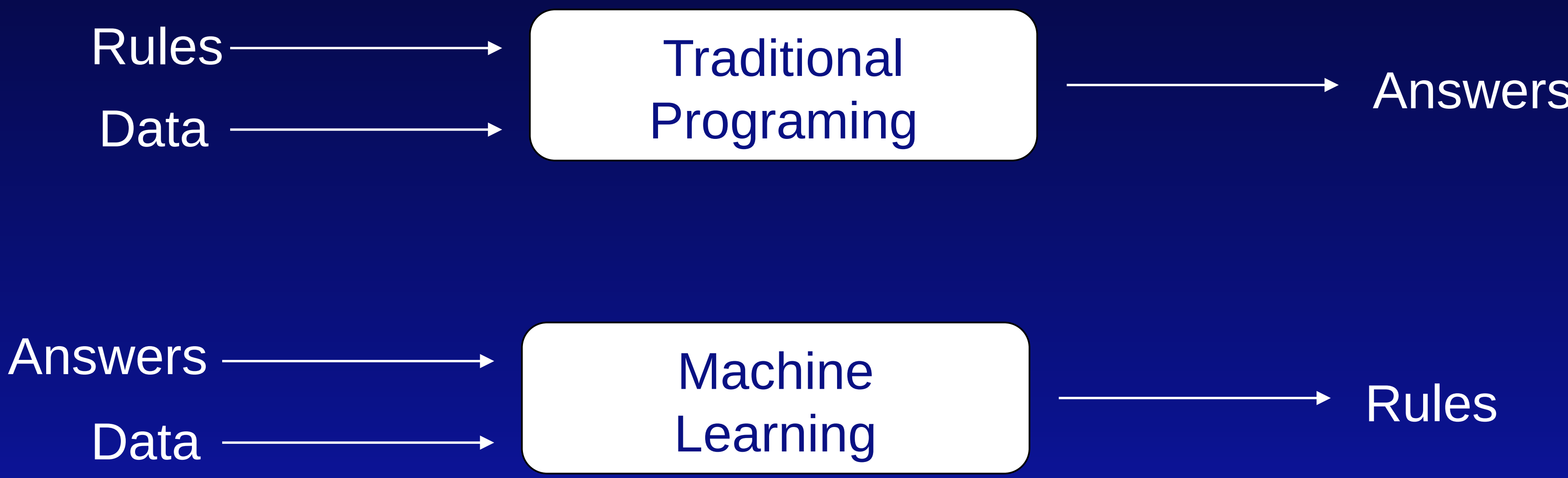
Diagnostic Fracture Injection Tests

Mohamed Ibrahim Mohamed

Phase I: Application of Machine Learning and Big Data

Machine Learning

- Machine Learning is a subset of AI that focuses on learning rules from data.



