Flow simulation models for unconventional reservoirs: the role of seismic data

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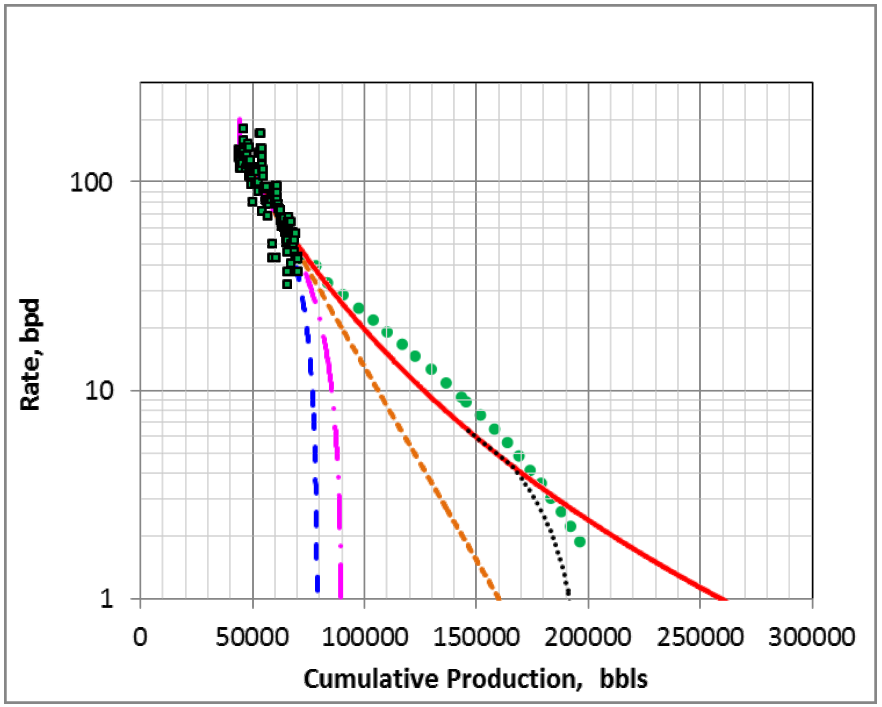
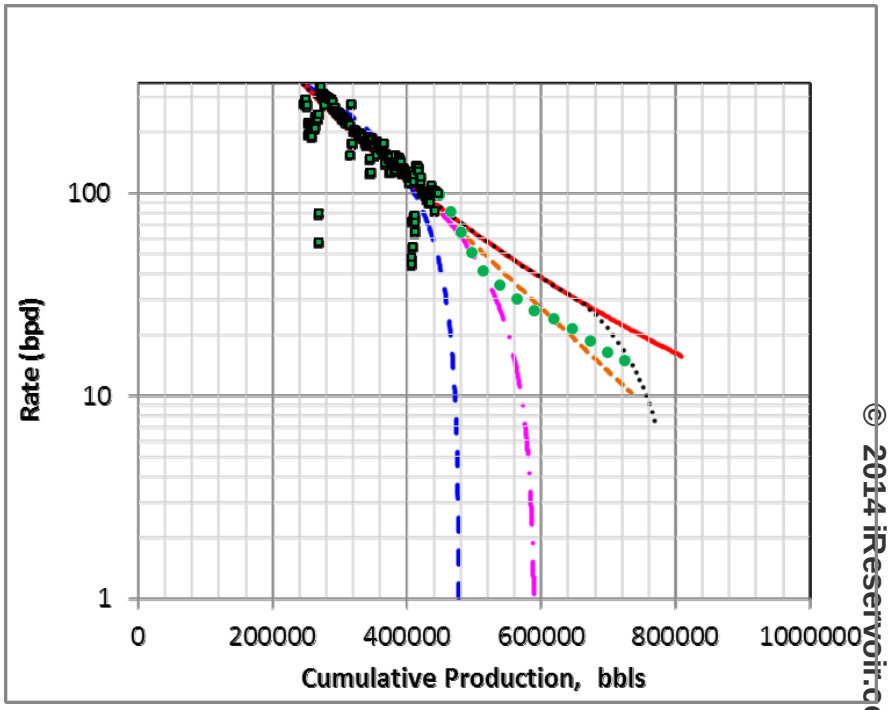
Decline curve fit in tight oil wells

Unconventional tight oil A



Unconventional tight oil B (overpressured, fractured)



Data
Exponential
Harmonic
Simulation
Hyperbolic
Modified hyperbolic
Power-law exponential

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Gilman and Fadaei (URTeC-2013)

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Why flow simulation?

- It takes into account all the *complex interactions* between fractures, matrix, and fluid behavior that determine the nature of the production decay in unconventional reservoirs
- It is the ultimate calibration tool for the concepts incorporated into the geological model

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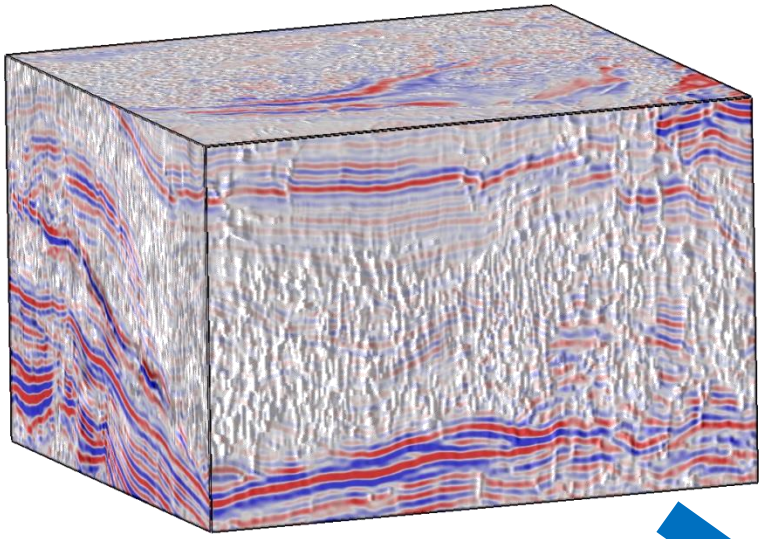
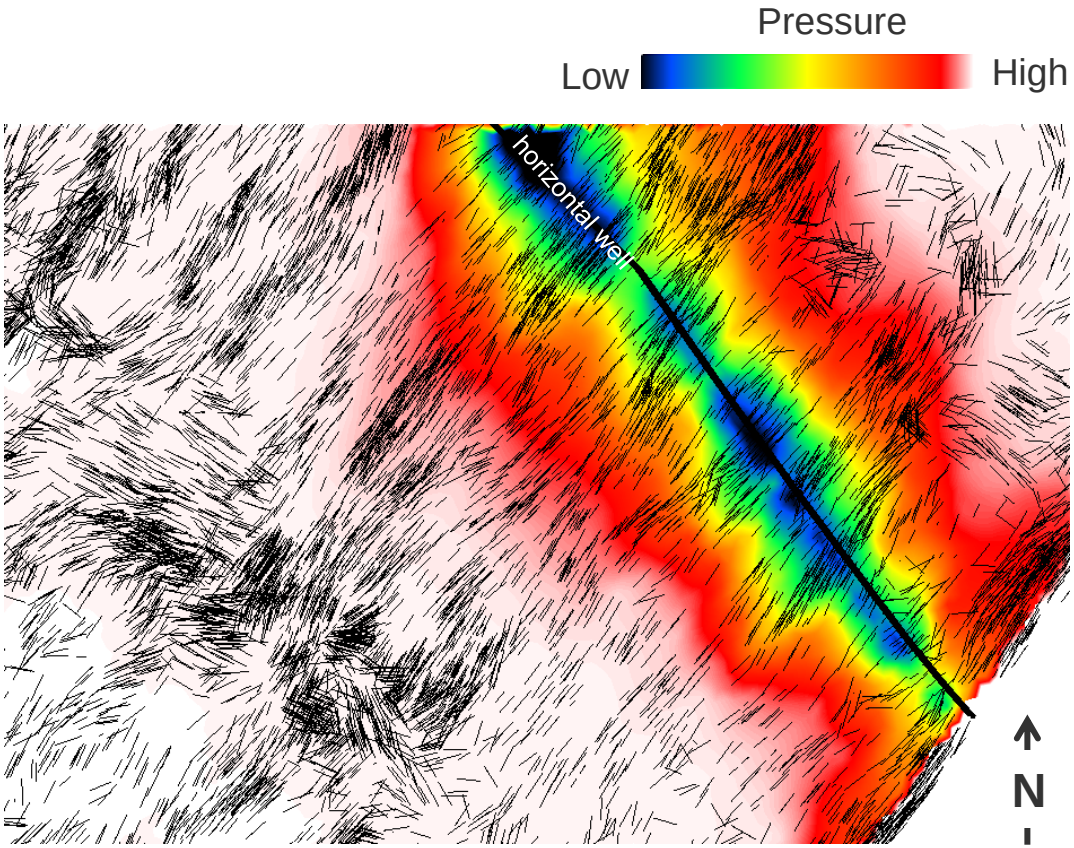
Objective: from seismic to flow simulation



Seismic data &
structural attribute



Pressure field in fractured reservoir
after 100 days

Variability in pressure field depends on both matrix and fracture permeability

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Seismic based modeling workflow

- **Facies definition**: decide what you're looking for at log scale based on production drivers. Be careful with automatic facies classifications!
- Seismic **calibration and mapping**: extract attributes, train data at well locations and apply to whole area.
- Modeling: consistent integration of petrophysics, geology, geophysics, and engineering to generate **matrix and fracture models**.
- Flow **simulation**: estimate/calibrate effective stimulated rock volume with geologic matrix-fracture models, microseismic data, hydraulic fracture conductivities, and production data. Iterate. Make forecasts.

