Seismic to Flow Simulation

in fractured, unconventional reservoirs

Simple engineering methods such as decline curve analysis may be inadequate in unconventional reservoirs because they do not take into account the complex interactions between fractures, geologic characteristics and fluid behavior that determine the nature of the production decline. Flow simulation takes into account these interactions and hence its importance in the complete understanding of unconventional, fracture reservoirs. iReservoir has developed technologies and workflows to extract information out of seismic data that can contribute to build complex flow simulation models that require detailed information about matrix and fractures. Calibration of the seismic derived information with independent well data is essential to build confidence in the results. Our methods focus on the characterization of the matrix and fracture components of the geological models. This brochure focuses on our approach for characterization, modeling and simulation of fractured reservoirs.

Local fracture Orientations from Structural Attributes

- Seemingly noisy local strikes may contain valuable information about fracture dispersion
- Local angle statistics are used to estimate families of fractures with different orientations, intensities and dispersions
- Local calibration is the key

Fractures Characterization and Modeling Workflow

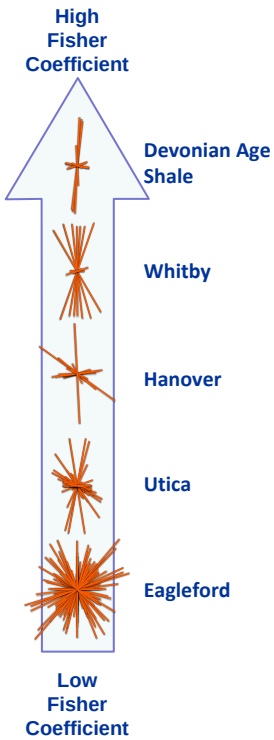
- **Interpret fractures**
  - Image log interpretation, fracture style in cores, diagenesis
- **Determine productive fractures**
  - Reconcile production indicators
- **Characterize mechanical stratigraphy**
  - Fracture properties by facie, thickness
- **Develop fracture distribution scheme**
  - Analog based, outcrops, geomechanical models, seismic attributes

Courtesy of Chris Zahm (BEG-UT Austin)

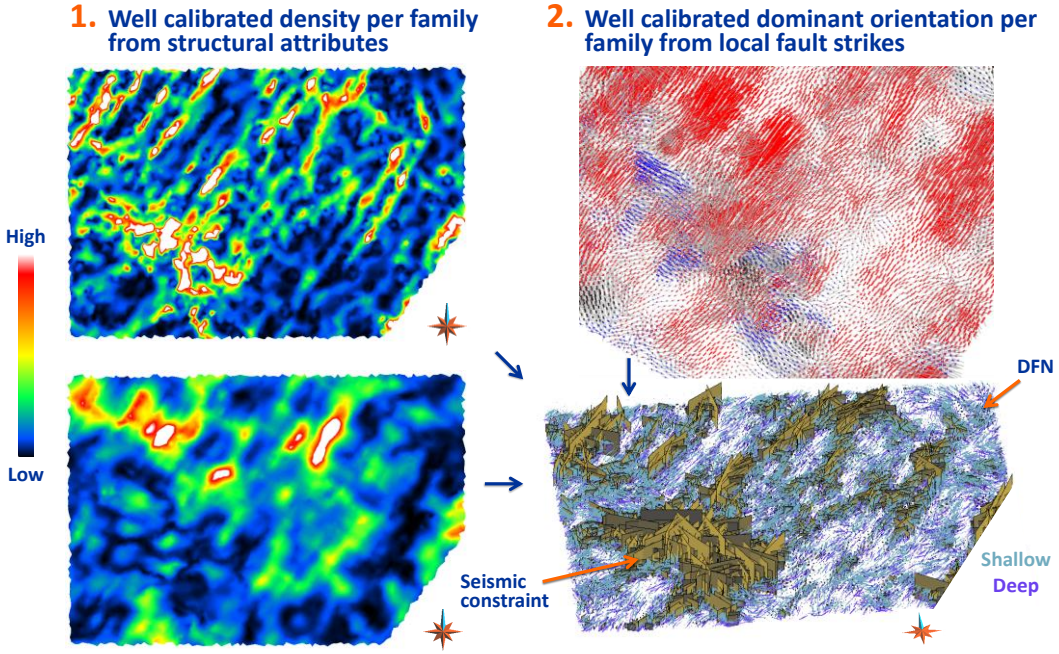
Discrete Fracture Network Modeling

Fracture modeling (discrete or continuous) requires information about background matrix and fractures

- **Background:**
  - Lithofacies, mechanical stratigraphy, deformation, geomechanics
- **Natural Fractures:**
  - Families, intensity, orientation, dispersion (Fisher Coefficient)
  - Size/aspect ratio, number, aperture / transmissivity



Seismic Input for Fracture Properties in DFN Modeling



Michelena et al. (2013)

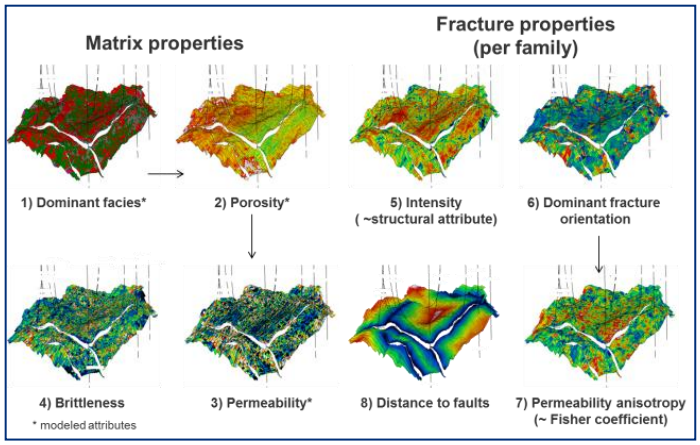
Seismic to Flow Simulation
in fractured, unconventional reservoirs (cont.)

