The role of natural fractures and reservoir stresses in integrated engineering workflows – constrained frac design and fast marching reservoir simulation for optimal development of unconventional reservoirs – Applications to Permian Basin

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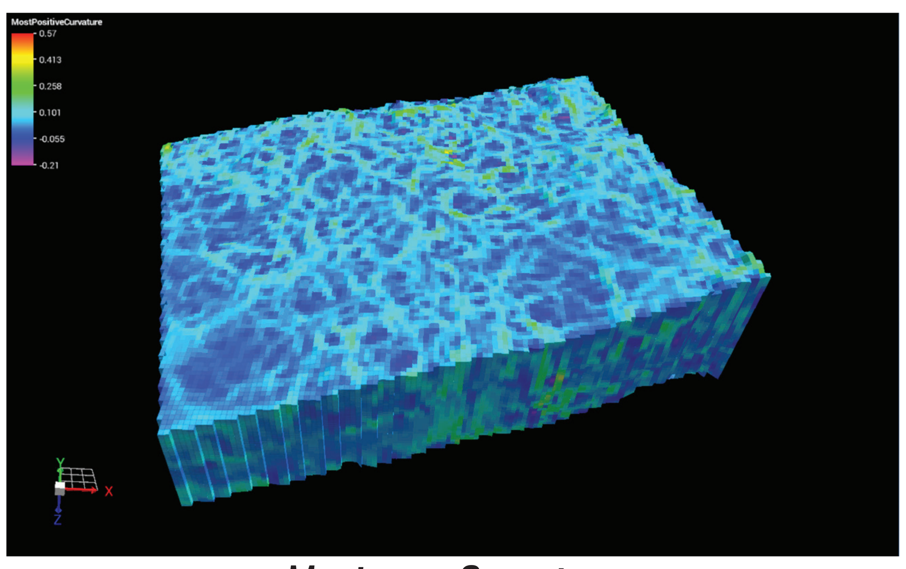
Introduction :

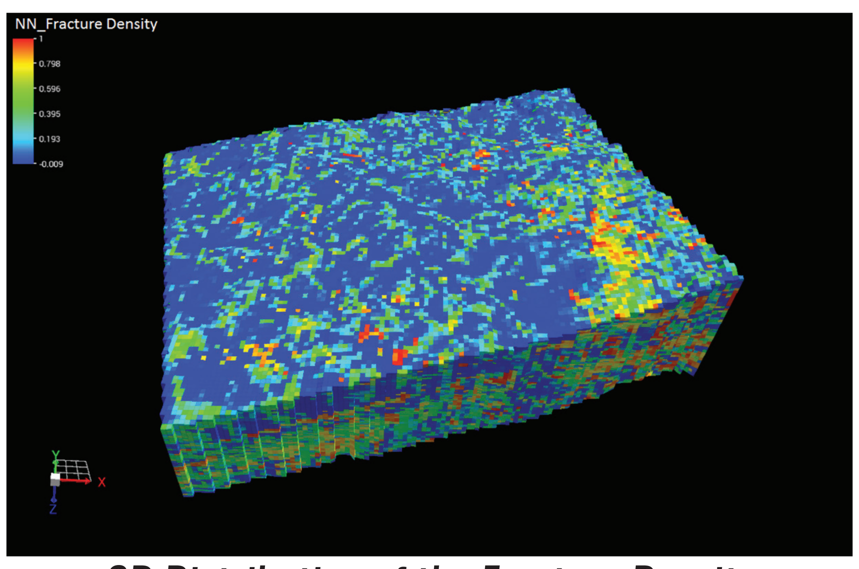
Geophysical attributes could contribute significantly to improving the estimation of the distribution of natural fractures and reservoir stresses when used as input in engineering integrated workflows where other disciplines such as structural geology and continuum mechanics (instead of statistical methods using very poor and biased statistics present in one or two wells) are used to estimate these key reservoir properties. Once these geologic realities are correctly estimated and validated with blind wells and predicted microseismicity they can then be trusted by engineers to be incorporated in their frac design and reservoir simulation tools and to help them better predict the frac geometry, the reservoir depletion and the resulting EUR. This study from the Permian Basin illustrates the reduction in engineering uncertainties when this very fast integrated workflow is used.