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MATRIX CHARACTERIZATION AND MODELING

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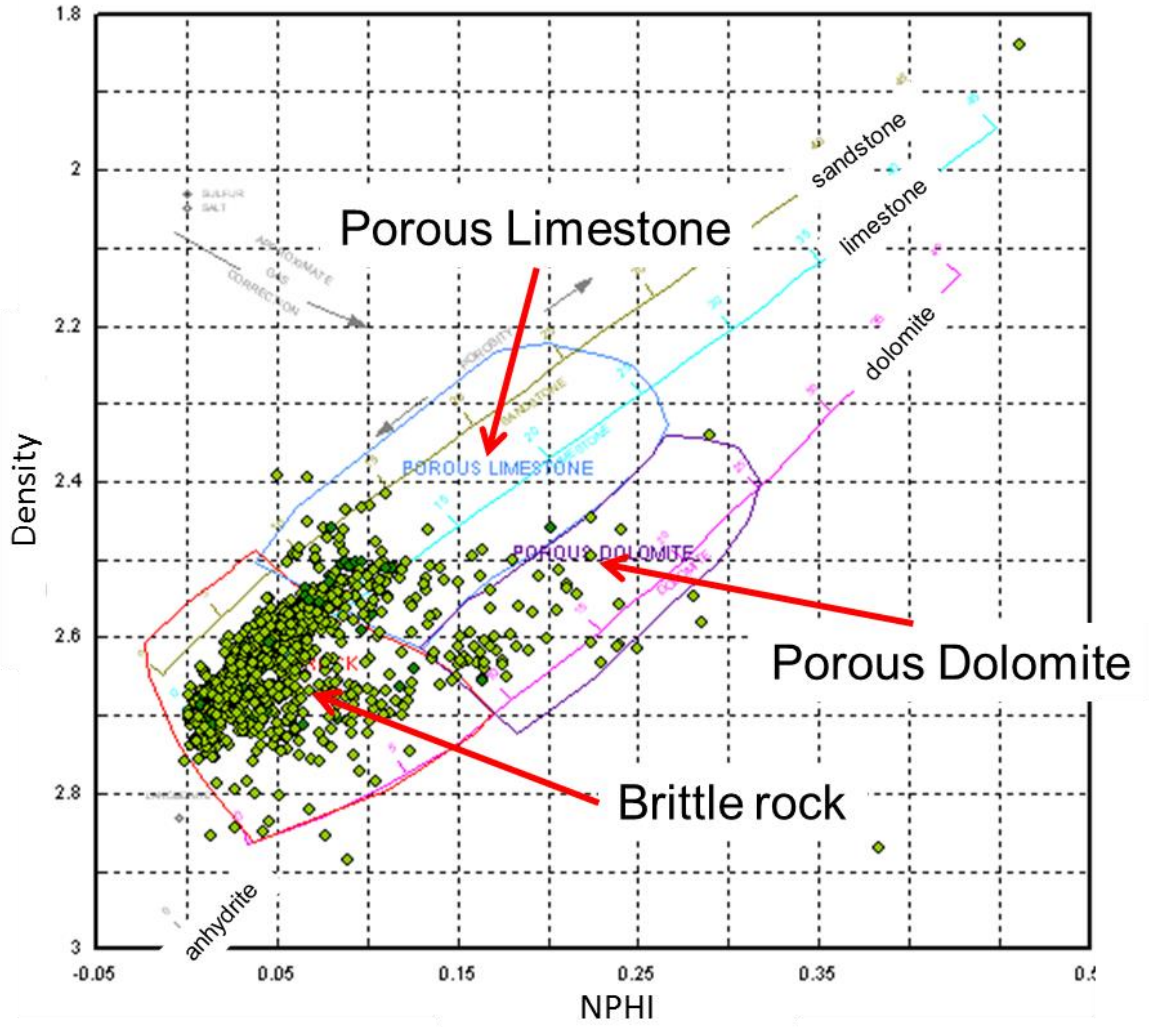
Definition of lithofacies using fracture* flags



*Only conductive and partially conductive fractures from FMI data are plotted

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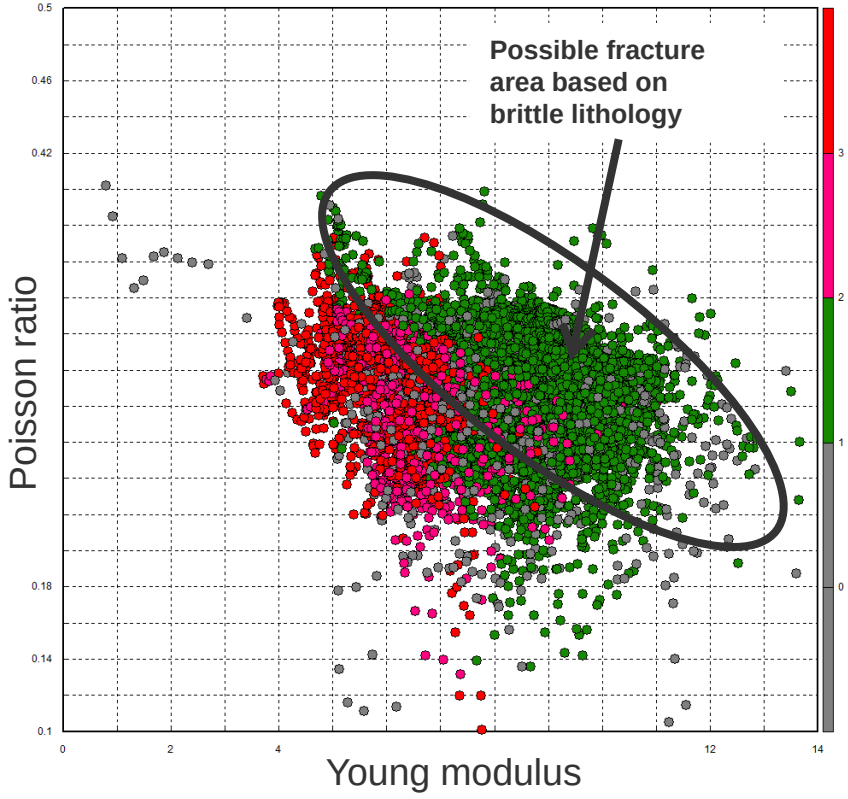
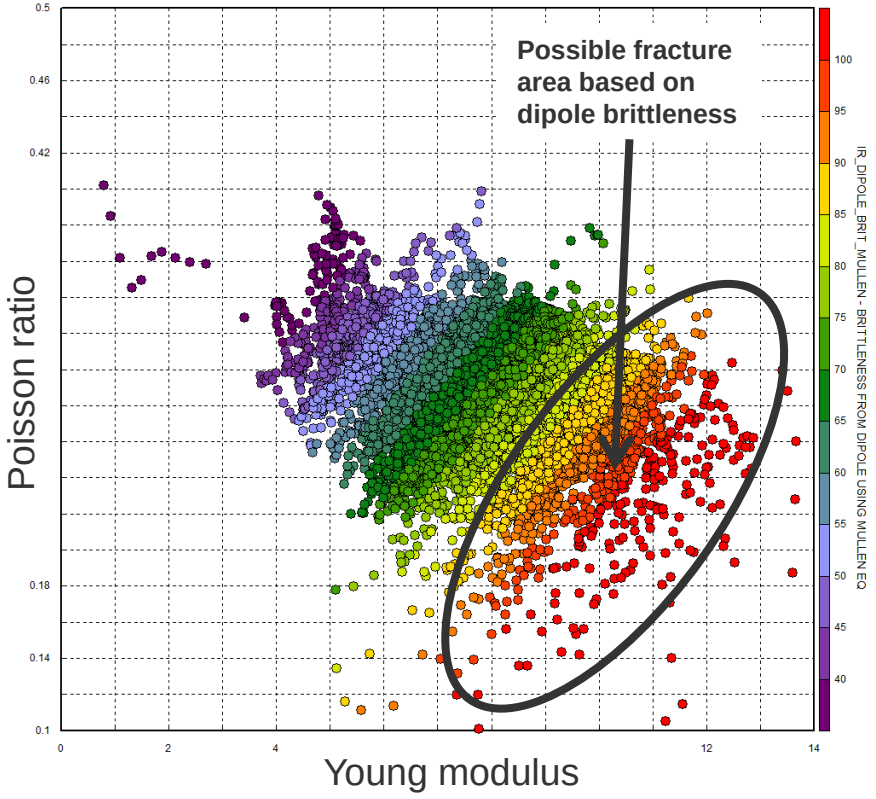
Log scale brittle facies vs brittleness



Lithofacies



Brittleness from dipole sonic

Brittle Limestone Dolomite Other

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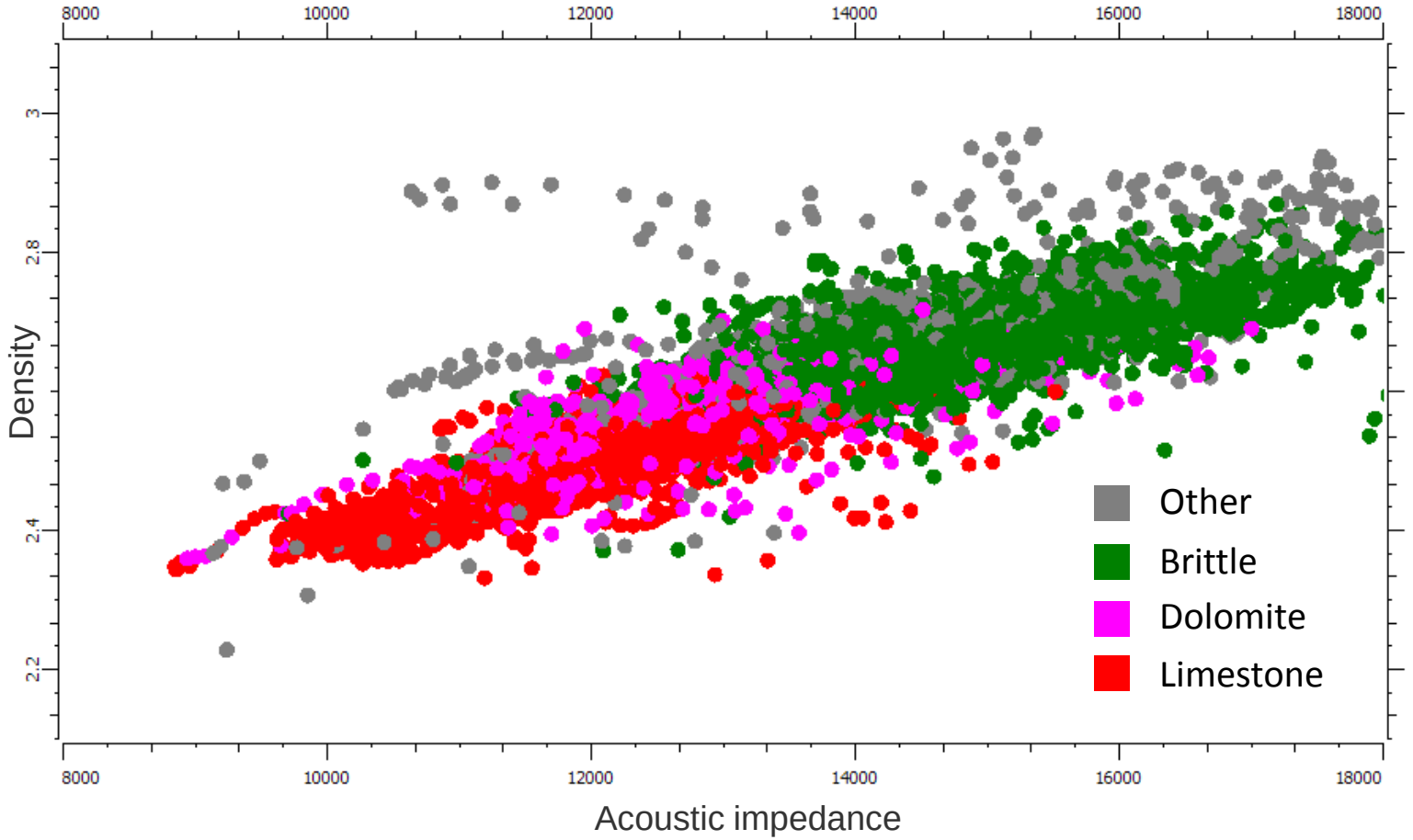
Log scale AI vs RHOB

