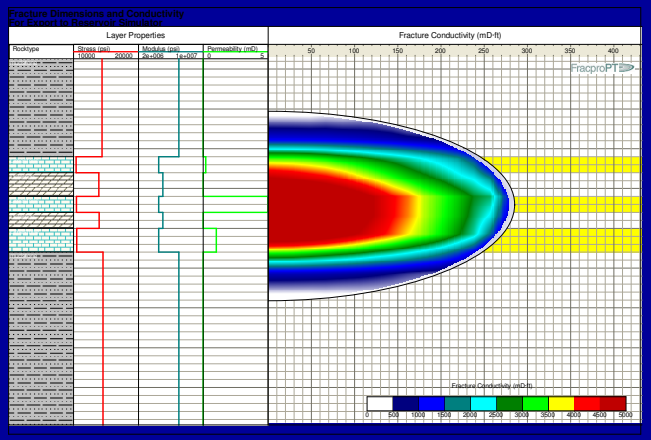
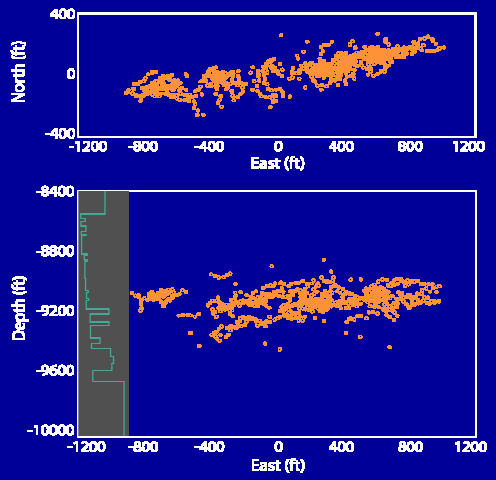
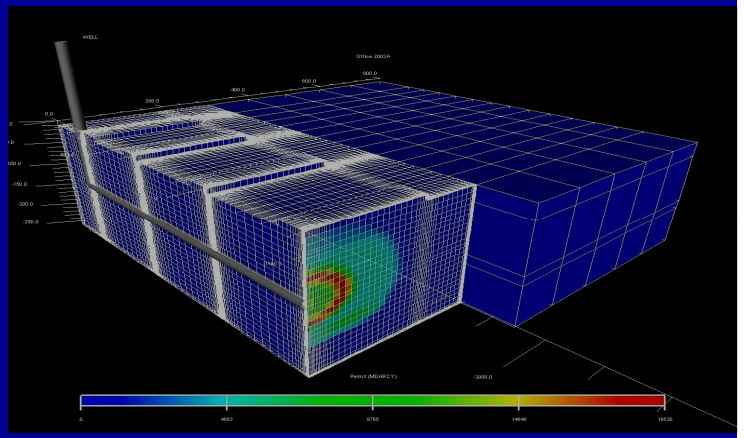
Advances in Treatment Design and Production Optimization

