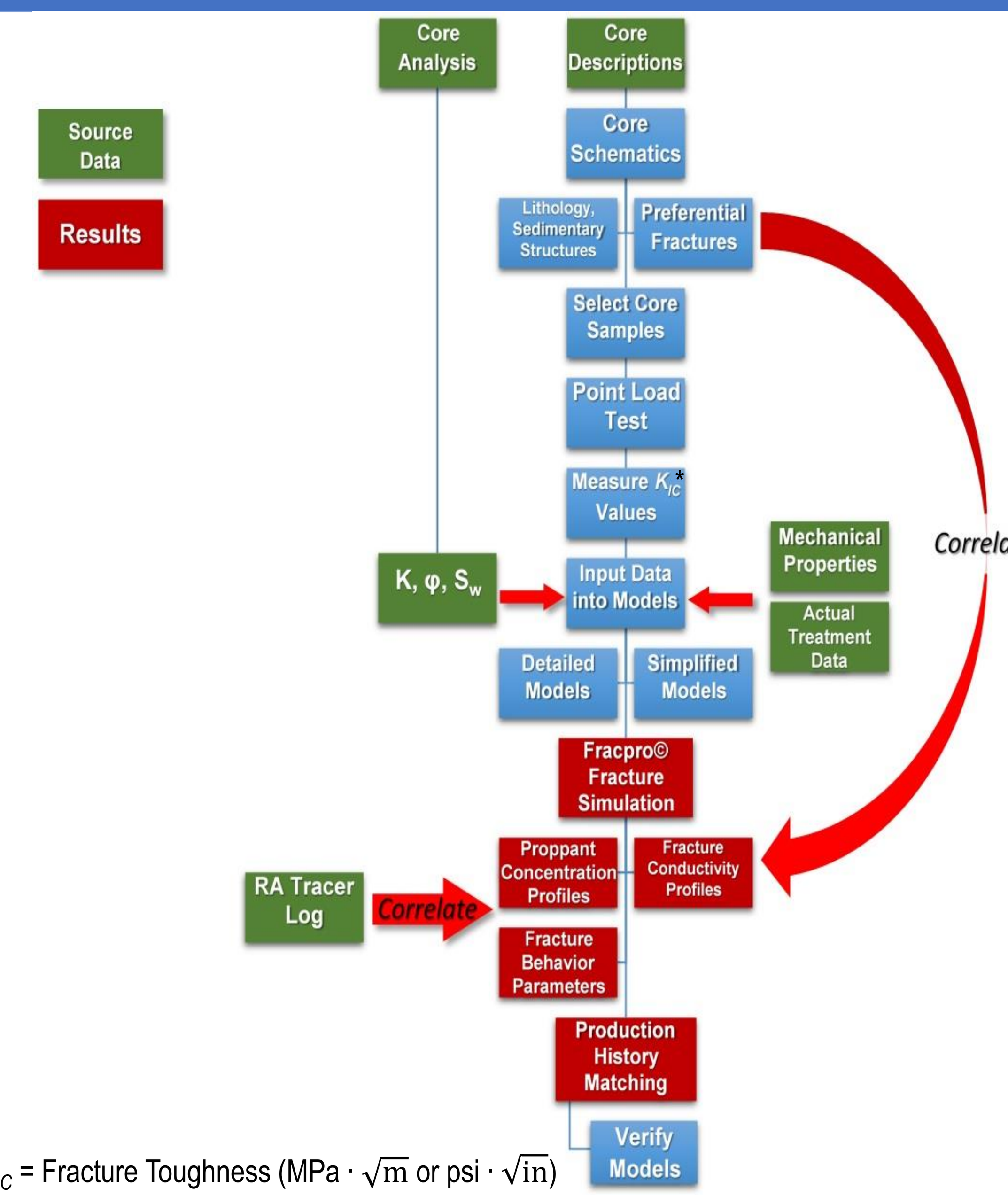
Examples of locations of "preferential fracturing" in the Nash Unit #23 core

Nash Unit #23 well data was used in this work, and is located in the Nash Draw field in Eddy County, southeast New Mexico. The lower Brushy Canyon formation is characterized by complex sand (reservoir) and organic-rich silt (trap and source) sequences.