Log data from 4 wells



Color: log scale lithofacies

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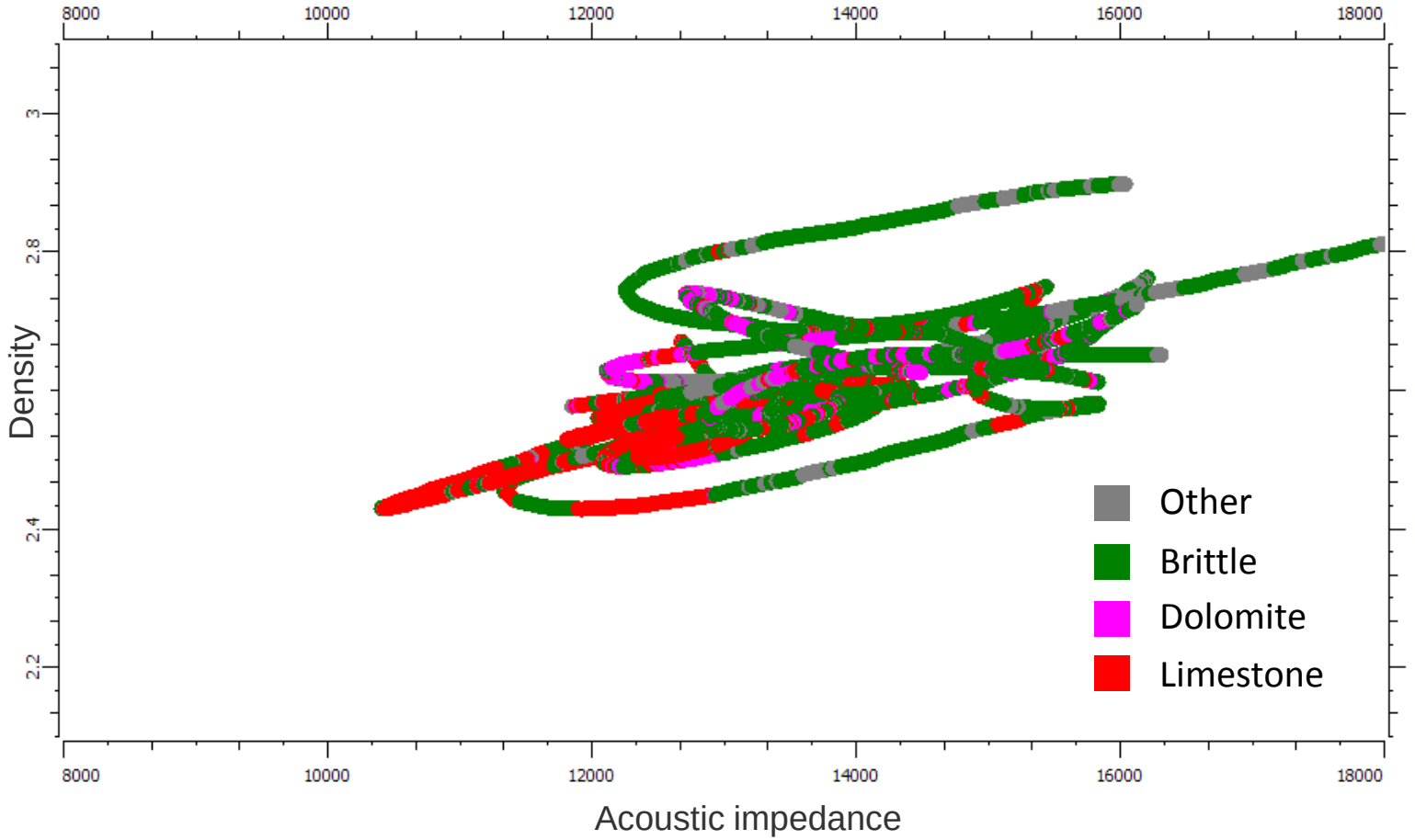
Seismic scale AI vs RHOB from inversion

Seismic data extracted along 4 wells



Color: log scale lithofacies

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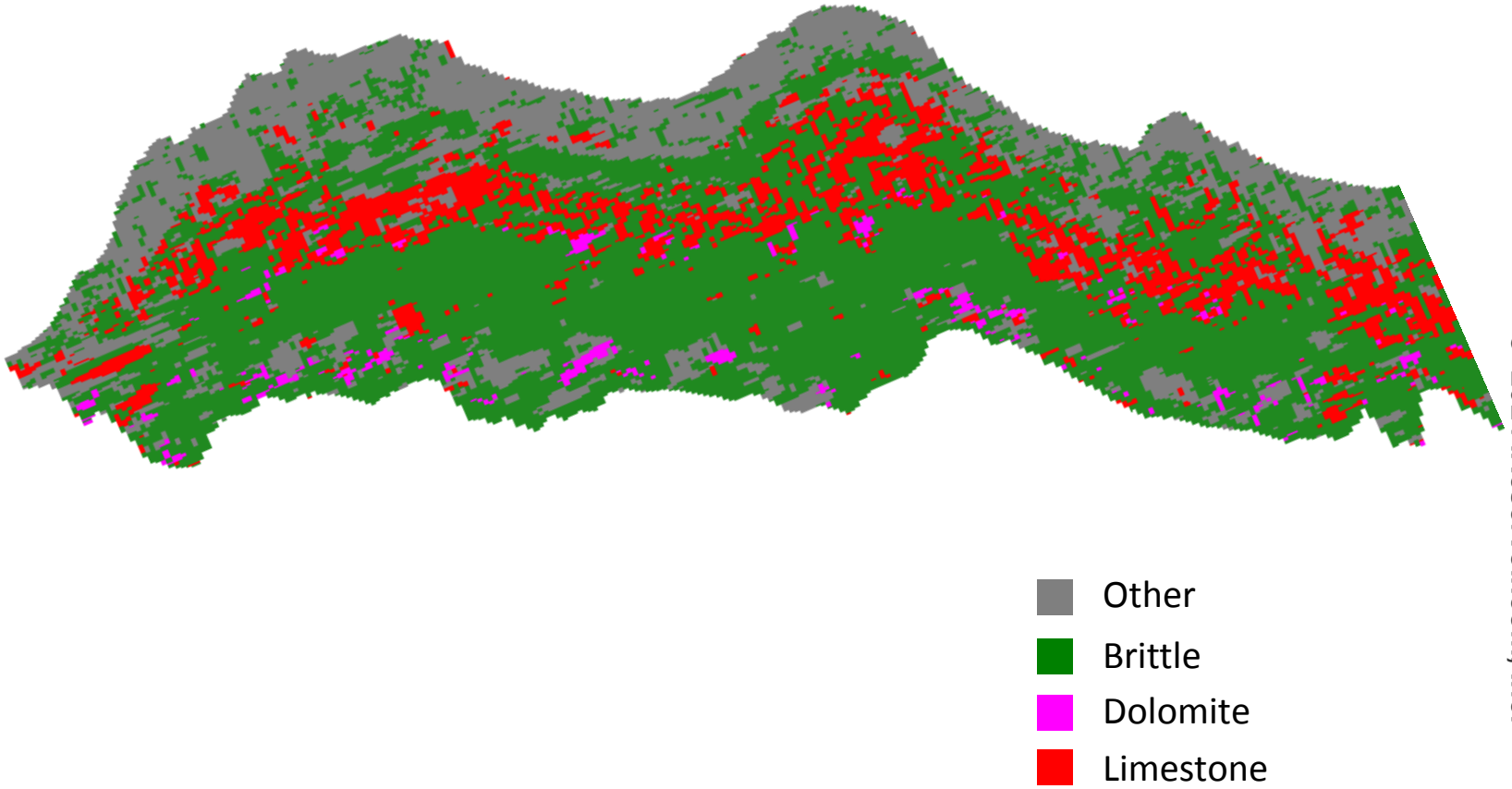
Most likely log facies cross section