Get Permeability from Data fracs, Calibrate Fracture Models and 3D

Reservoir Simulation of Fractured Wells





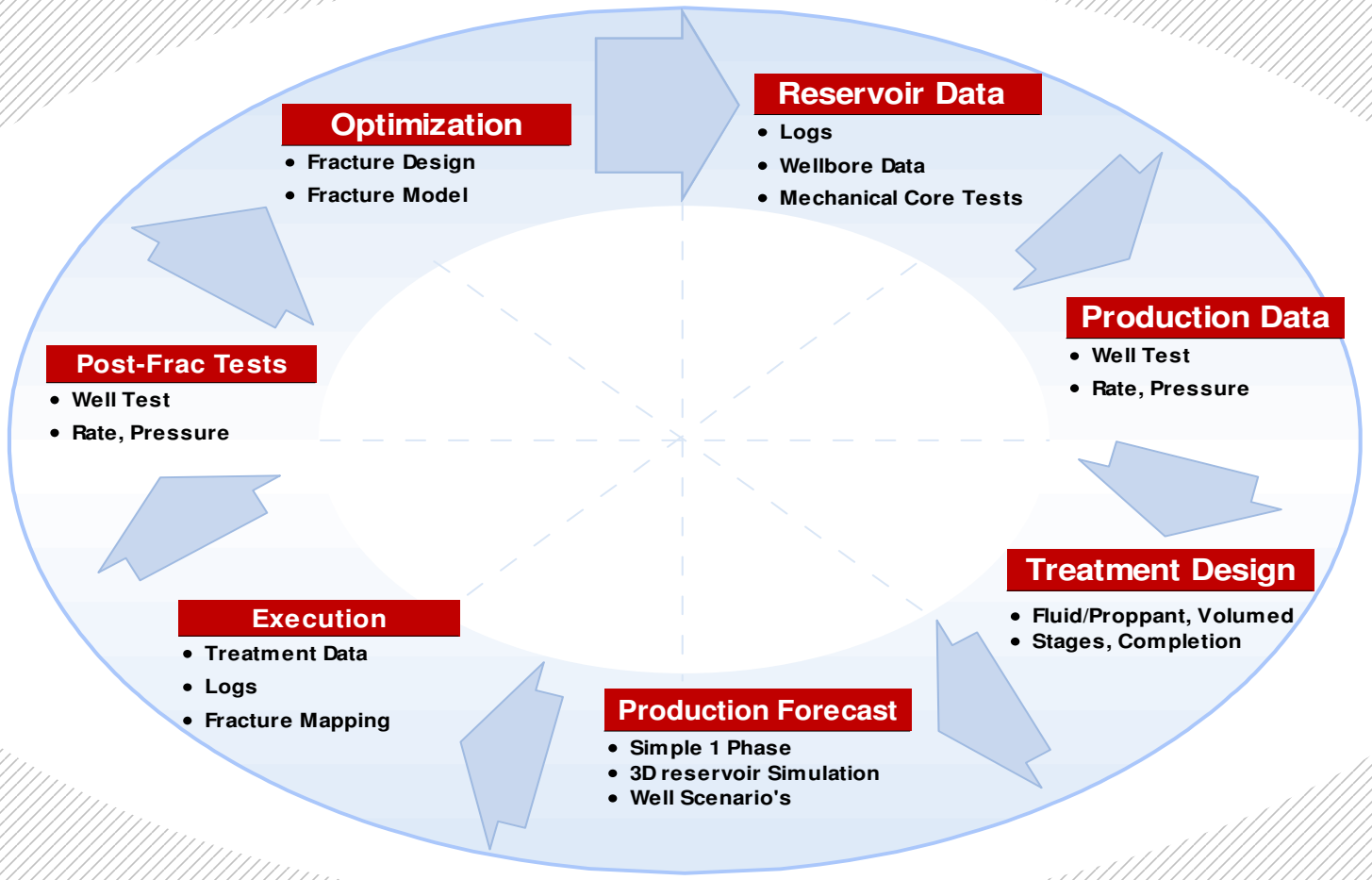


EBN-TNO Tight Gas Symposium 19 September 2006

Hans de Pater, Josef Shaoul

Pinnacle Technologies

The Fracture Engineering Loop



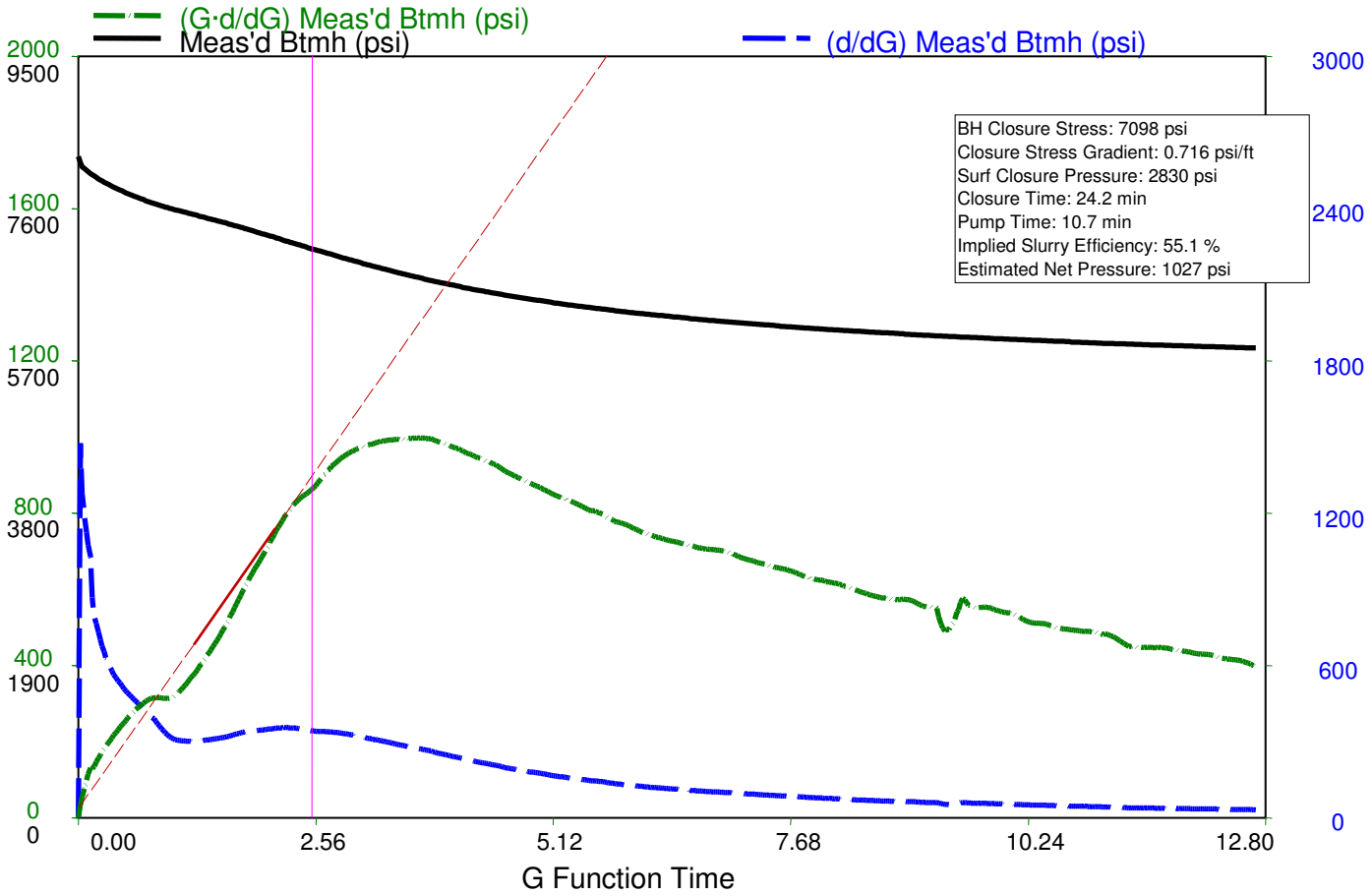
Tight Gas Issues

- Permeability and Pressure Poorly Known
  - After Closure Analysis (Nolte-SPE25425, Mayerhofer)
- Need Long Fractures, but Fracture Geometry Cannot be Predicted
  - Base Models on Frac Mapping
- Production Forecast Needs to Consider Transient (Flush Production)
  - Link Design to 3D Reservoir Simulator