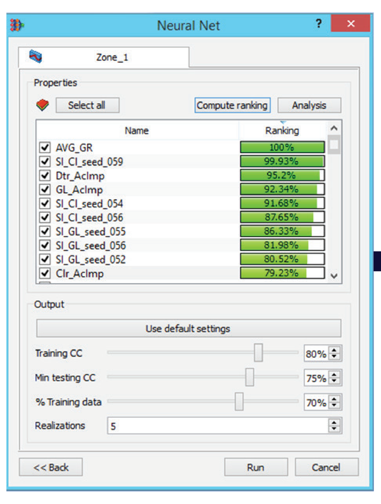
Maximum Curvature

Geological Modeling of Natural Fractures

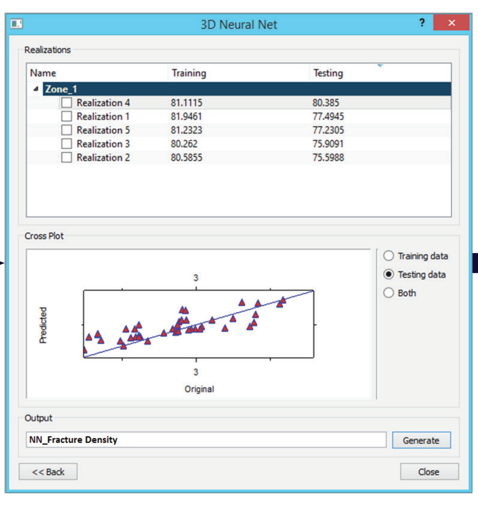
Natural Fracture Models are derived using artificial intelligence (3D Neural Networks) to reconcile geophysical attributes such as curvatures, and petrophysical models with fracture information collected at wells. These models are validated using blind well tests.