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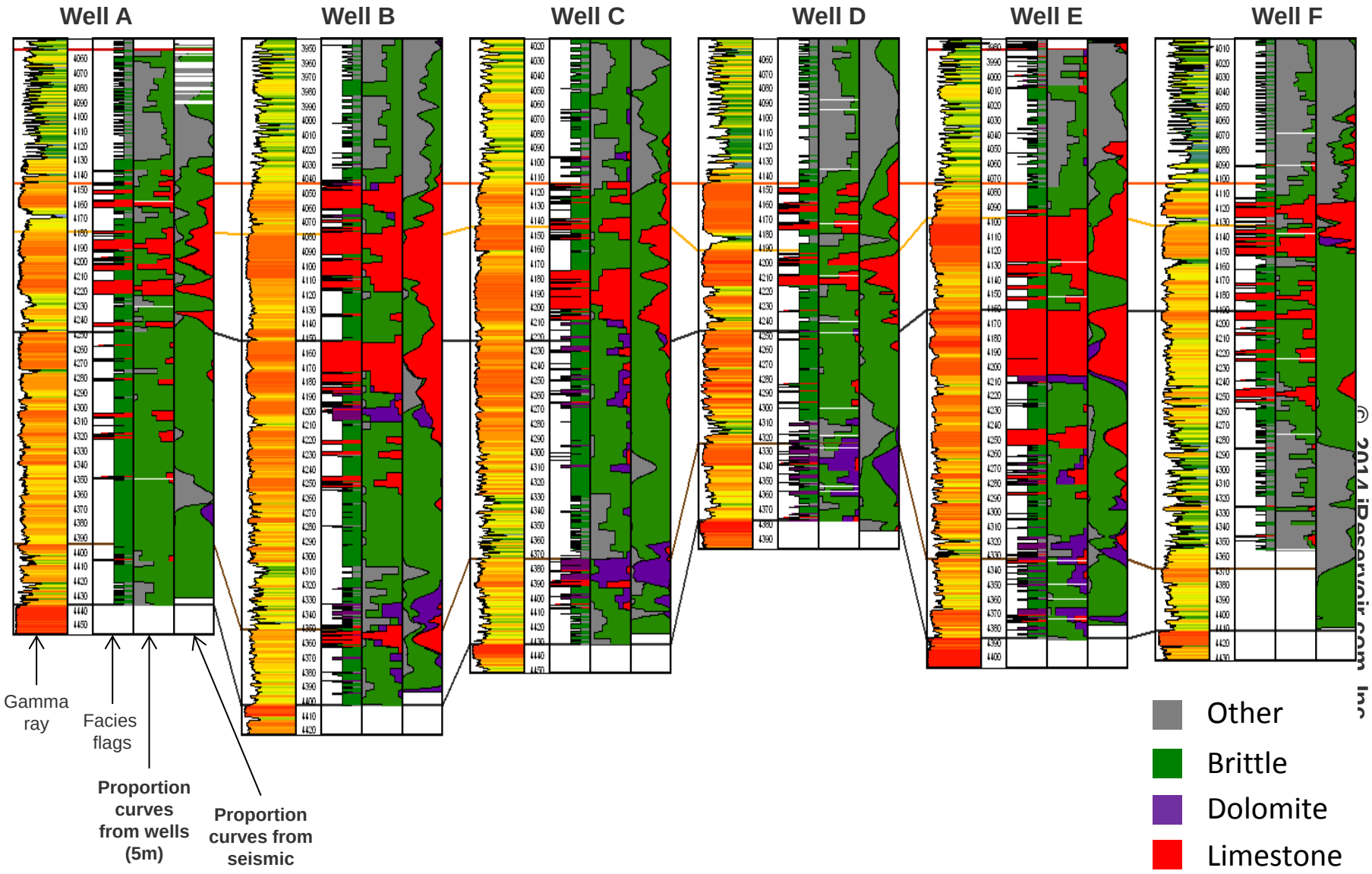
Facies proportion curves from wells vs. seismic



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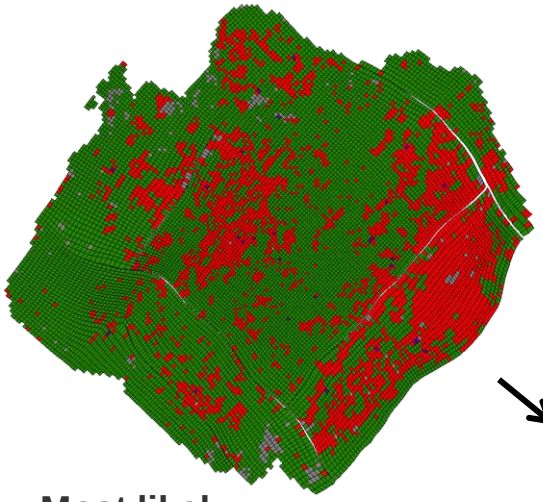
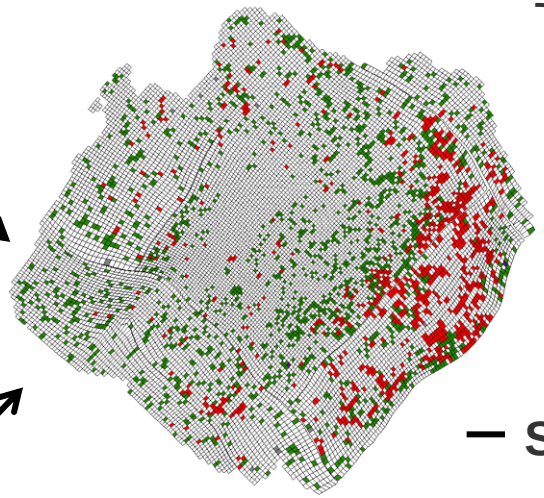
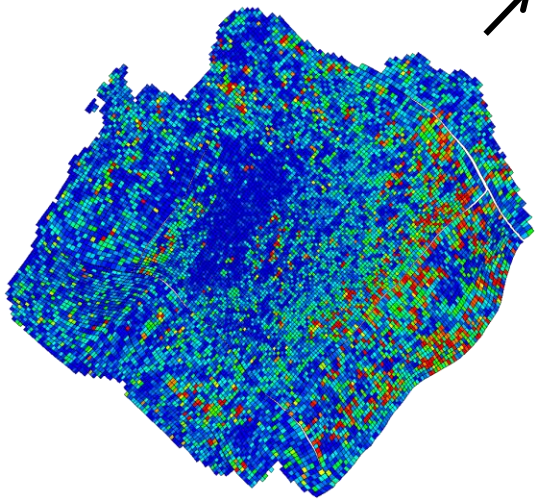
Seismic constrained facies modeling



Most likely facies

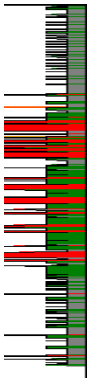
Seismic derived facies (only high reliability-high probability)





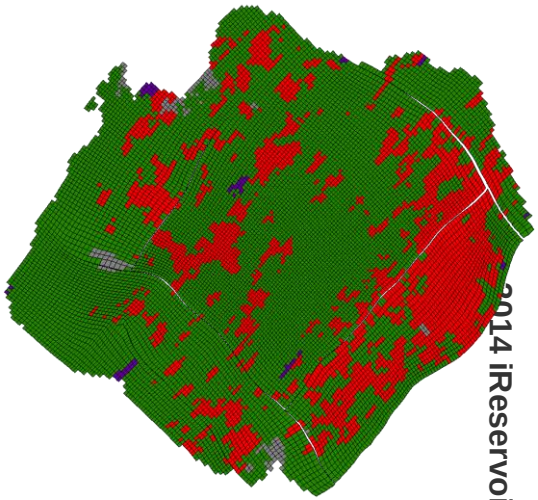
Facies reliability

Low High



Facies logs, facies proportion curves

SIS



Modeled facies

Other
Brittle
Dolomite
Limestone

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FRACTURE CHARACTERIZATION AND MODELING

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Input for fracture modeling

- **Background:**
  - Lithofacies, mechanical stratigraphy, structural deformation, geomechanics
- **Fractures:**
  - Intensity, orientation, dispersion (Fisher coefficient)
  - Size/aspect ratio
  - Number
  - Aperture/transmissivity
  - *…(for each family)*

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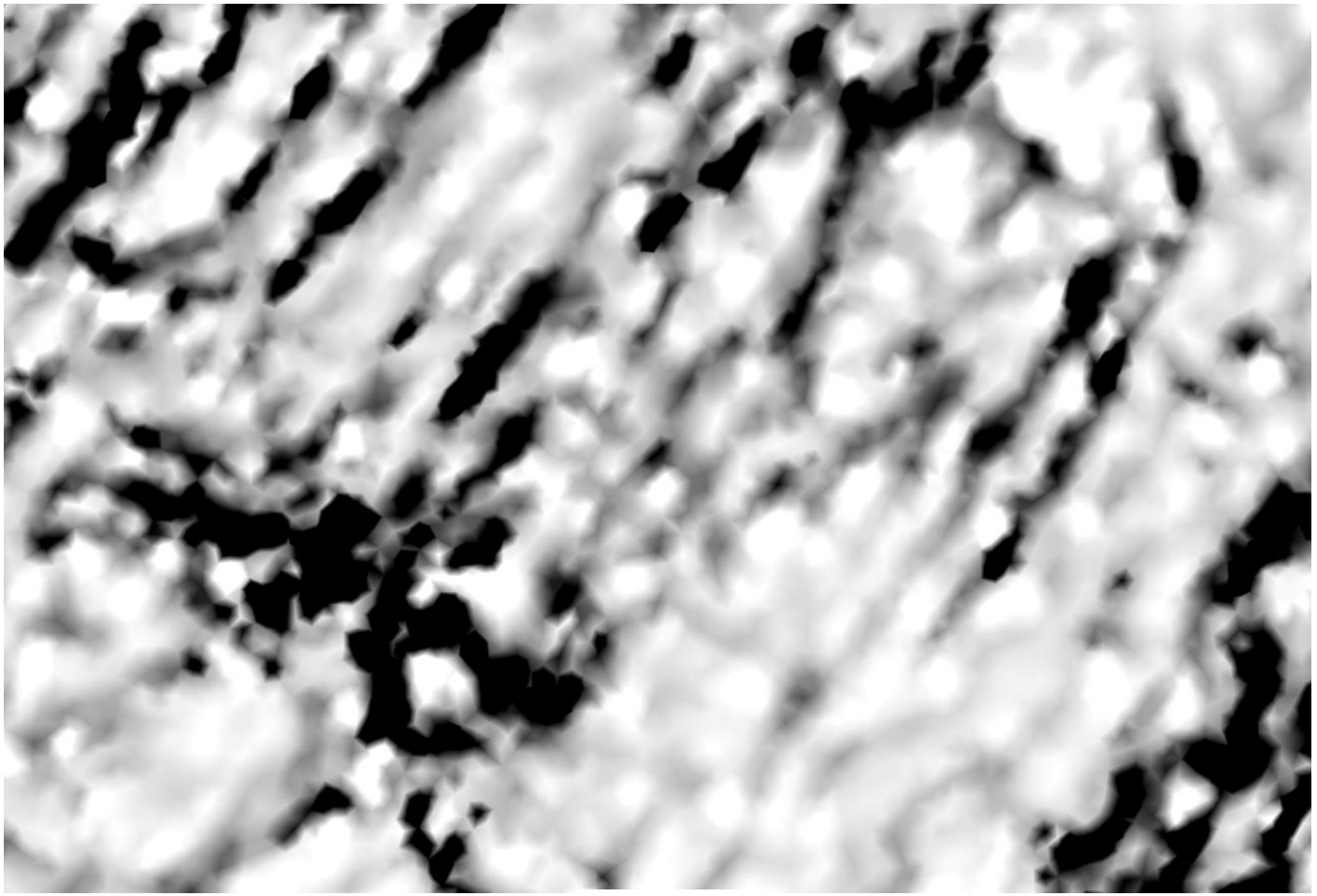
Structural attribute