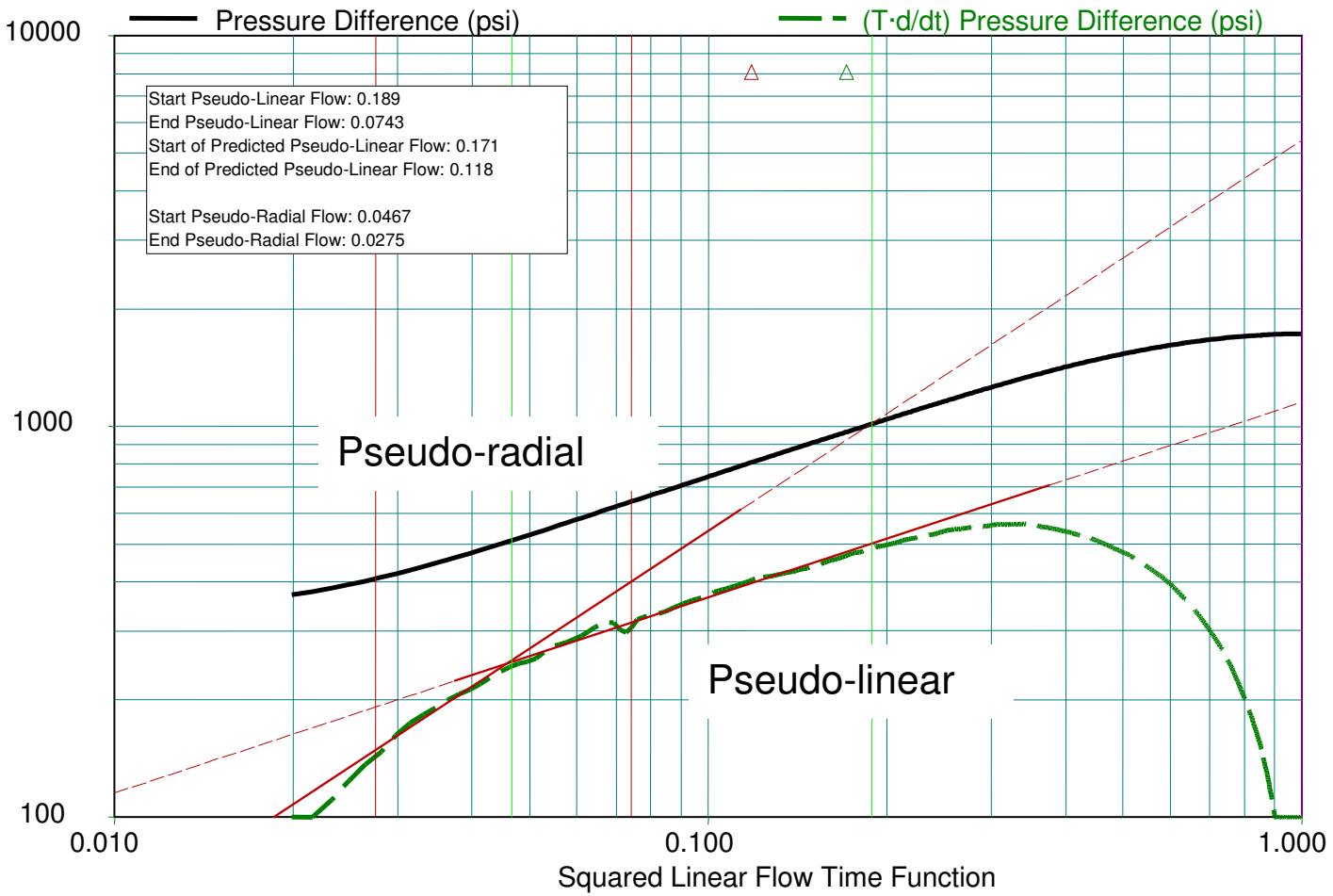
Injection Test Analysis

- Perform small injections with treated water and gel
- Observe pressure decline with high quality gauge
- Determine closure, match pressure to estimate fracture length
- Use linear and pseudo-radial after-closure slopes to estimate pressure and transmissibility. Feed back to initial estimate of fracture height

Injection Test Analysis: Fracture Closure Analysis



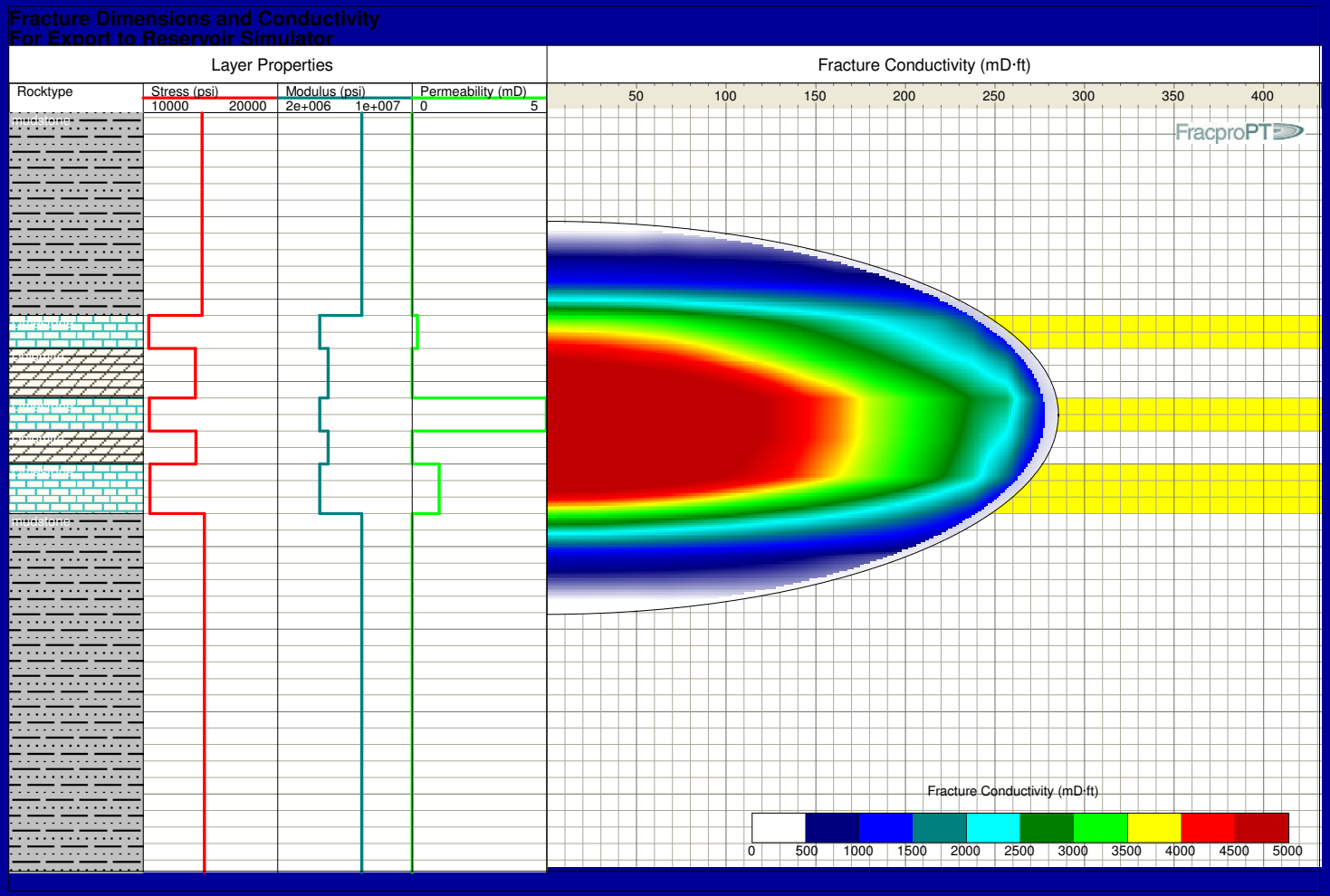
Injection Test Analysis: Reservoir Permeability Estimate (Mayerhofer Method)