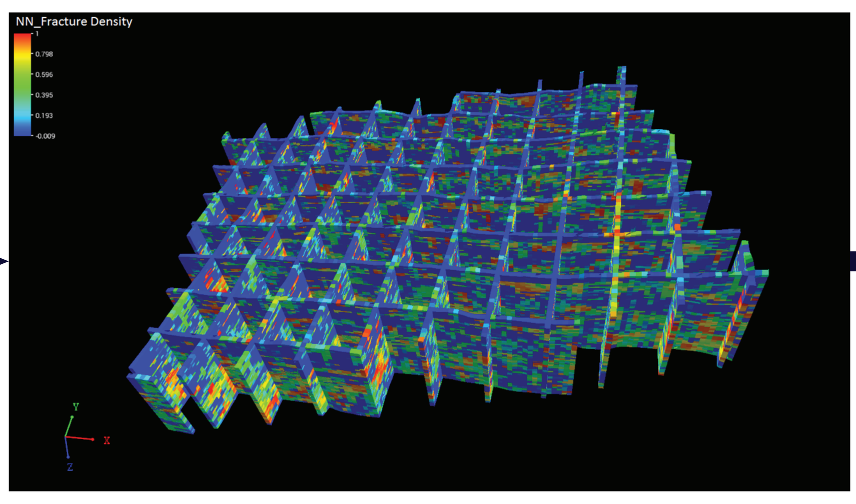
3D Distribution of the Fracture Density



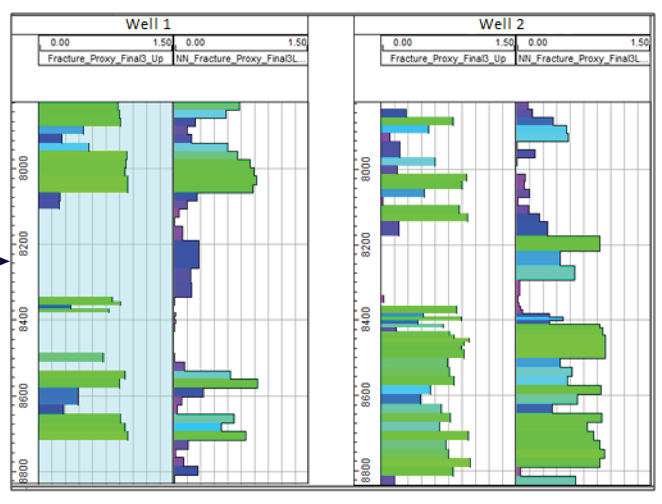
Ranking of the attributes



Neural Networks Modeling



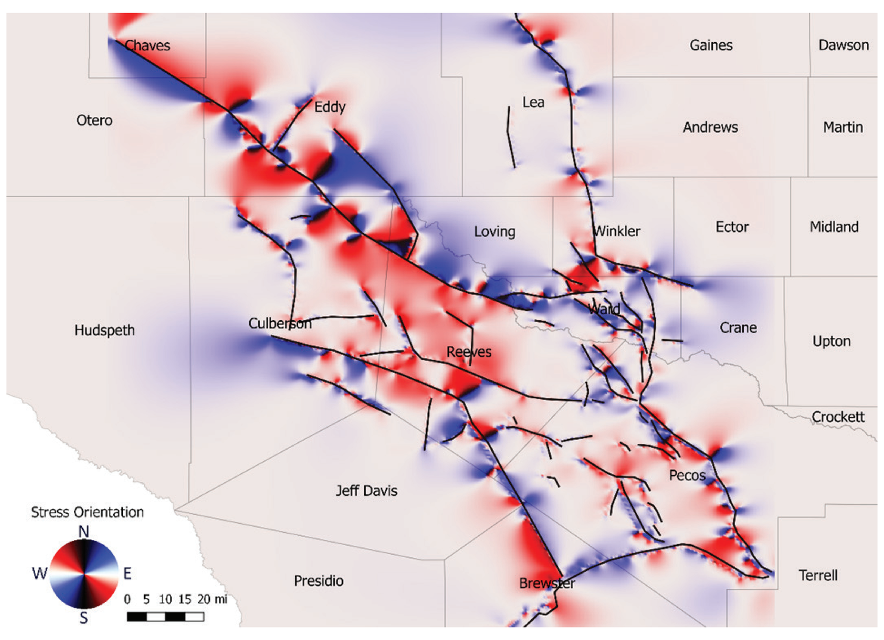
3D Distribution of the Fracture Density (fence diagram)



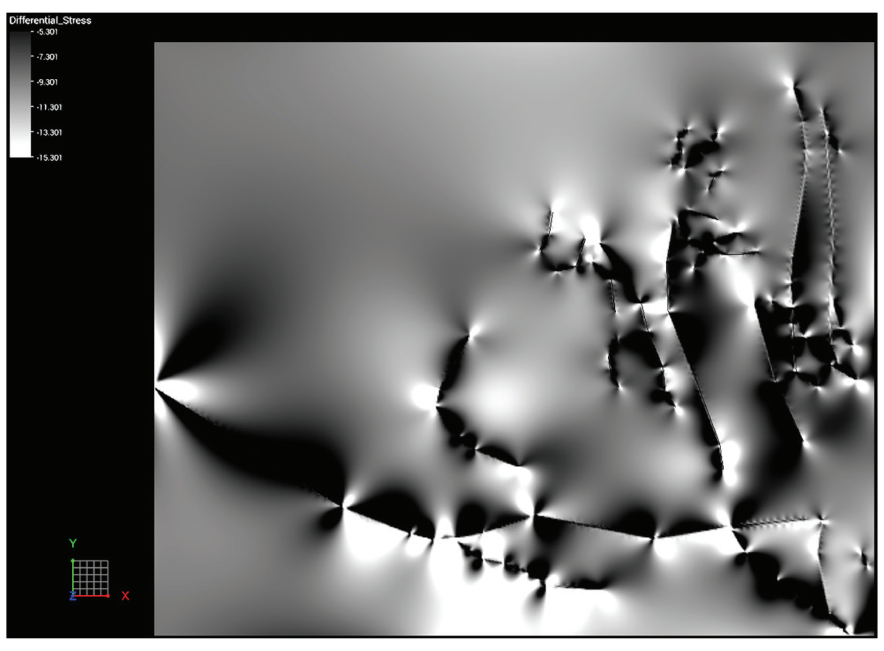
Validation of the fracture density with blind wells