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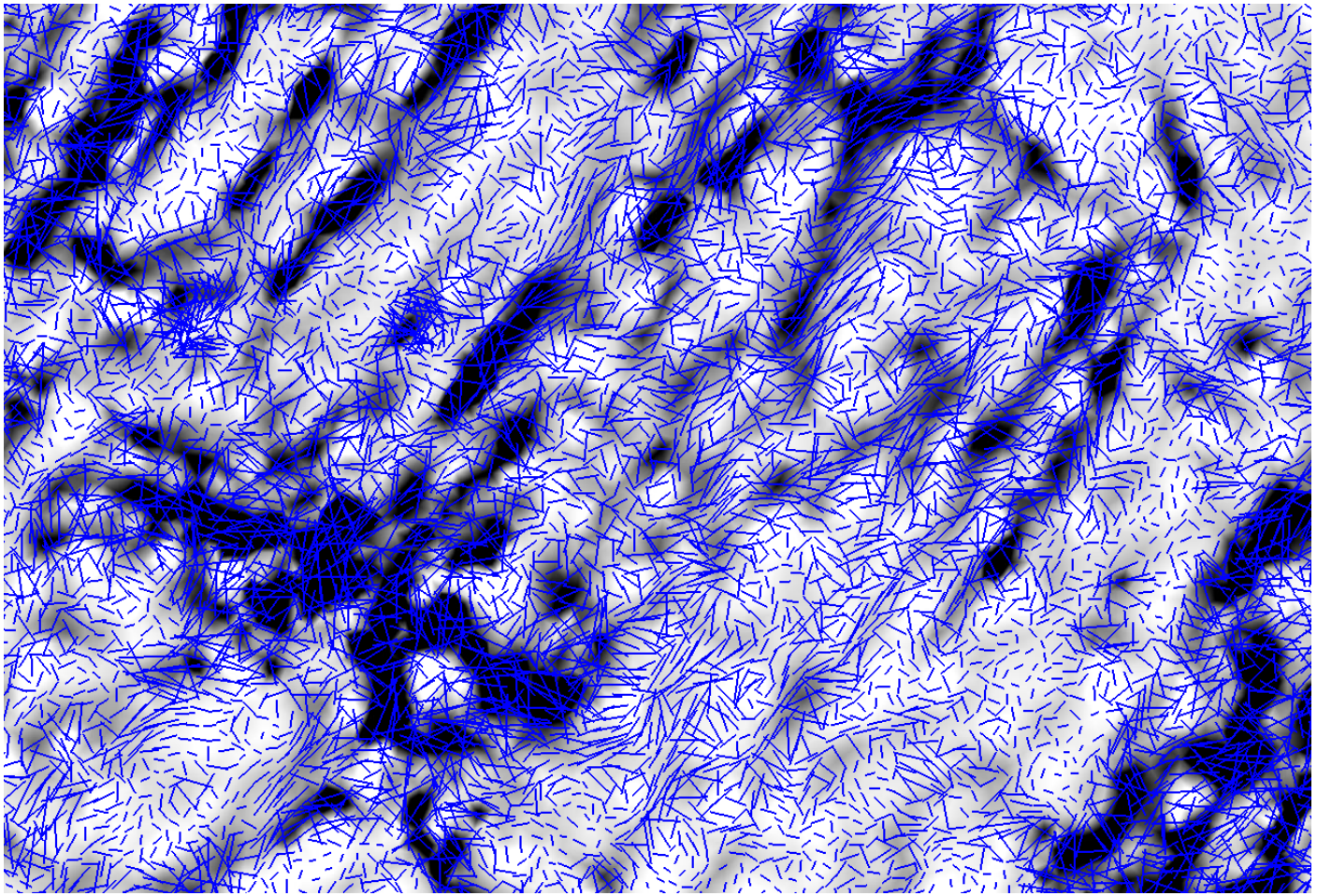
Structural attribute and local orientations



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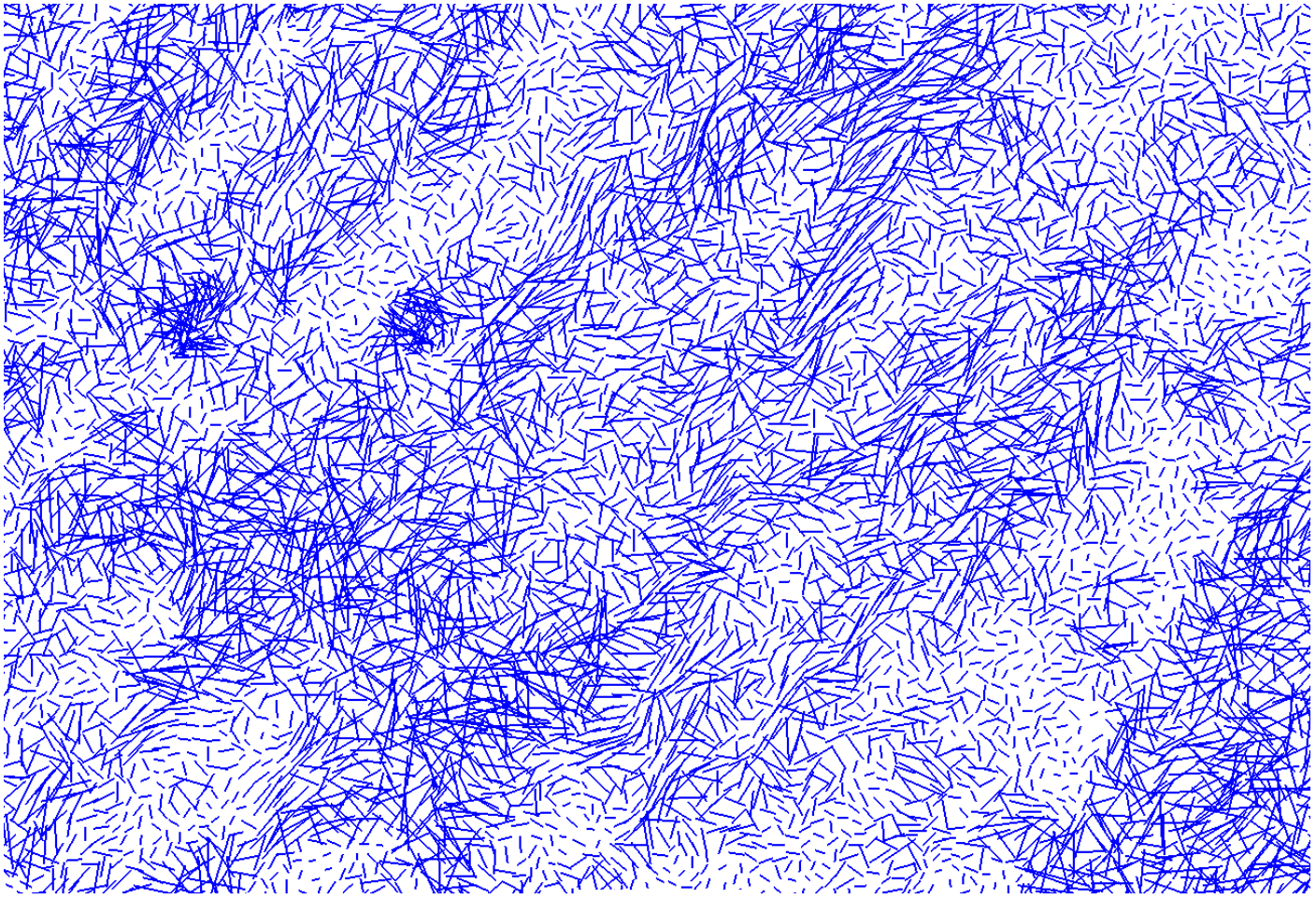
Local orientations



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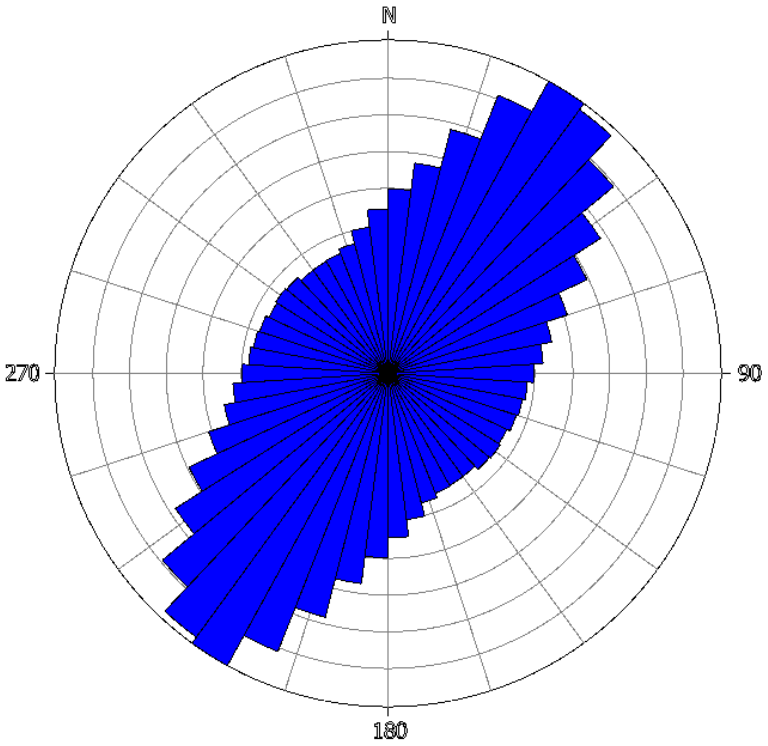
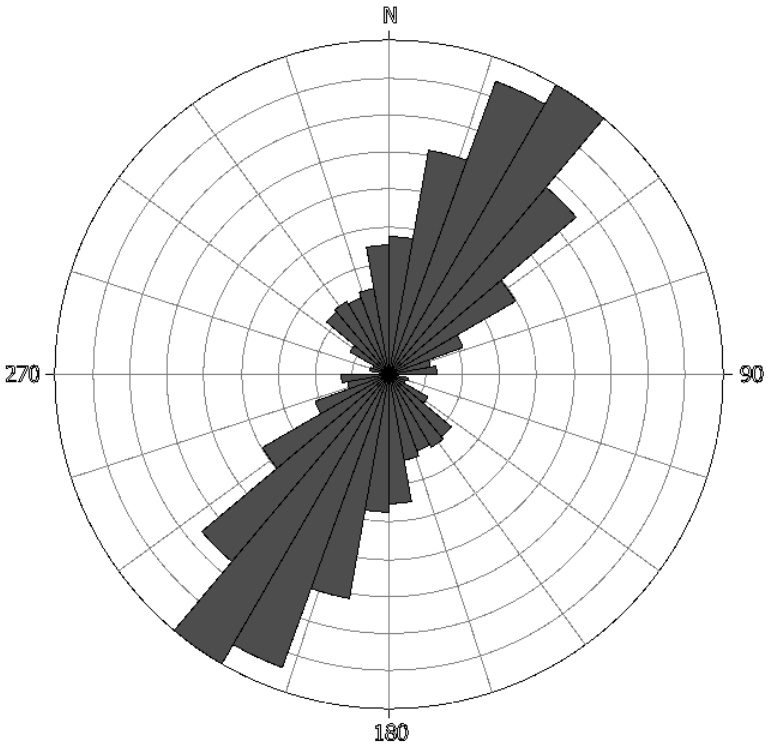
QC of seismic derived orientations