Fracture Growth Model Inputs/Outputs

- Inputs
  - Reservoir information (permeability, stress)
  - Treatment schedule (acid, proppant, rate, conc.)
  - Proppant data (permeability vs stress, non-Darcy)
- Outputs
  - Fracture dimensions (length, height, width)
  - Fracture conductivity (pressure dependant)
  - Fluid leakoff profile (filtrate depth vs length)

Fracture Model Output
Dimensions and Conductivity

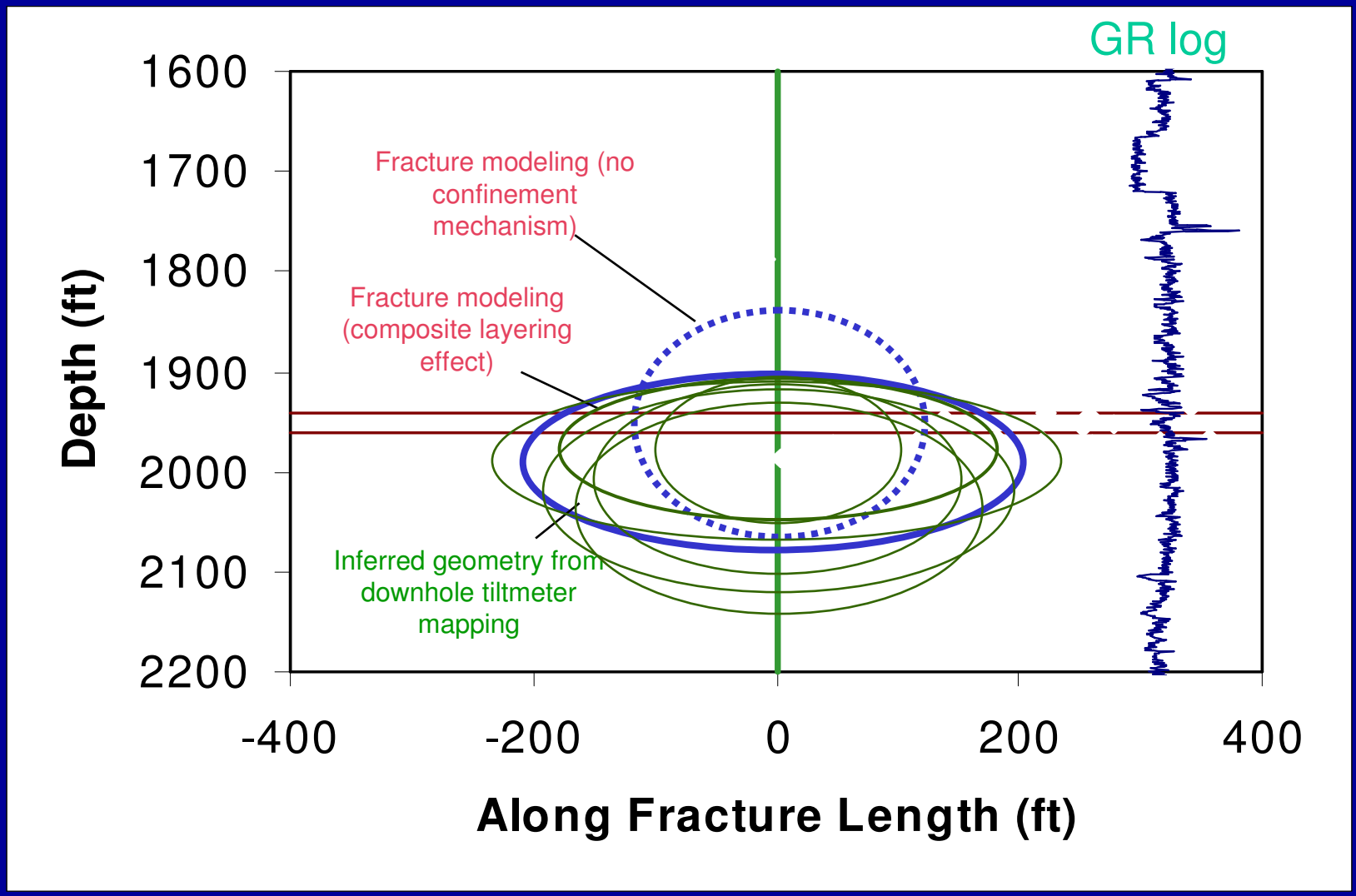


Fracture Height and Length

- Modeling based on pressure measurement may be non-unique or non-predictive.
- Measure fracture dimensions independently in selected treatments
  - Improve models by calibration of key parameters
  - Guide choice of fracture geometry (contained vs. uncontained)