Geomechanics

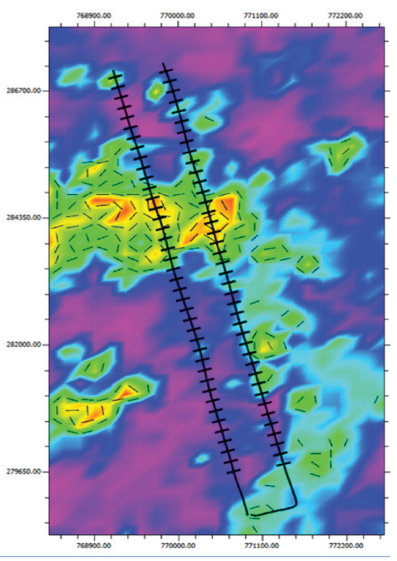
The faults and fractures from G&G modeling efforts are used as input in a continuum mechanics model to capture the interaction of far-field stresses and faults using the Material Point Method (MPM). The first results of this effort are at a gross scale which captures maximum horizontal stress orientations variability, and differential stresses in the field. These help to understand the direction of hydraulic fracture propagation (and optimal well trajectory) and also the expected complexity of the hydraulic fracture stimulation. These results are used as the input in a modeling workflow to account for the interaction between hydraulic fractures and natural fractures using MPM to better understand SRV development when fracing one or multiple wells in a pad. This is captured by creating an envelope around the strained rock in the reservoir. This envelope will be used as a proxy for lateral stress gradients and will constrain the frac design.



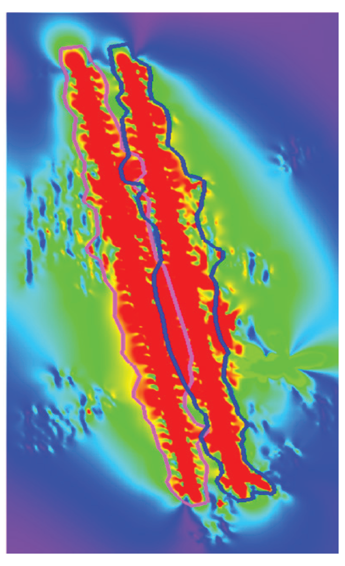
GMX Predictor MPM simulation of Stress orientation -Grisham Fault, Delaware Basin



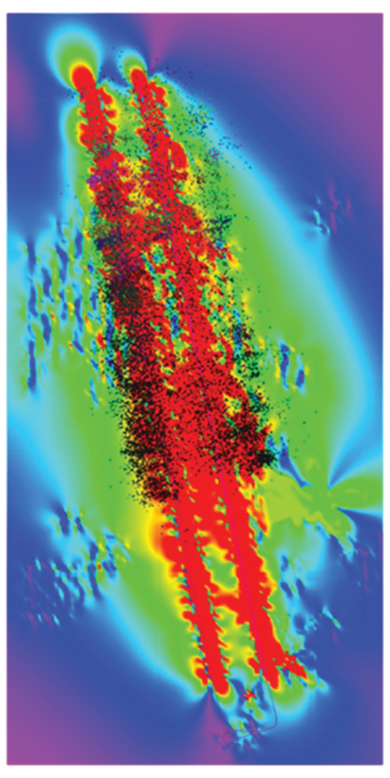
GMX Predictor MPM simulation of the Differential Stress -Grisham Fault, Delaware Basin