From seismic data



From image logs
(or microseismic)

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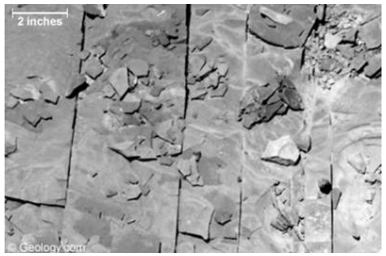
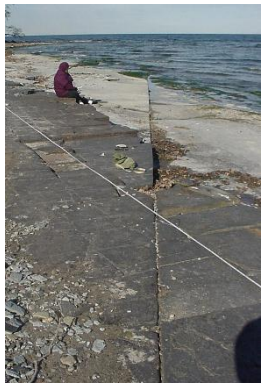
Fractured shale pavement outcrops



Geology.com

Durham U.(photo taken by Jonny Imber)



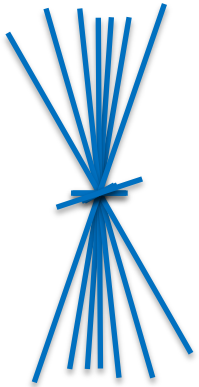
SUNY Fredonia

AAPG (photo taken by Bob Jacobi)

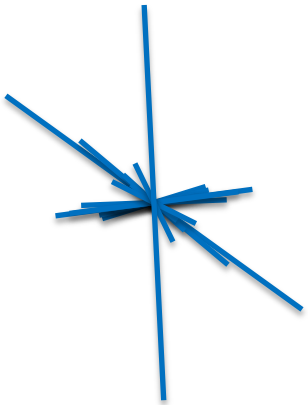
FLICKR (photo taken by Aikko Heiwa)

Devonian-age shale

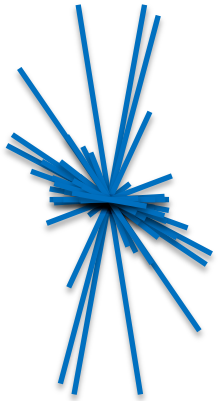
Whitby Mudstone



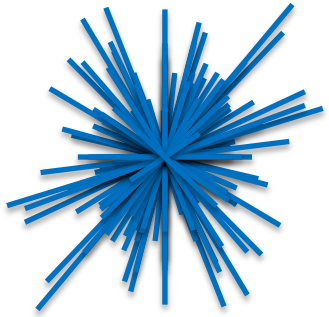
Hanover



Utica



Eagleford



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High Fisher Coefficient → **Increase dispersion in fracture orientations** → **Small Fisher Coefficient**

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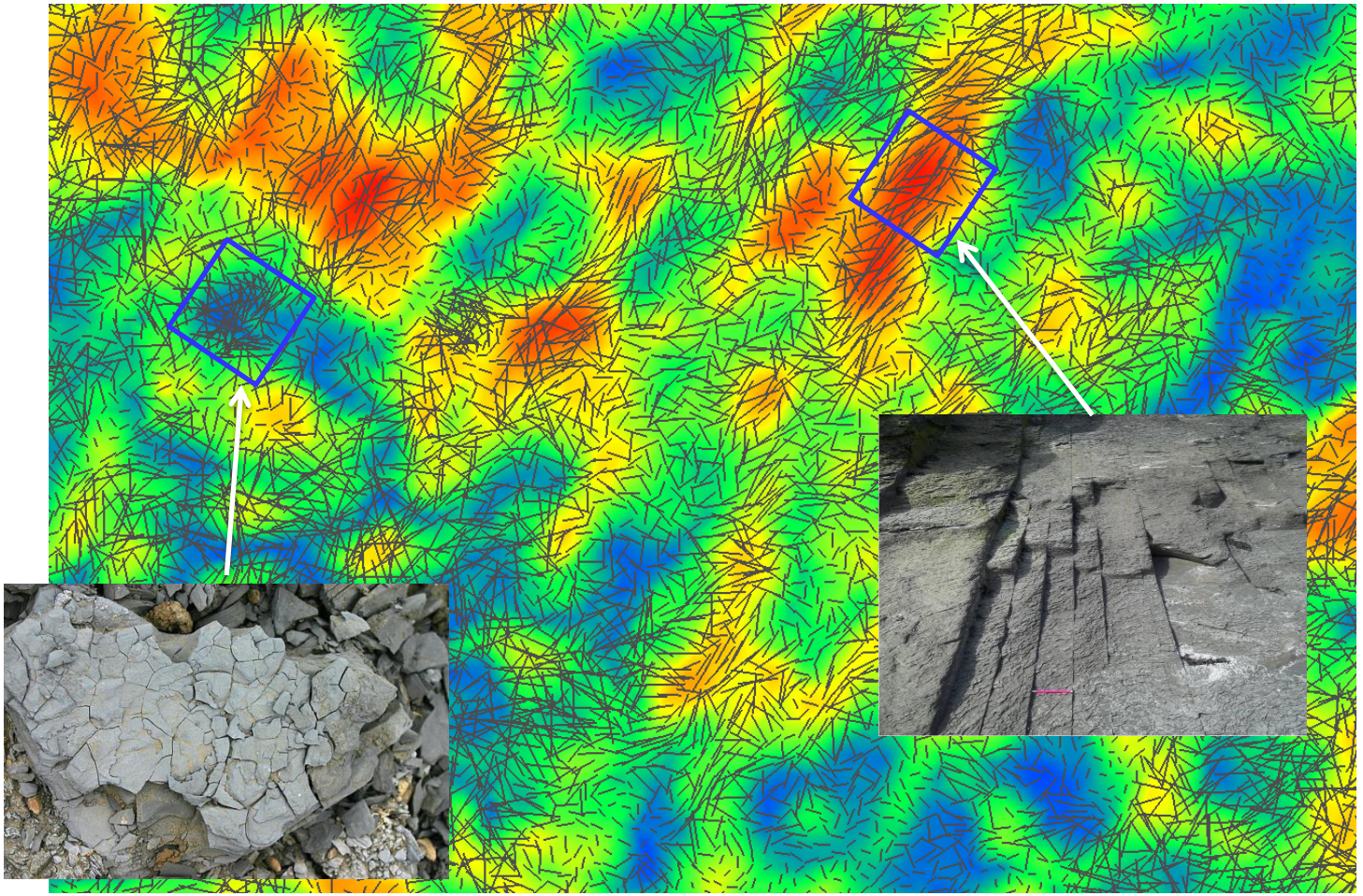
From local orientations to Fisher coefficient



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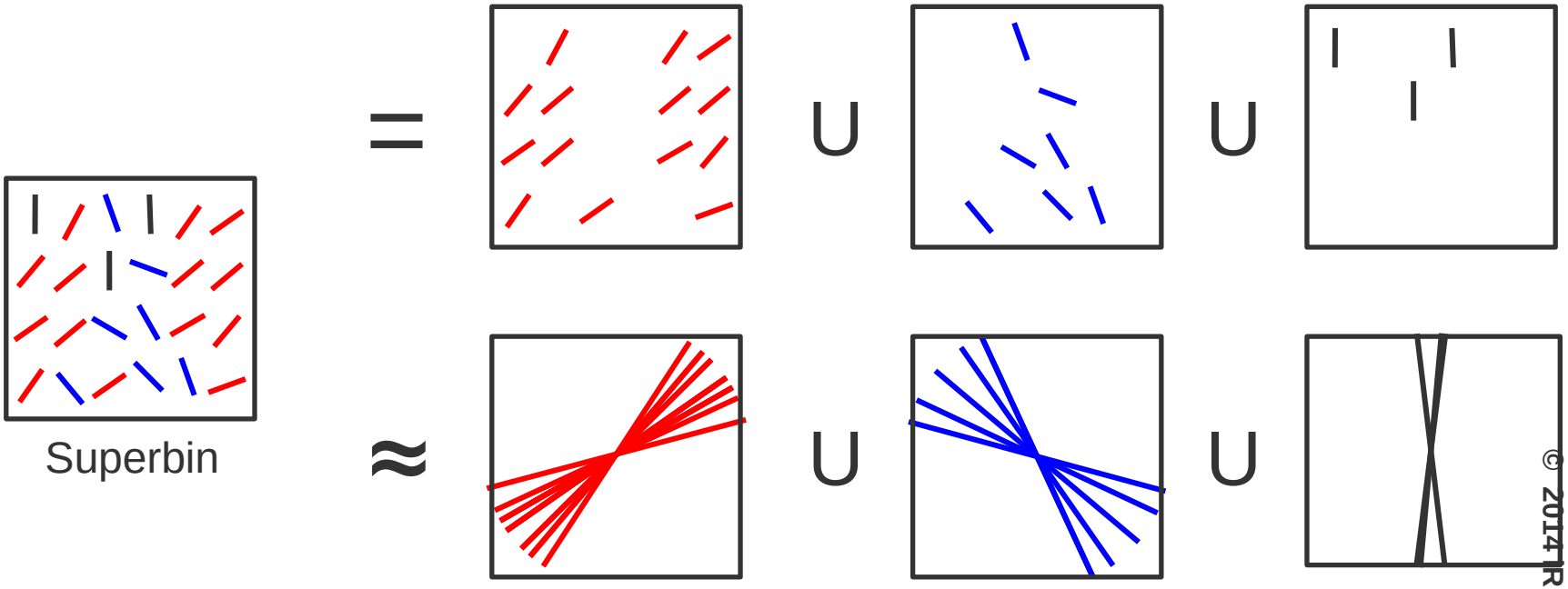
Michelena et al. (TLE- Dec 2013)

“Equivalent” families of fractures



Dominant orientation	→	α = N45E	α = N45W	α = N
Fisher Coefficient	→	*K* = 20	*K* = 15	*K* = 50
Count	→	*N* = 14	*N* = 7	*N* = 3

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Different families are assigned different flow properties for simulation