Often, Models Don't Work with our Initial Assumptions

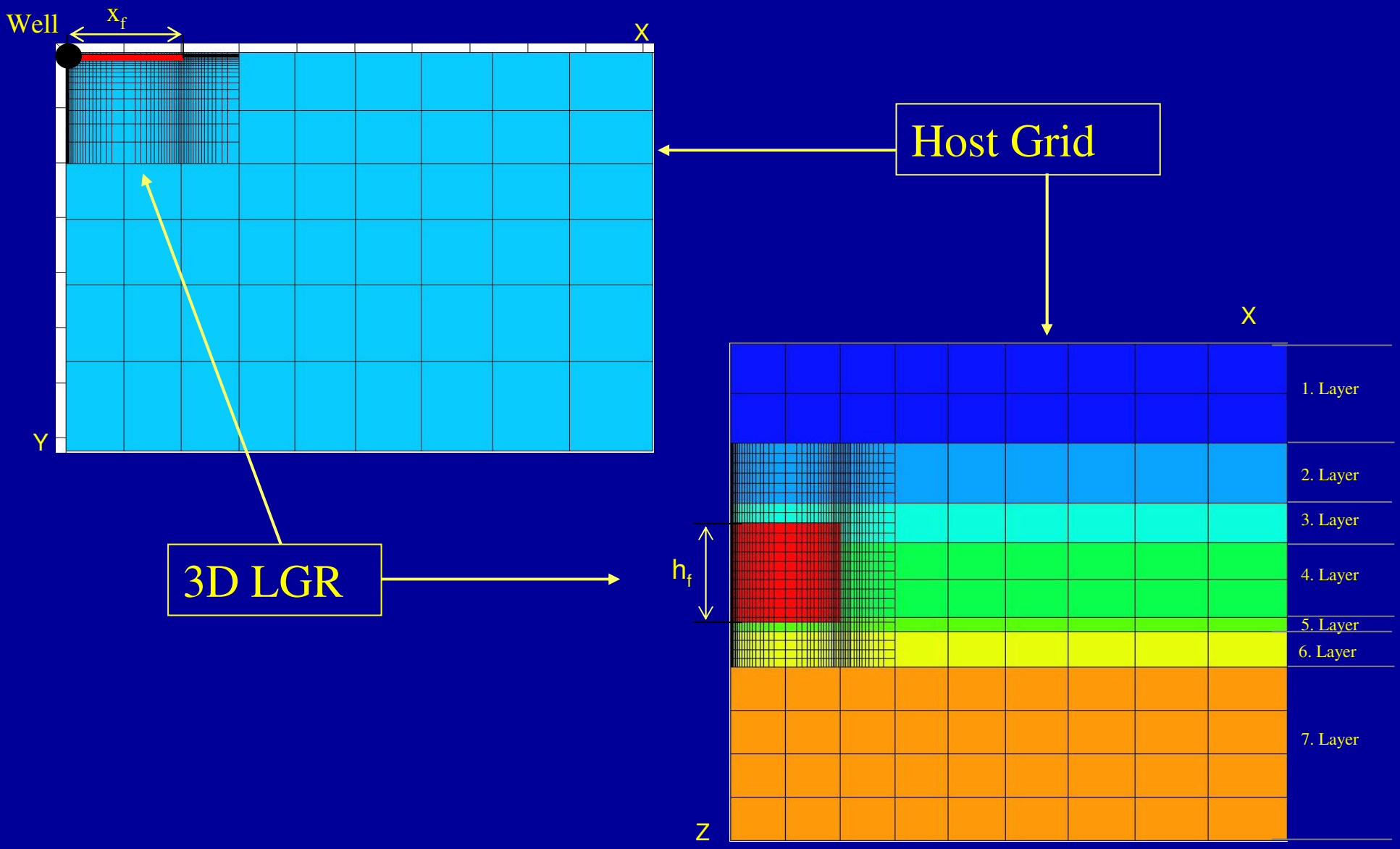
(for the Atoka Shale in Mounds, Oklahoma – Drill Cuttings Injection Project, SPE 63032)



Close the Loop from Treatment to Performance: Production Forecast with Reservoir Simulator

- Inputs:
  - Reservoir properties
    - X, Y & Z Permeability, Porosity, Reservoir Pressure, Initial saturations
  - Simulation Grid
    - Fine grid near fracture (LGR), Coarse grid elsewhere
  - Fracture properties
    - Conductivity as equivalent permeability
    - Pressure dependence of permeability