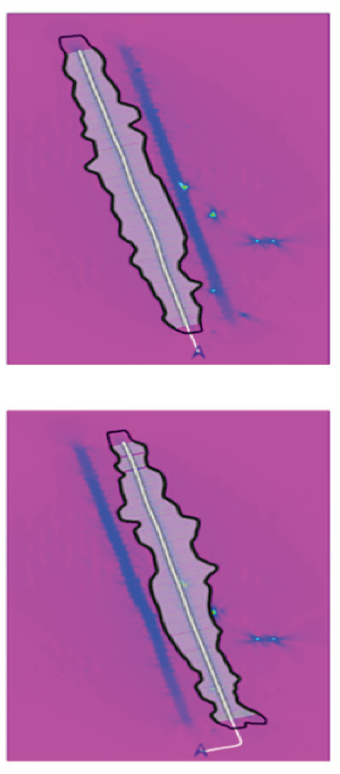
Equivalent Fracture Model



Strain resulting from fracing of the wells



Comparison of strain to microseismic

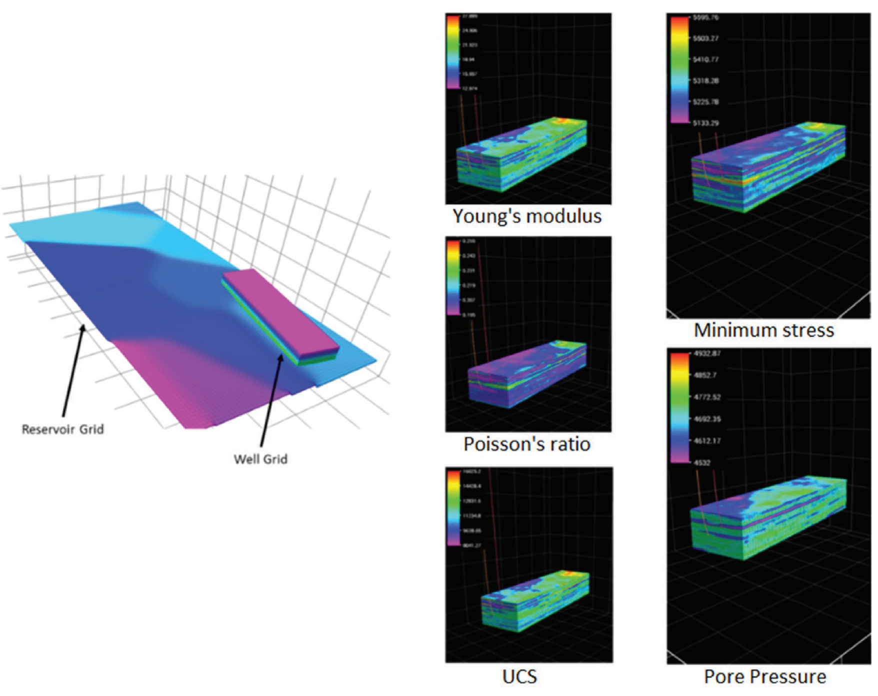


Strain envelope

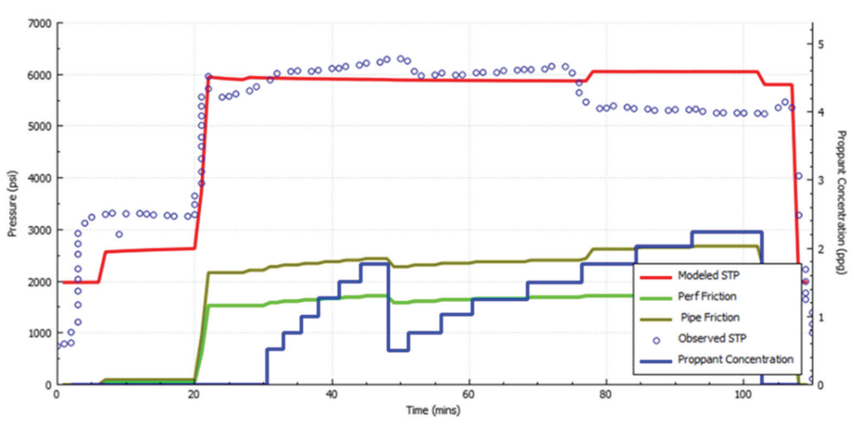
Frac design and reservoir simulation

The frac design takes the lateral stress gradients from the geomechanical simulation and couples the envelope derived from the strain map with a 3D distribution of rock properties derived using 3D neural networks (Young's modulus, Poisson's ratio, unconfined compressive strength, minimum stress, pore pressure) to compute the propped volumes achieved in the fracing using all available G&G and geomechanical information.