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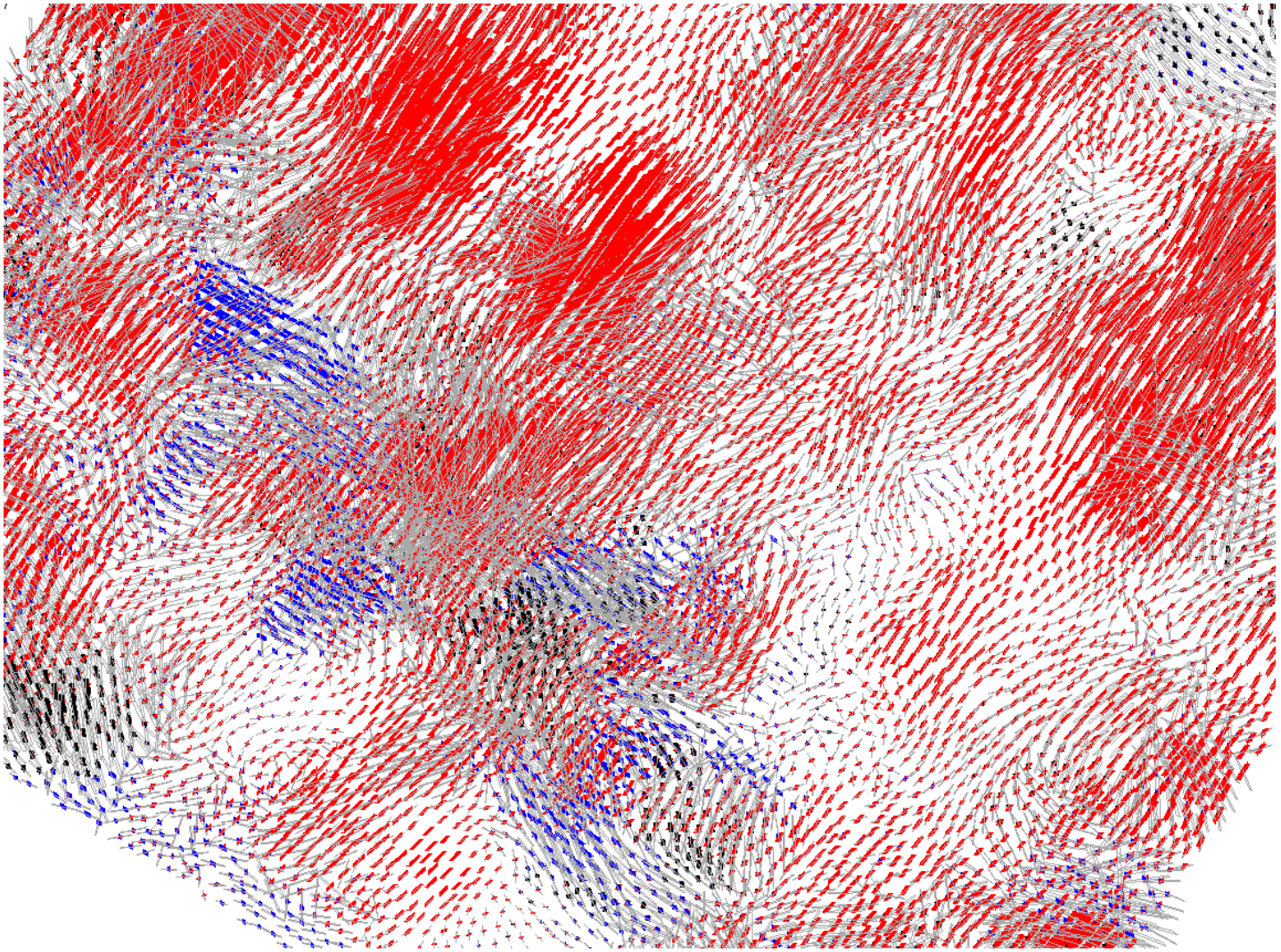
Orientations of fracture families



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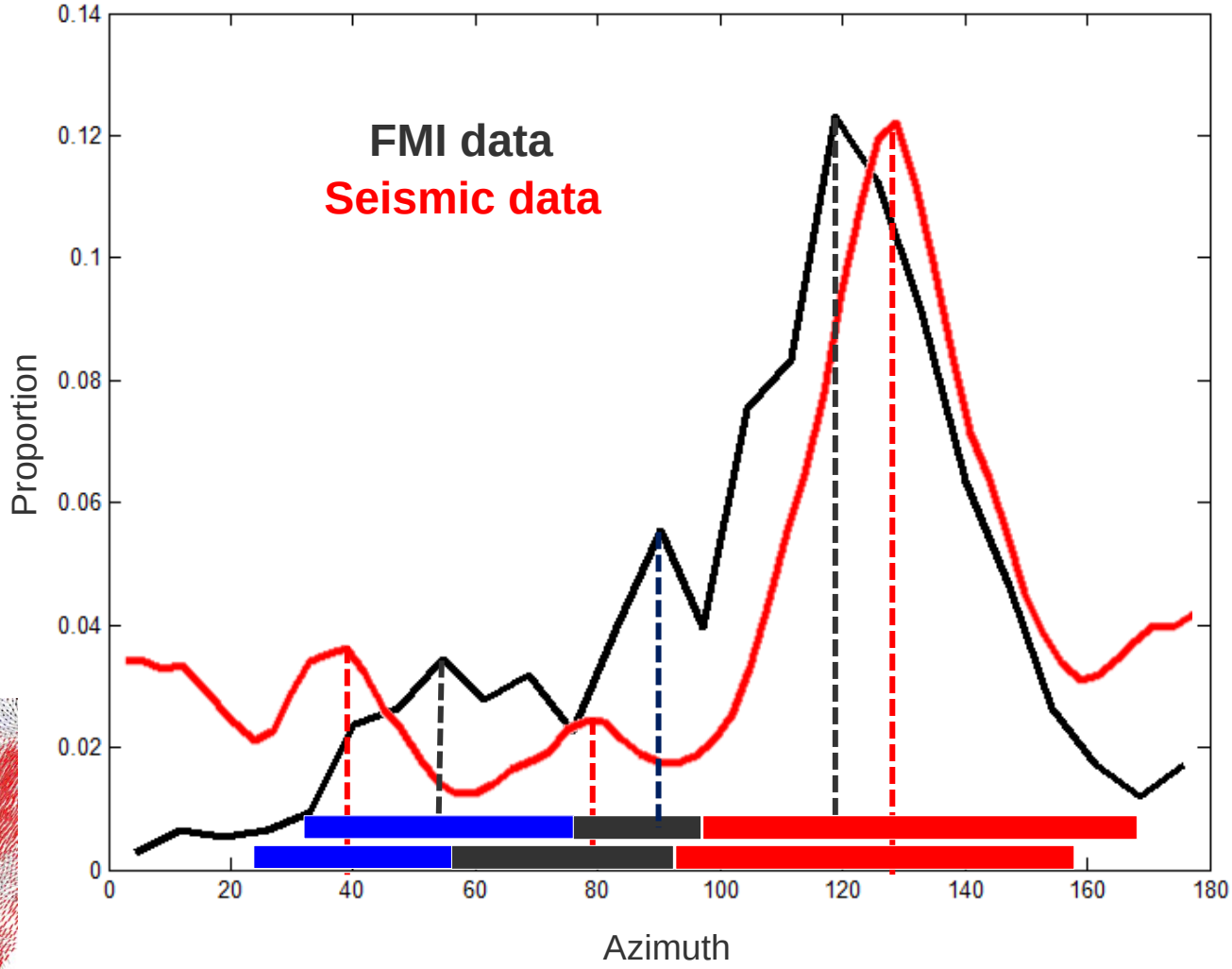
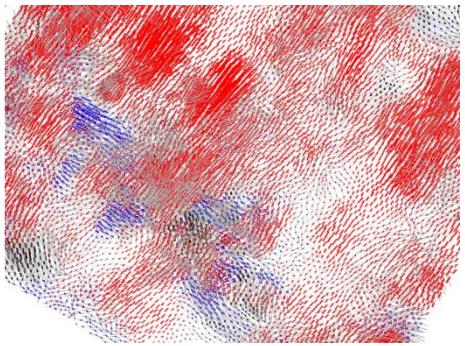
QC of fracture families orientations





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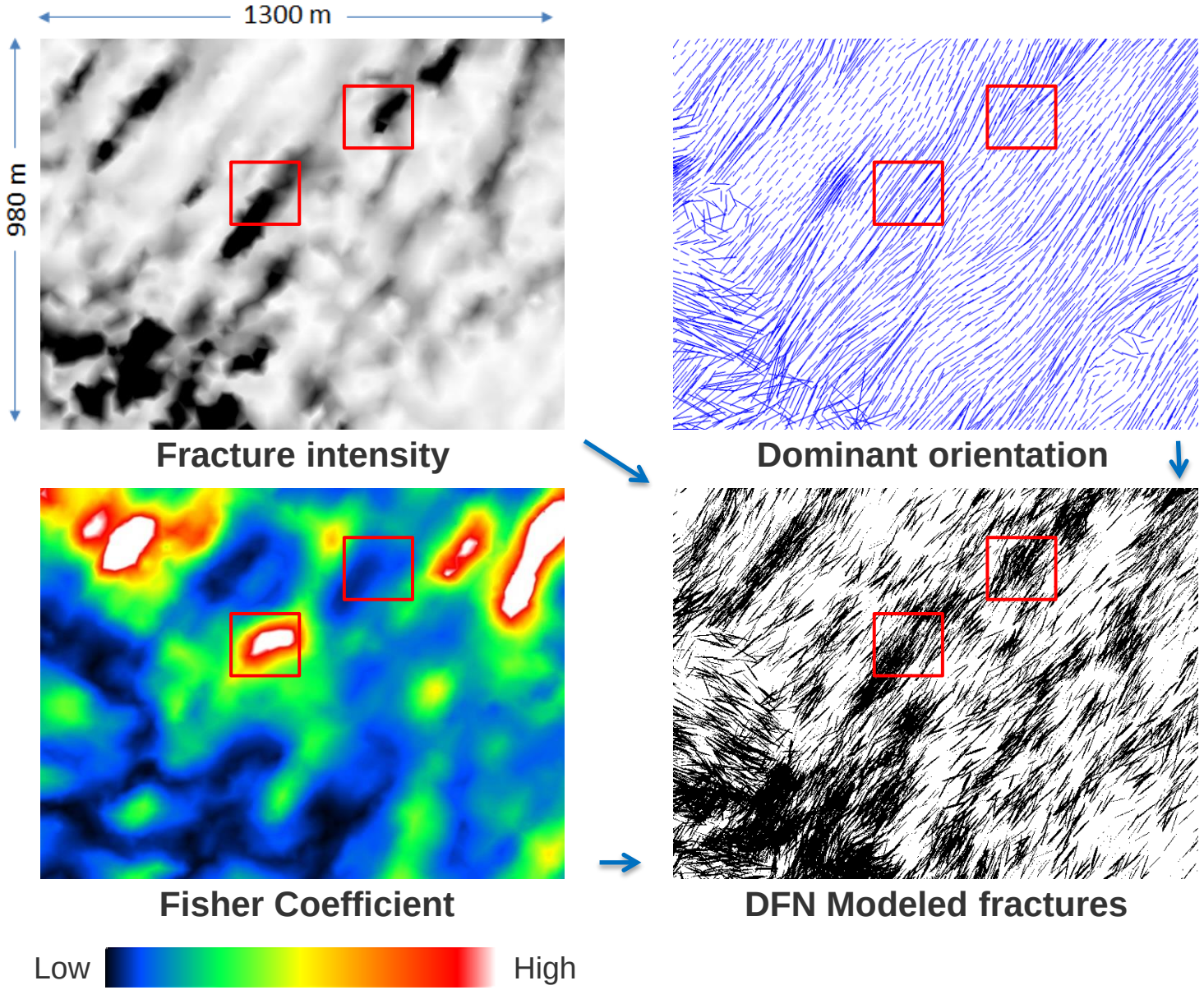
From seismic to DFN