Machine Learning

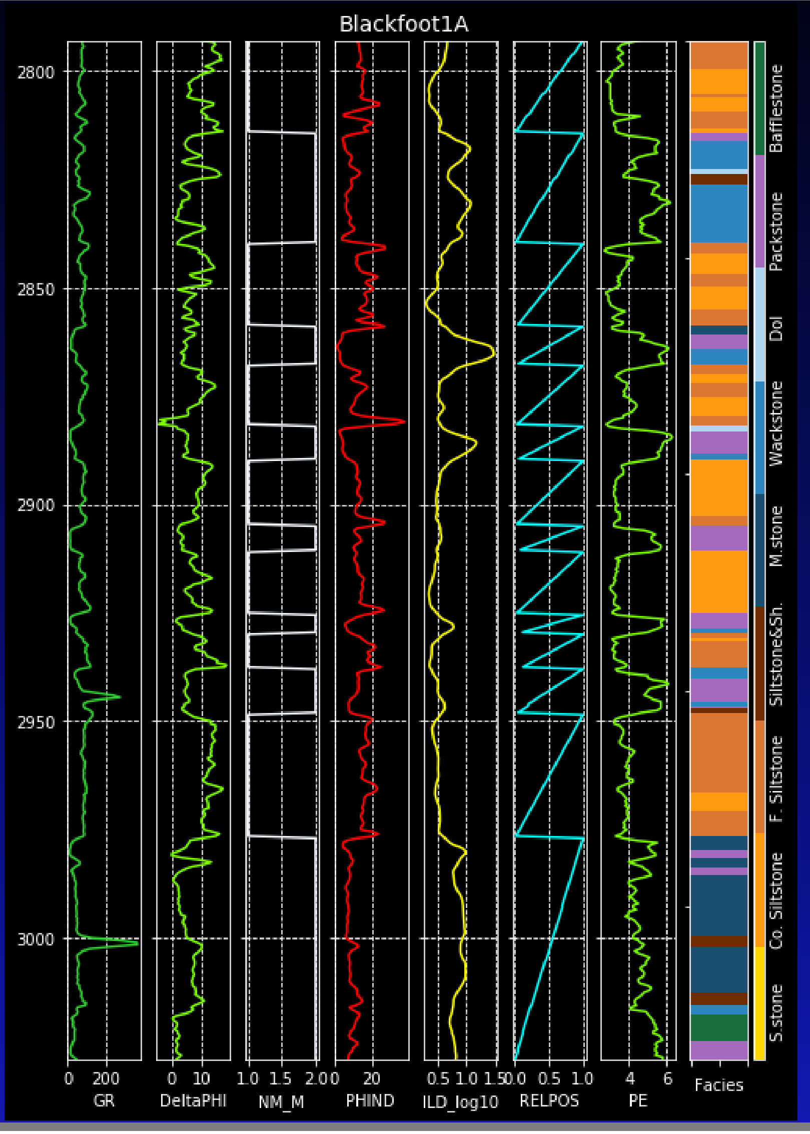
- Type of machine learning:
  - Supervised:
    - Predicting outputs based on inputs
    - Ex: Regression and Classification
  - Unsupervised:
    - Reveal hidden structure in the data.
    - Ex: Clustering