Objective

- Determine if using detailed reservoir rock properties provides fracture design parameters that better represent the actual fracture behavior and subsequent well performance.

Methods & Procedures: Workflow



*K_{IC} = Fracture Toughness (MPa · $\sqrt{m}$ or psi · $\sqrt{in}$)

Modeling

- The models were created to compare the results of the hydraulic fracture stimulations using both simplified values and detailed test- and log-derived values.
- Models were designed to show how variations in layer resolution (multiple layers vs. lumped/averaged layers) affect the simulation results.

- **Detailed properties:** porosity, permeability, fracture toughness, and mechanical properties derived from well logs, point load tests, and core analysis. "**Actual Values.**" *Multi-layer, heterogeneous reservoir.*

- **Simplified properties:** averaged petrophysical properties, derived from software-default values. "**Default Values.**" *Single-layer, homogeneous reservoir.*

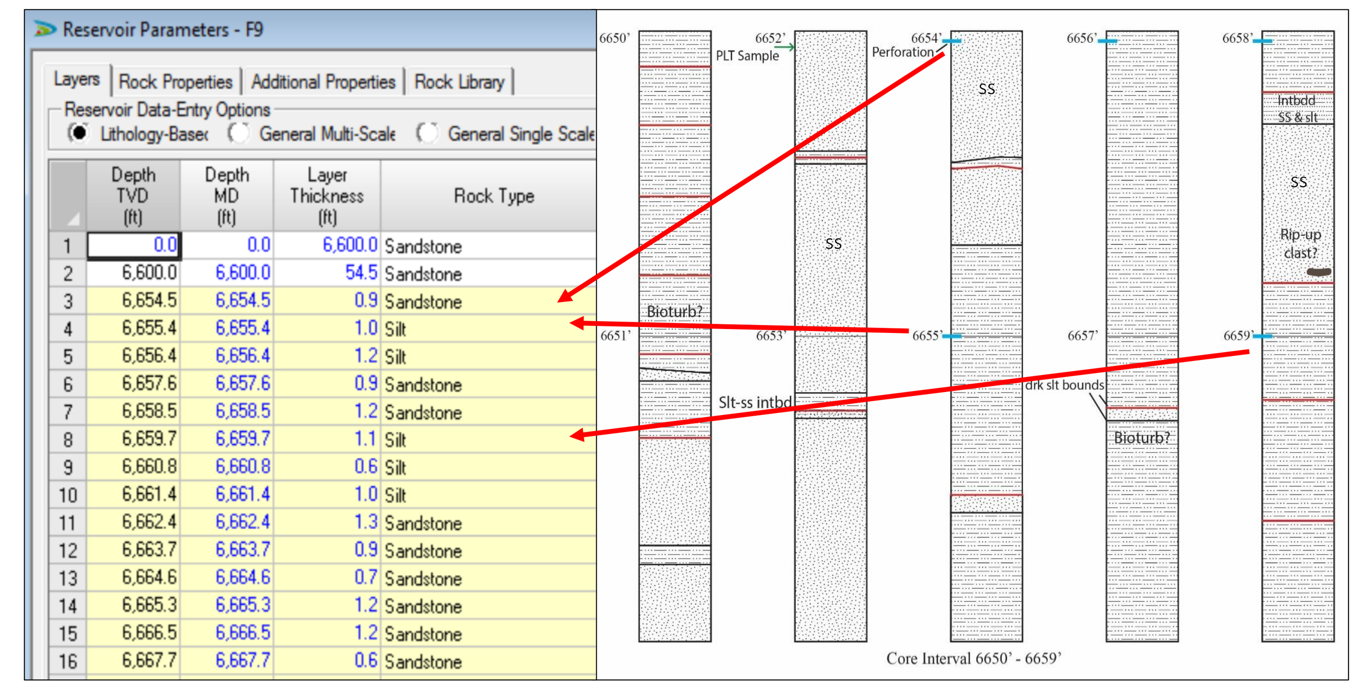
Young's Modulus Values (Mpsi)		
Lithology	Default	Actual
SS	5.00	4.50
LS	1.00	5.32
Slt	N/A	4.50
Bioturb	N/A	4.25

Poisson's Ratio Values		
Lithology	Default	Actual
SS	0.20	0.26
LS	0.30	0.27
Slt	N/A	0.24
Bioturb	N/A	0.24