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FLOW SIMULATION MODEL

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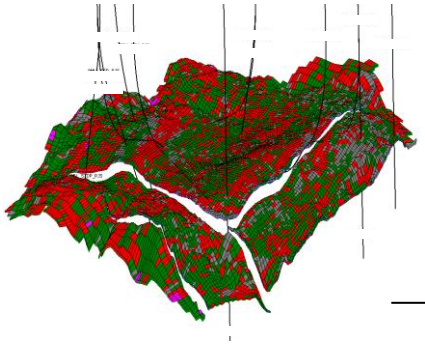
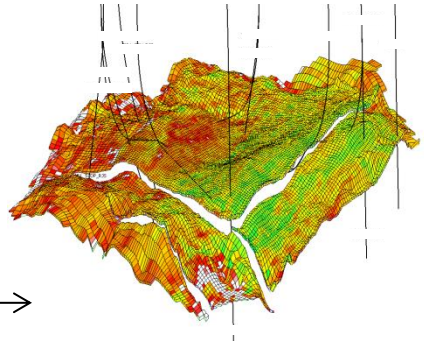
Attributes mapped to flow simulation grid

Matrix properties

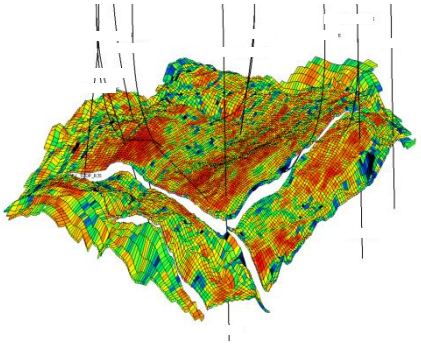
Fracture properties (per family)



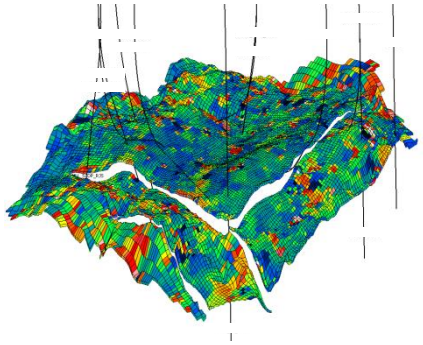
1) Dominant facies*



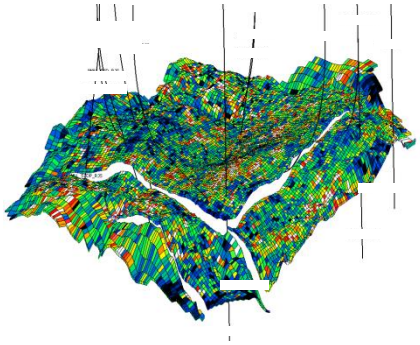
3) Porosity*



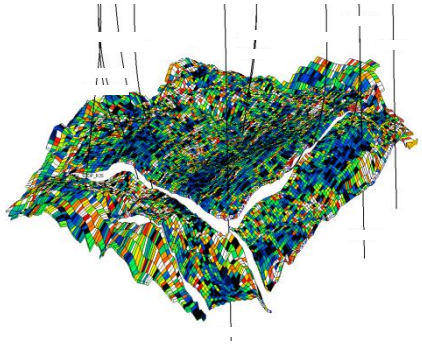
5) Intensity
(~structural attribute)



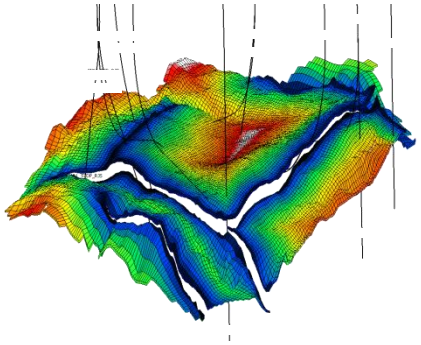
6) Dominant fracture orientation



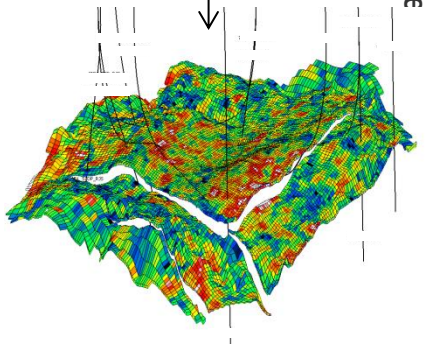
2) Brittleness



4) Permeability*



8) Distance to faults



7) Permeability anisotropy
(~ Fisher coefficient)

* modeled attributes

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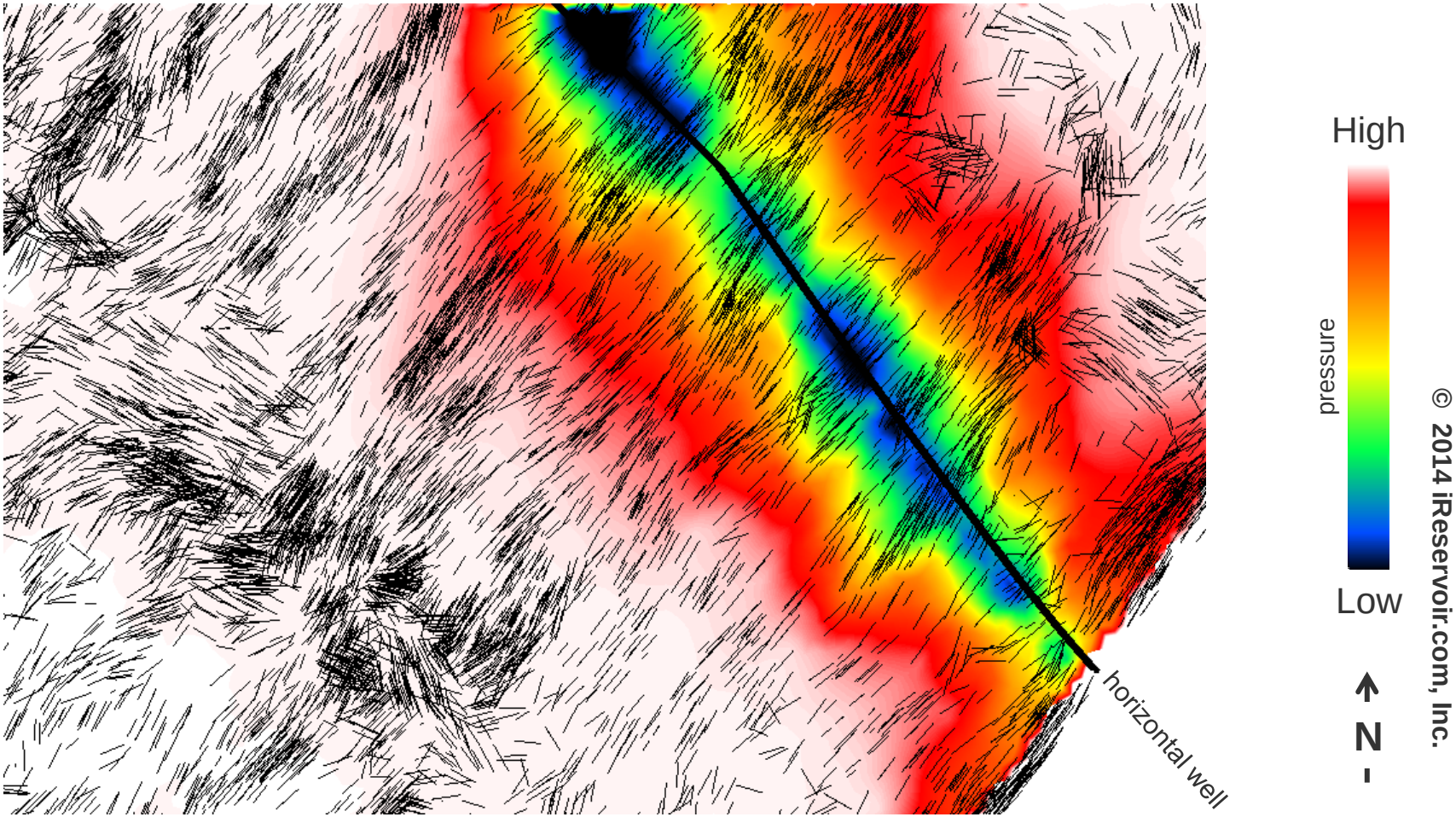
Flow simulation results: pressure field

Segments = DFN fractures



Pressure field after 100 days

Variability in pressure field depends on both matrix and fracture permeability

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From seismic to flow simulation: Who bridges the gap?

- **Geophysicists:**
  - Ultimate responsibility for the correct use of his/her seismic attributes
  - Not sufficient to just generate fancy attributes
  - Responsible for calibrating and mapping attributes to simulation grid.
  - Don't let this work to simulation engineers
- **Engineers:**
  - Iterate with geoscientists if something doesn't work
  - Don't change models in ways that are geologically unreasonable

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Final remarks

- Seismic data can help understanding of both matrix and fracture components critical for efficient development of unconventional reservoirs
- Consistent facies definition is important to enhance seismic detection and map areas more prone to fractures
- Useful fracture properties can be extracted from poststack data and used as a proxy for directionally varying flow properties in the simulator
- Faster flow simulators that can handle these complex, fractured models are more use of microseismic data are the road ahead for iterative calibration of the results

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