Well Logging Machine Learning Example

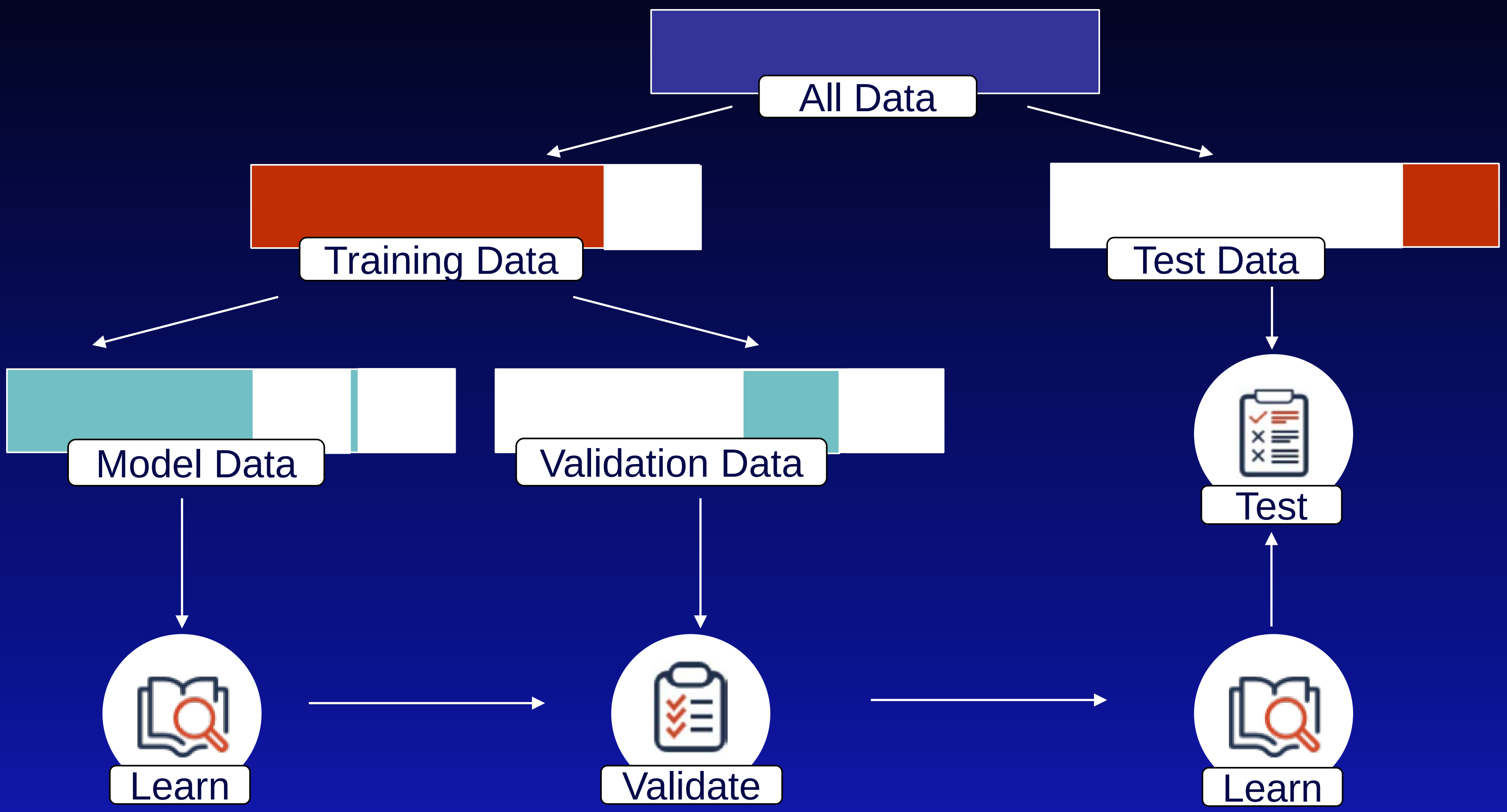
- Data set
  - Carbonate gas reservoir
  - Eight wells
  - Seven logs predictor variables
    - GR, Resistivity, PE, Neutron density porosity, average Neutron density porosity.
    - Non-marine indicator and relative position

Well Logging Machine Learning Example

- Nine discrete rock facies:
  - Sandstone
  - Coarse siltstone
  - Fine siltstone
  - Siltstone and shale
  - Mudstone
  - Wakestone
  - Dolomite
  - Packstone
  - Bafflestone