Fracture to Reservoir Grid Scheme



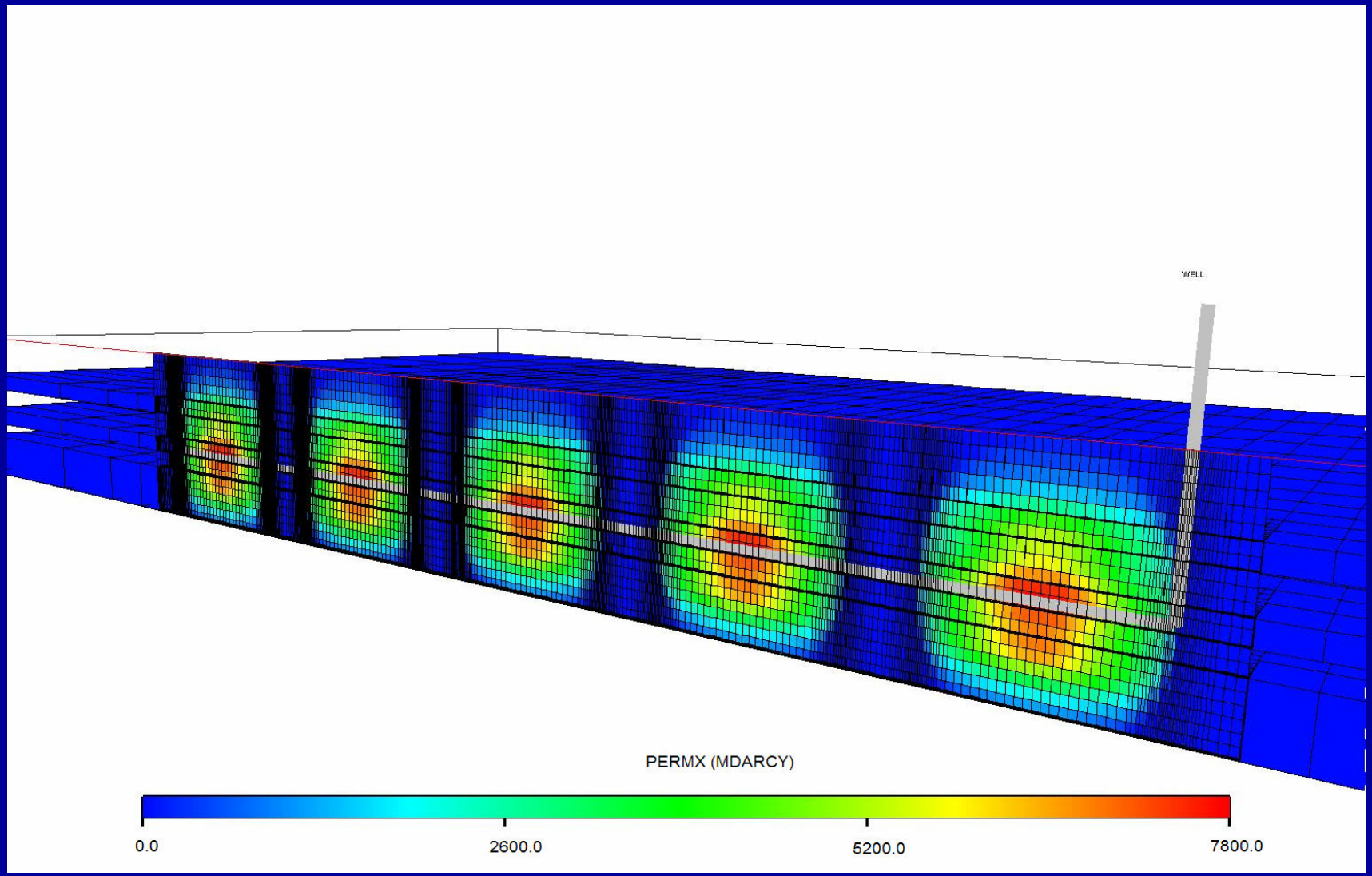
Additional Inputs Needed

- PVT and Relative Permeability data.
  - Rel-perms can be different for fracture and reservoir
- Production wellbore configuration or lift tables
- Production constraints for simulation
  - Minimum bottomhole pressure
  - Minimum surface pressure,
  - Maximum oil/gas/water rates

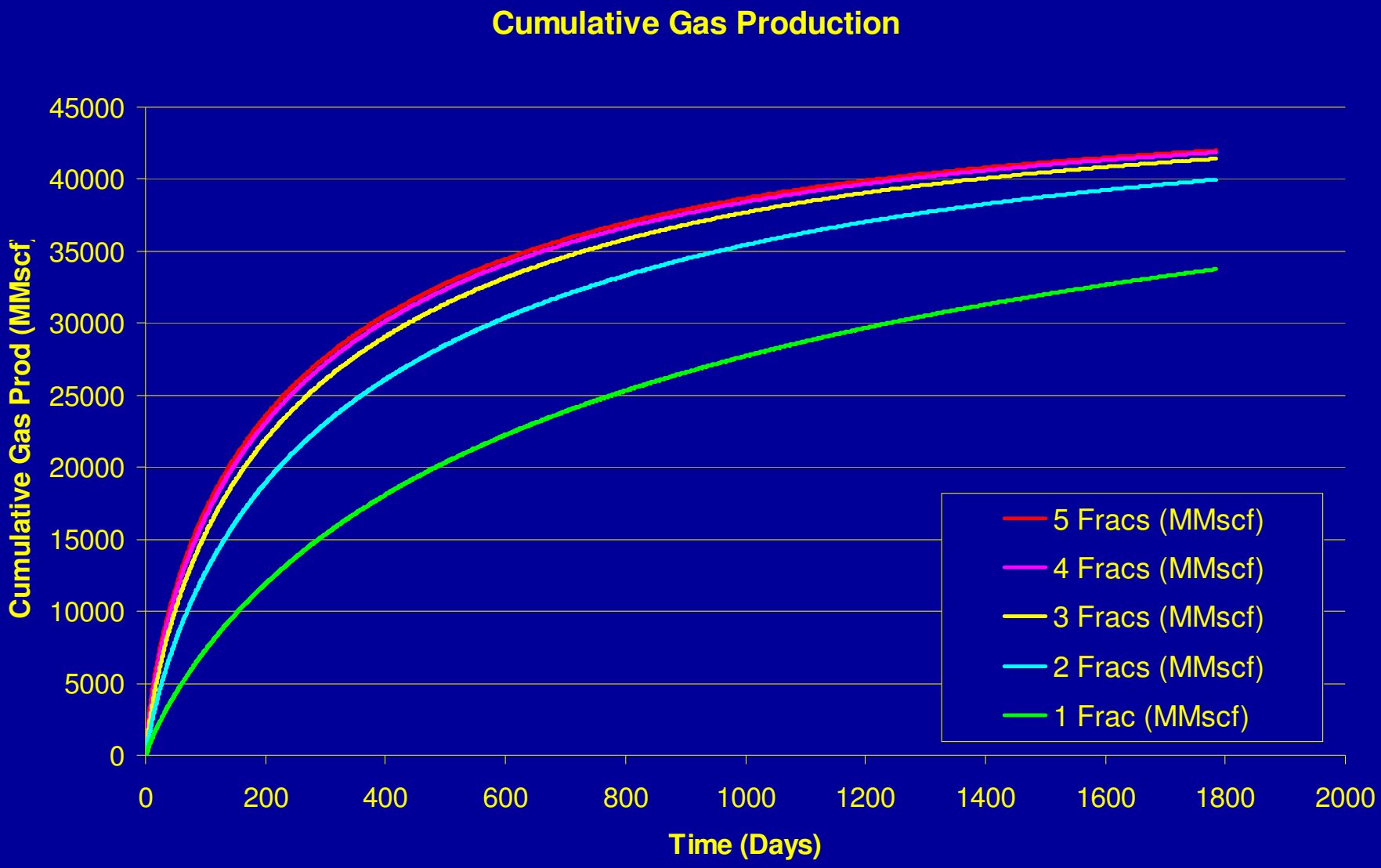
Examples

- Horizontal longitudinal propped fractured well
  - gas + water
- Horizontal transverse acid fractured well
  - oil + water + gas