Stress Gradient Values (psi/ft)		
Lithology	Default	Actual
SS	0.62	0.57
LS	0.68	0.59
Slt	N/A	0.54
Bioturb	N/A	0.56

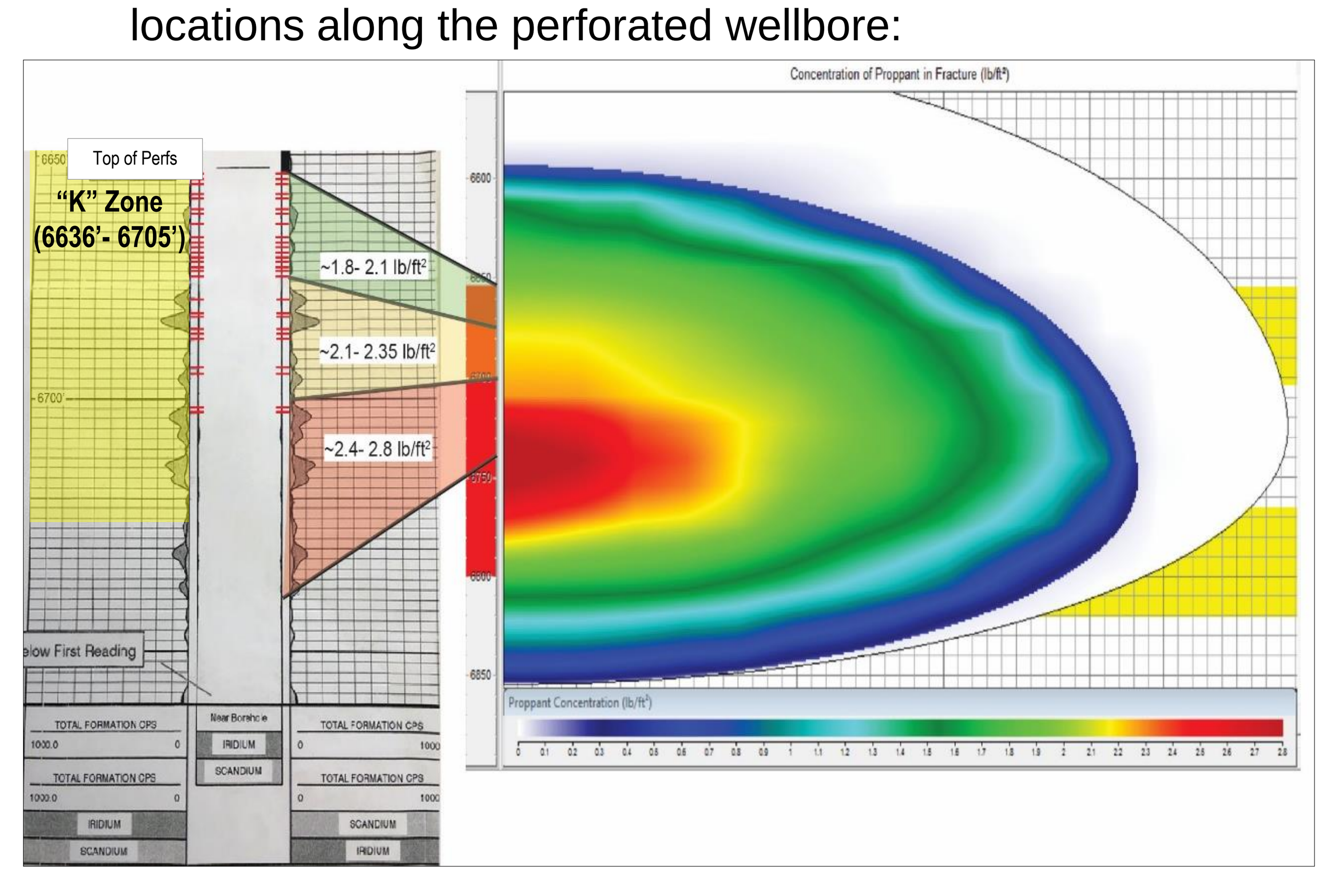
Fracture Toughness Values (psi*in$^{1/2}$)		
Lithology	Default	Actual
SS	1000	596
LS	500	N/A
Slt	N/A	982
Bioturb	N/A	1027.1

- Digital core schematic (right) was created for simplified visualization of the detailed and complex features in the Nash Unit #23 core. 1-ft layer resolution for the Detailed, Actual Values Model in the software is shown (left).