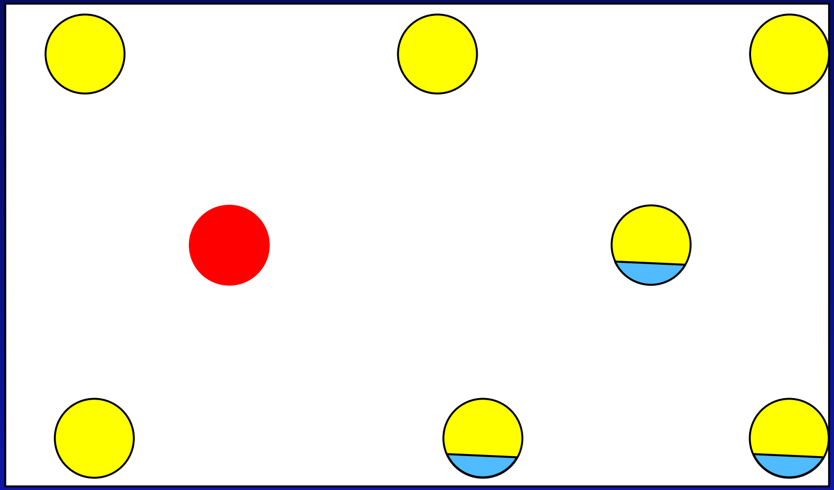


Well Logging Machine Learning Example



Well Logging Machine Learning Example

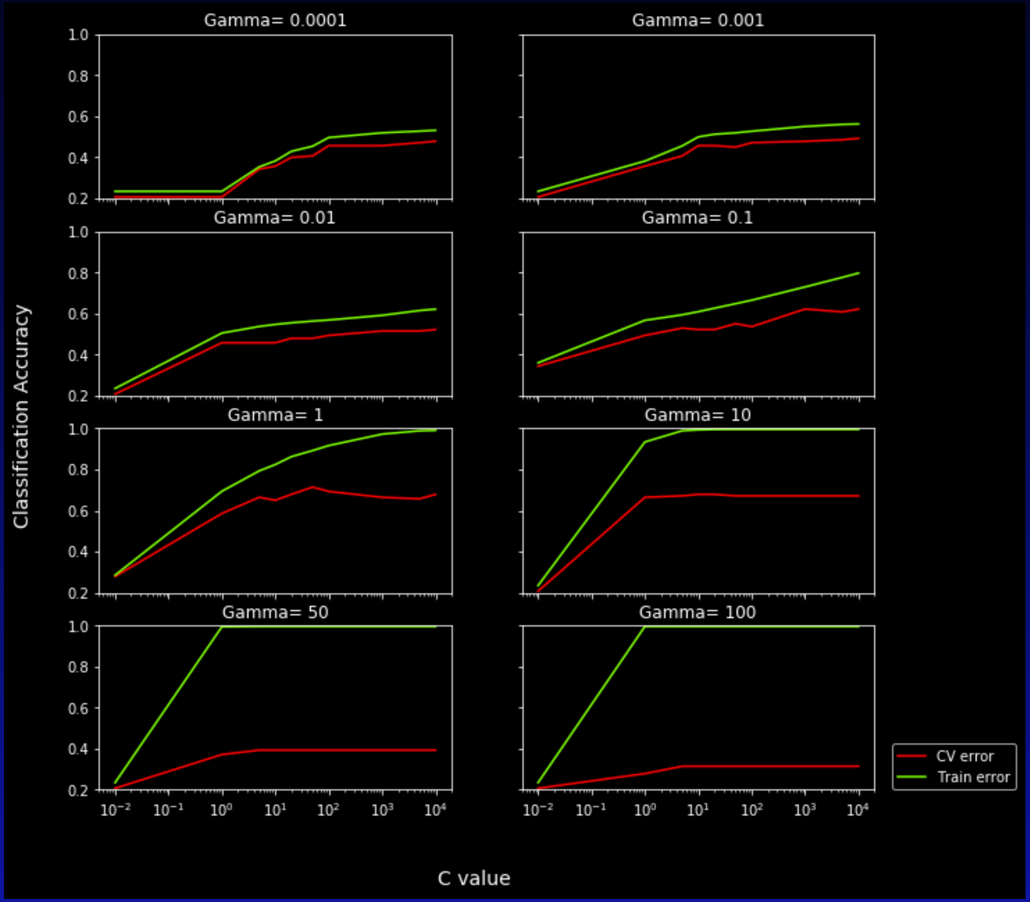
- Seven training wells
  - Total points: 3232
  - 20% test set
- One blind test well
- Extract feature variables
  - GR, Resistivity, PE,
    Neutron density porosity,
    average Neutron density porosity.