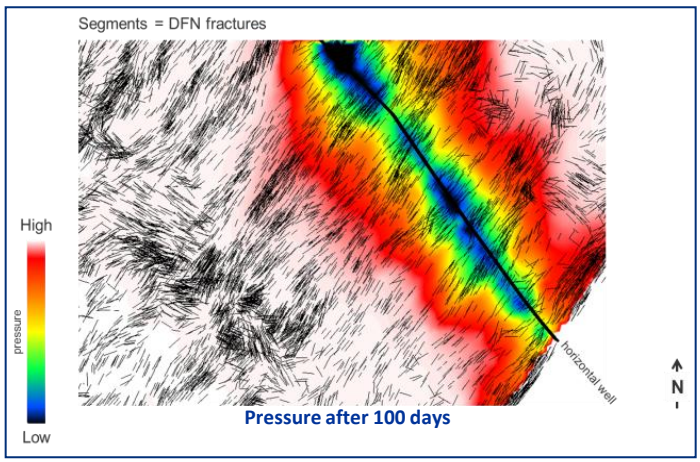
Flow Simulation

Factors that impact filed recovery:

- **Matrix characteristics and 3D distribution**
  - Porosity, permeability, facies, water saturation, compaction
- **Fracture characteristics and 3D distribution**
  - Intensity, porosity, permeability (directional), water saturation, compaction, shearing, opening, propping
- **Hydraulic fracture / SRV characteristics (variability by stage)**
  - Conductivity (varies along length), length, height
  - Open/shear fractures vs tensile opening of new fractures
  - Skin damage (e.g. completion fluids)
- **Nature of fluids and fluid/rock interaction**
  - Fluid compressibility, solution gas, critical gas saturation
  - Wettability (fractional flow and capillary pressure)
- **Well operations**
  - Variable flowing pressure, turbulence, perforation skin effect
  - Long-term pressure interference

Attribute Volumes Mapped to Flow Simulation Grid





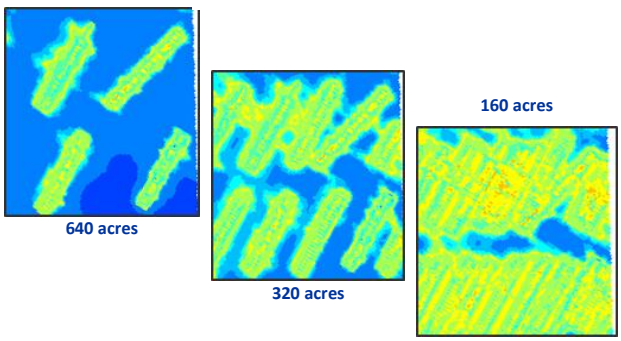
Pressure after 100 days

Challenges

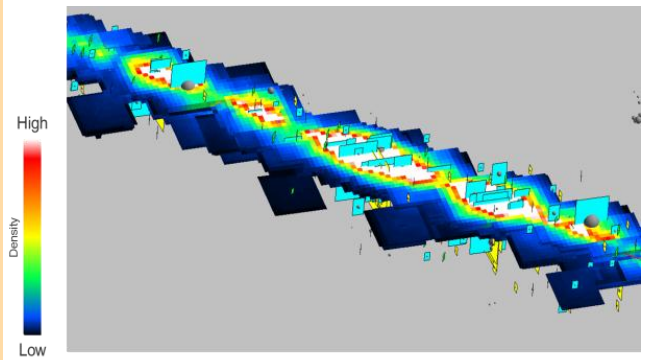
- **Matrix Characterization and Modeling**
  - Efficient use of sparse data from large amounts of horizontal wells
  - Improved estimation of matrix properties with limited collocated data
- **Fracture characterization and modeling**
  - Diverse, uncollocated data (3D seismic, microseismic, engineering)
  - Reliable processing, interpretation and calibration of microseismic data
  - Constrain 3D fracture models using 1D, biased fracture data
- **Flow simulation**
  - Lack of engineering data (BHP, frac stage flow back oil tracers, etc.)
  - Constant vs variable SRV and fracture conductivity
  - Uncertainty on forecasts
  - Need super-fast flow simulator that can handle detailed/complex matrix/fracture models (millions of cells)

Flow Calibration – Variable SRV and Fracture Conductivity

30-year recovery



SRV Calibration Using Microseismic Data



Reference

Michelena, R.J., Godbey, K.S., Wang, H., Gilman, J.R., and Zahm, C.K., 2013, Estimation of dispersion in orientations of natural fractures from seismic data: Application to DFN modeling and flow simulation: The Leading Edge, 32, No. 12, pp. 1502-1512.

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