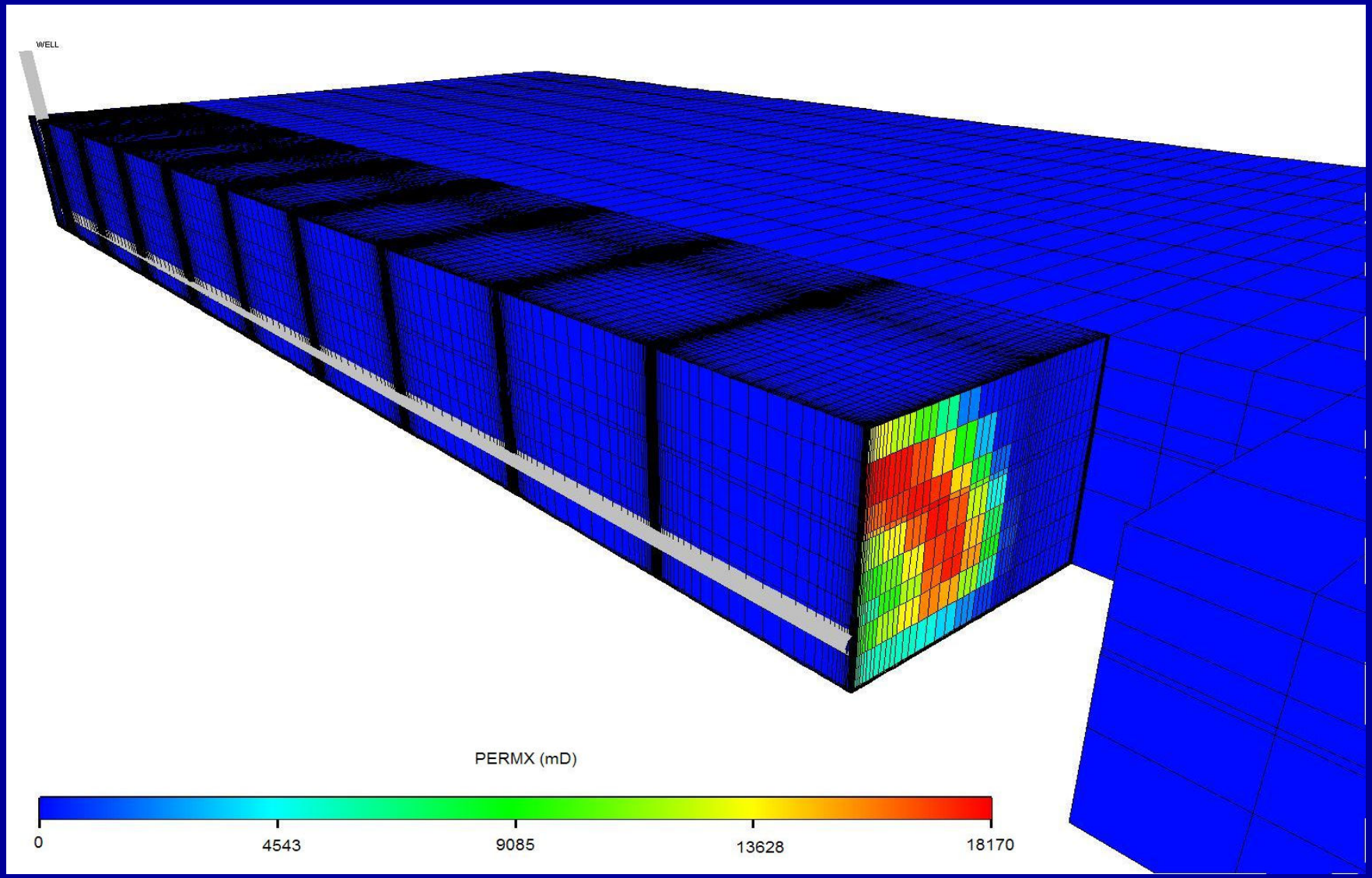
Longitudinal Propped Fracture
Gas + Water