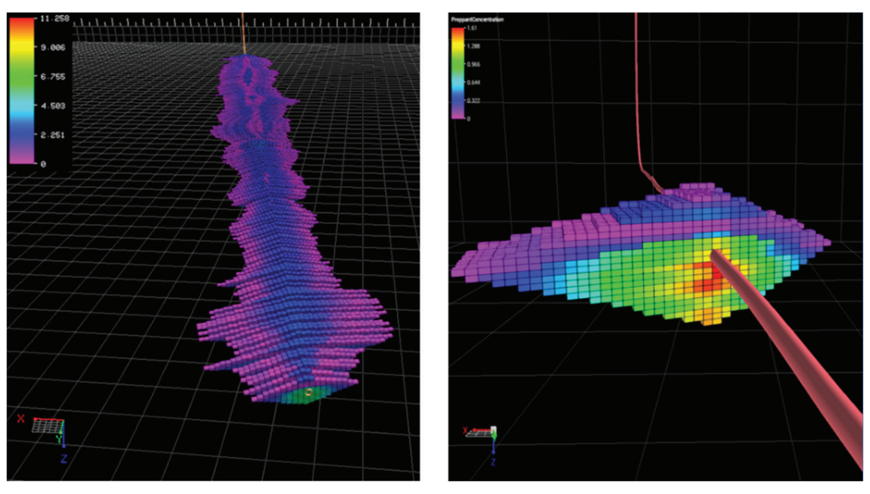
The net pressure and the ISIP are history-matched to calibrate the frac model. These conductivities are fed seamlessly to the Fast marching method simulator to provide depletions around the wellbore and estimate the impact of the interference between wells in only a few minutes.



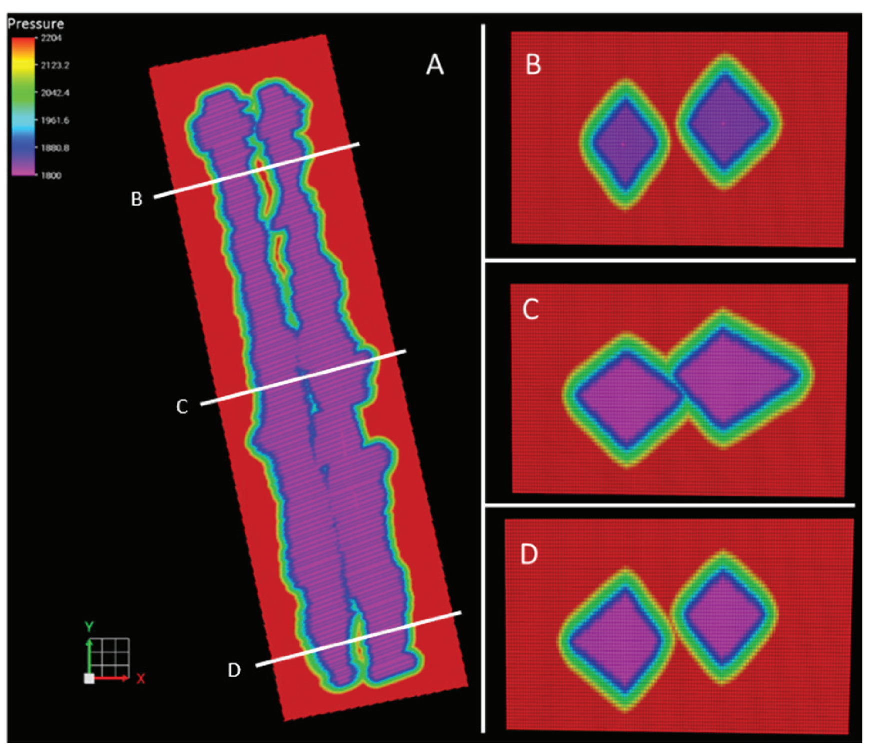
3D rock properties used for frac design



Net pressure matching



Fracture conductivity



Pressure depletion (areal view and cross sections)

Conclusion:

The workflow presented here details effective methods to combing G&G information and through the use of geomechanics it translates the effects of the reservoir properties on fracing to be used by engineers. By doing this all on a single platform, multitudes of well plans are quickly iterated and can quickly be investigated to arrive at the highest NPV achievable for a planned well.

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