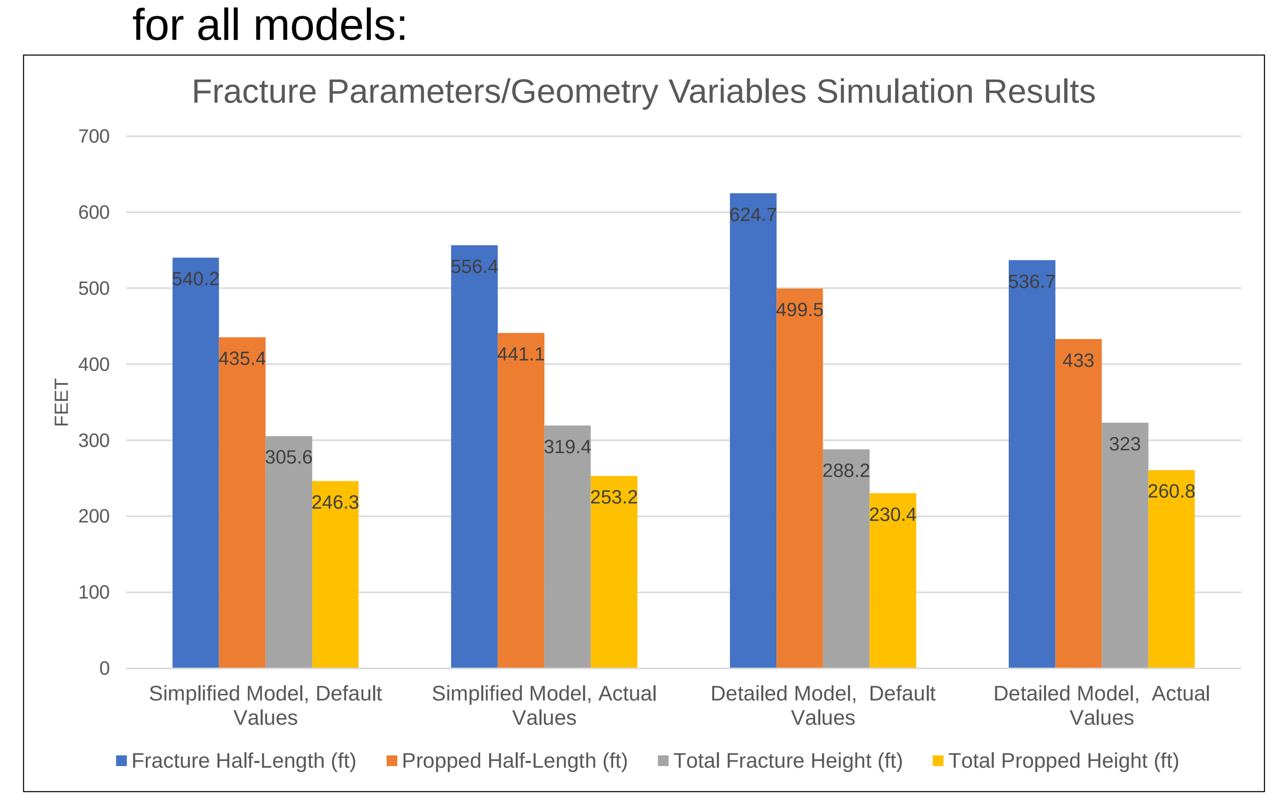


Results & Analysis

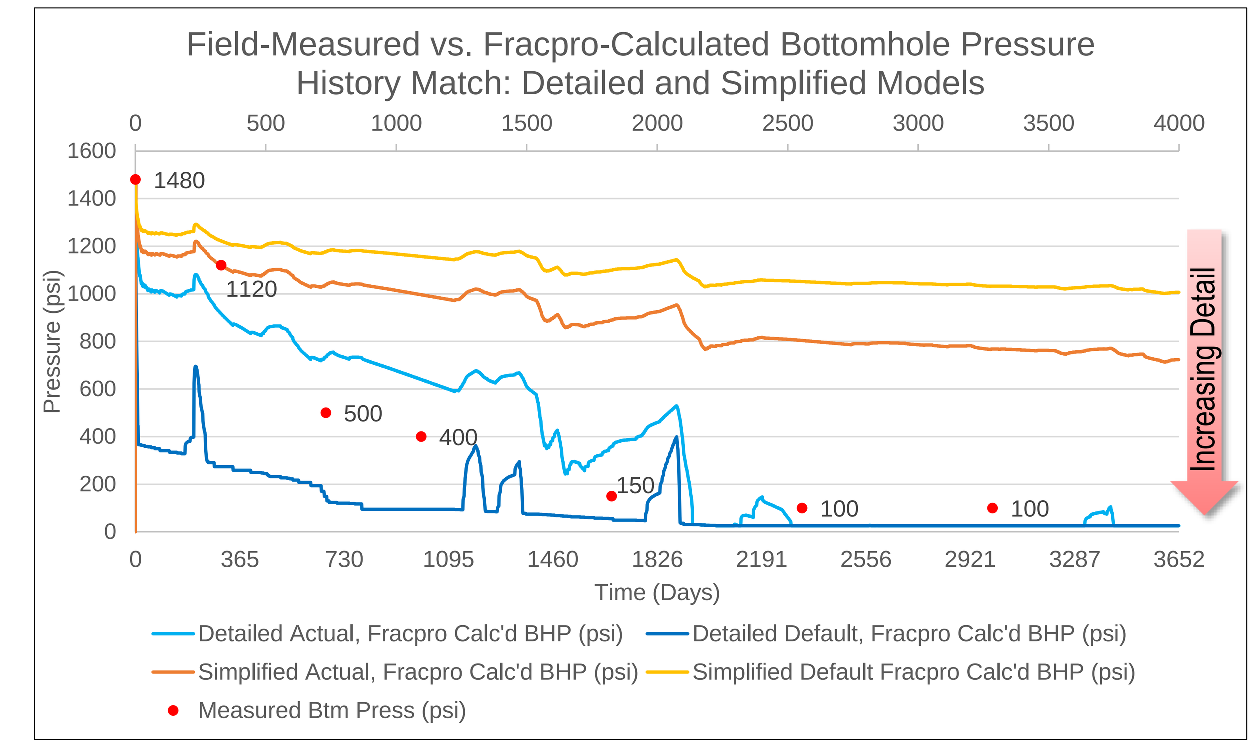
- RA tracer log (left) and the proppant concentration profile (right) show correlation between the simulated proppant concentration and the RA-tagged proppant locations along the perforated wellbore:



- Fracture parameters and geometries simulation results for all models:



- Production history match: production rate was constrained, and field-measured bottomhole pressure (BHP) was the matching variable.
- BHP match is achieved with increasing layer-thickness resolution and when actual, test-derived petrophysical values are used in fracture and production simulations.



Conclusions

- Modeling hydraulic fracture behavior using simplified reservoir parameters results in consistently over- or under-estimated fracture parameters, ultimately affecting simulated production behavior.
- The use of detailed vs. simplified layers for a given model makes a significant difference in the hydrocarbon pore volume calculations, which affects the BHP and production history matching results.
- As layer thickness resolution increases from simplified to detailed (e.g. from one lumped layer to 1-ft increments), hydrocarbon pore volume decreases, resulting in a more accurate pressure match.
- Preferential fracturing in the reservoir exists and the impact on fracture behavior can be modeled. Certain lithologies, sedimentary structures and features create boundaries of weakness and predispose the reservoir to preferential fracturing.
- *The degree of detail in layer thickness resolution, lithologic representation, and the use of software-default vs. actual petrophysical values affect the resultant production behavior.*

Acknowledgements & References

Many thanks to Strata Production Co. for providing the well data used in this work. Thank you to Fracpro© and my thesis committee members, Dr. Tom Engler, Ron Broadhead, and Dr. Mike Kelly.

References

Scott, G., & Carrasco, A. (1996). Delaware sandstone reservoir completions and real-time monitoring of hydraulic fractures. Publications- Society of Economic Palaeontologists and Mineralogists Permian Basin Section PBS SEPM, 183-188.