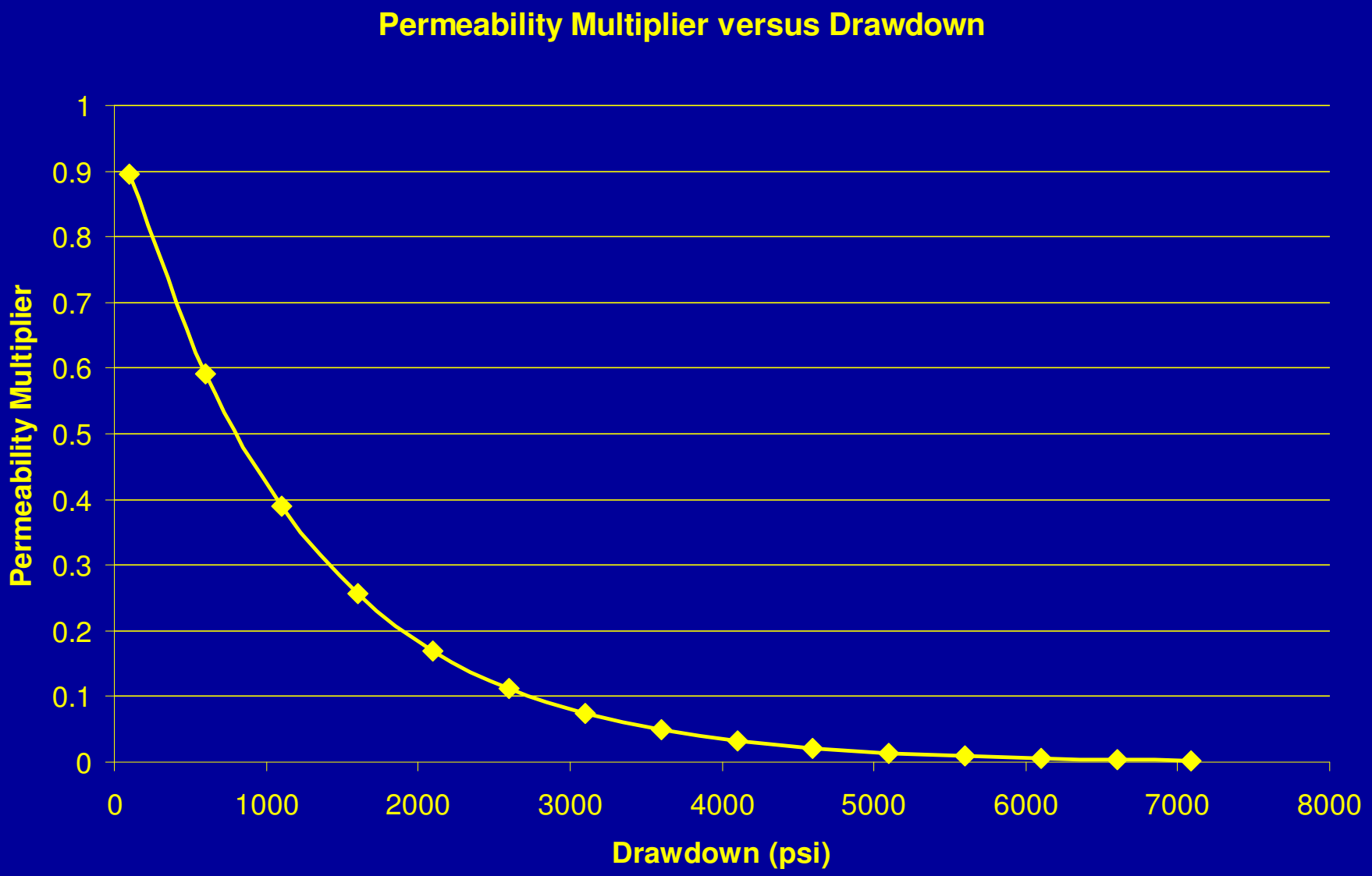
Cumulative Gas Production vs. # Fracs



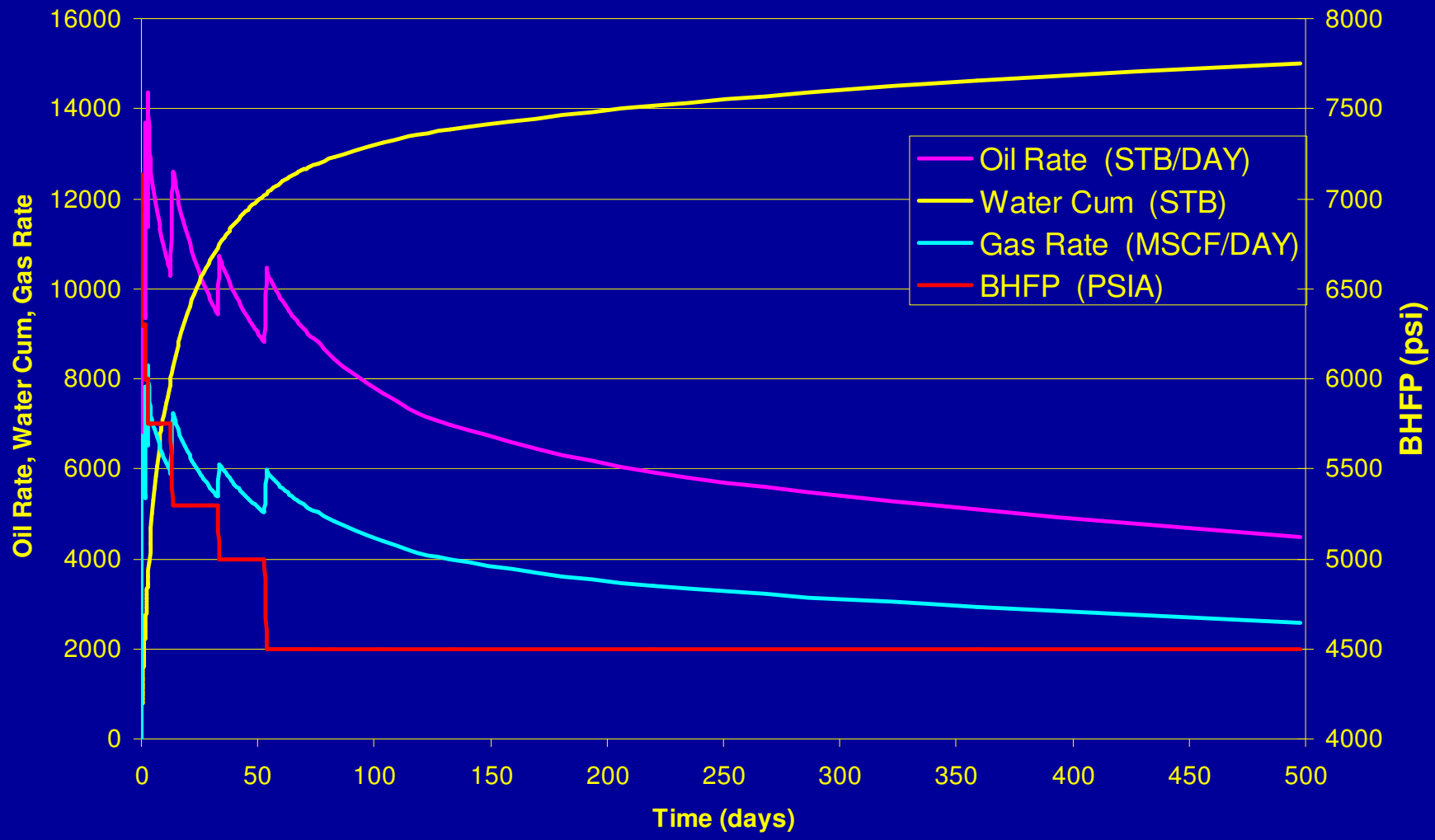
Transverse Acid Fractured Well
Oil + Water + Gas



Acid Fracture Conductivity Transferred to Reservoir Model



Production & Pressure vs Time



Conclusions

- Advanced Minifrac Analaysis provides Pressure and Perm in cases where Pre-frac PBU are costly or impractical
- Uncertainty in Fracture geometry can be Relieved with Direct Fracture Mapping
- Generate reservoir simulator input files for hydraulically fractured wells.
  - Reservoir simulations run in minutes.
  - Possible to optimize horizontal well fracture designs using full numerical model.