Well Logging project Example

- Models used:
- Support Vector Machines
  - Model Parameter Selection
    - Gamma = 50, and C = 50

	Precision	Recall	F1-score	Support
1	1	0.75	0.86	16
2	0.79	0.93	0.86	29
3	0.77	0.71	0.74	14
4	0.43	0.43	0.43	7
5	0.67	0.44	0.53	18
6	0.62	0.7	0.65	23
7	1	0.33	0.5	3
8	0.59	0.7	0.64	23
9	0.88	1	0.93	7
avg / total	0.73	0.71	0.71	140

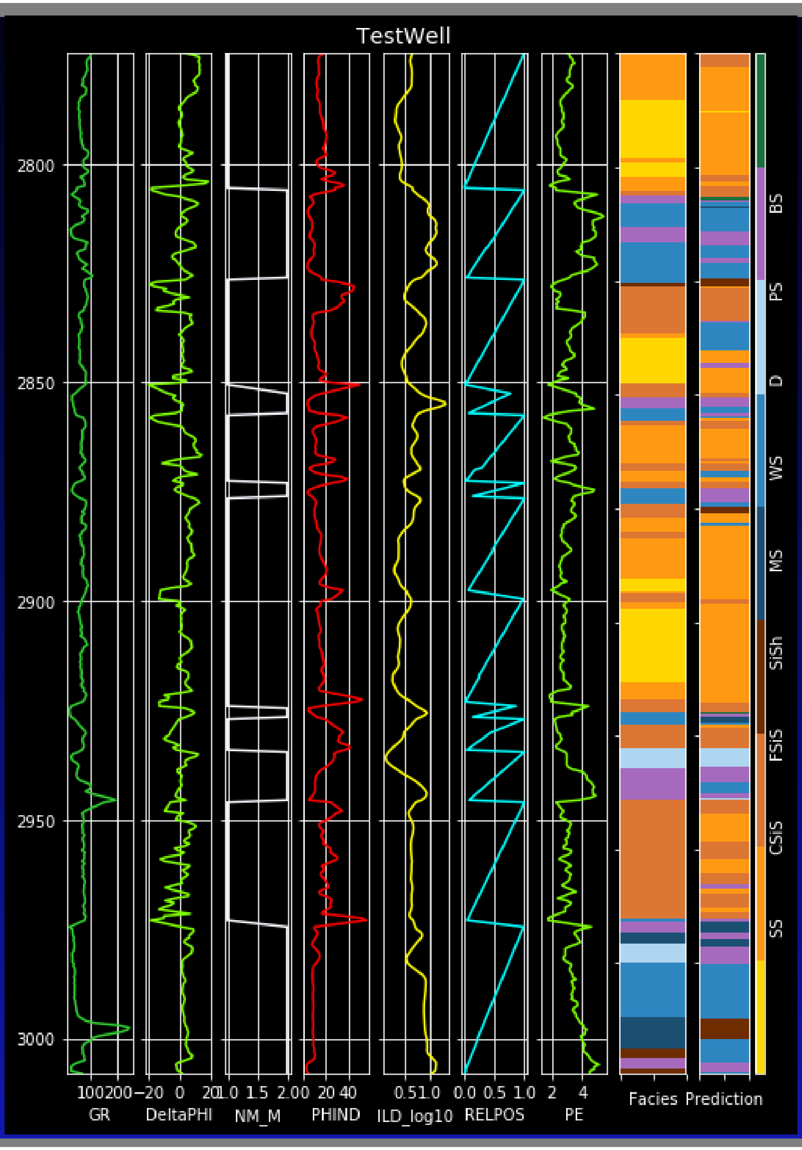


Well Logging project Example

- Models used:
- K nearest Neighbor
  - `F1-Score: 0.43`
- Random Forrest Classifier
  - `F1-Score: 0.43`

Well Logging project Example

- Applying the classification model to the blind data
- Now that we have a trained facies classification model we can use it to identify facies in wells that do not have core data.

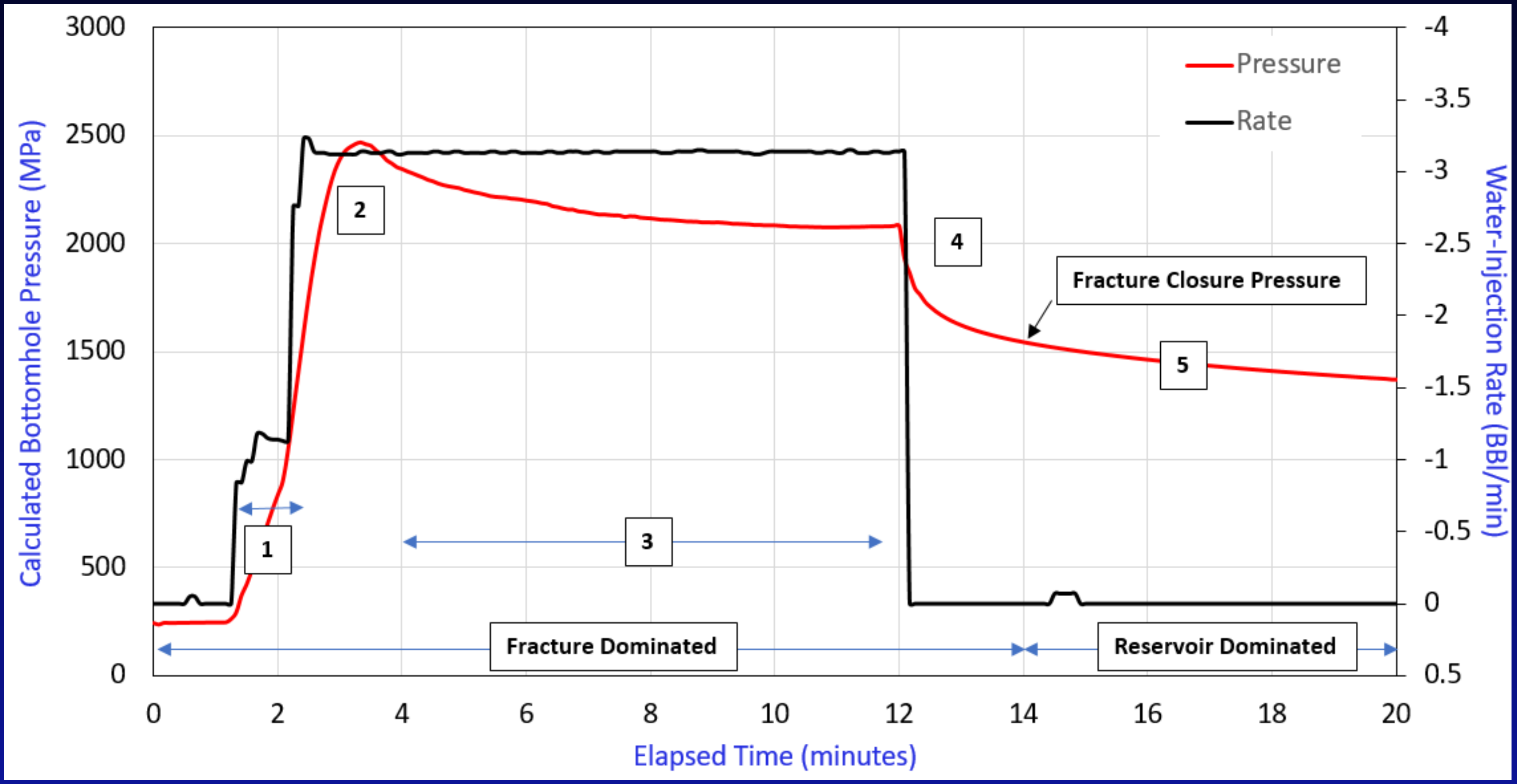


Diagnostic Fracture Injection Tests

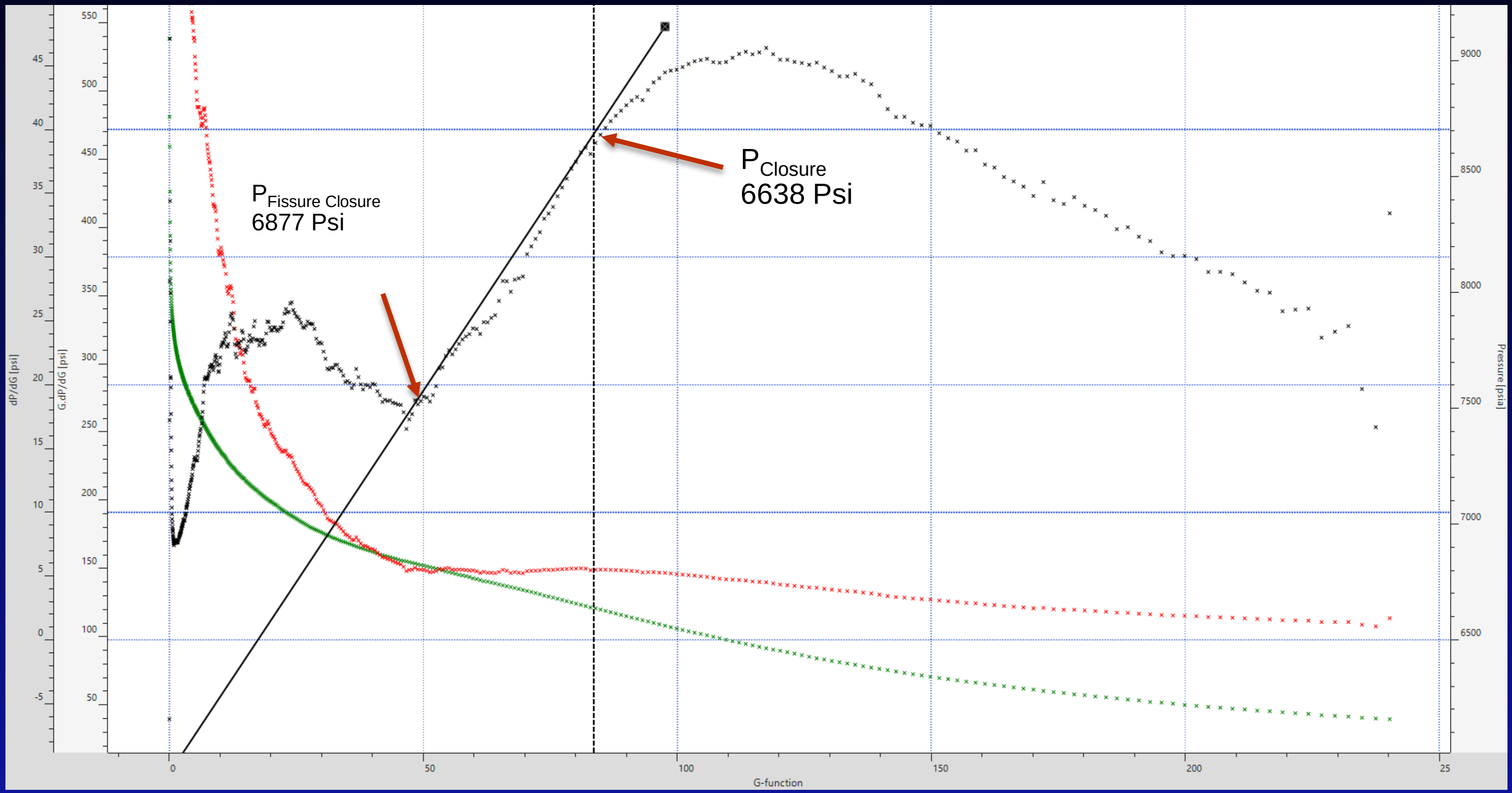
- A short injection/falloff diagnostic test performed without proppant before a main fracture stimulation treatment

- The intent is to break down the formation to create a short fracture during the injection period, and then to observe closure of the fracture system during the falloff period.

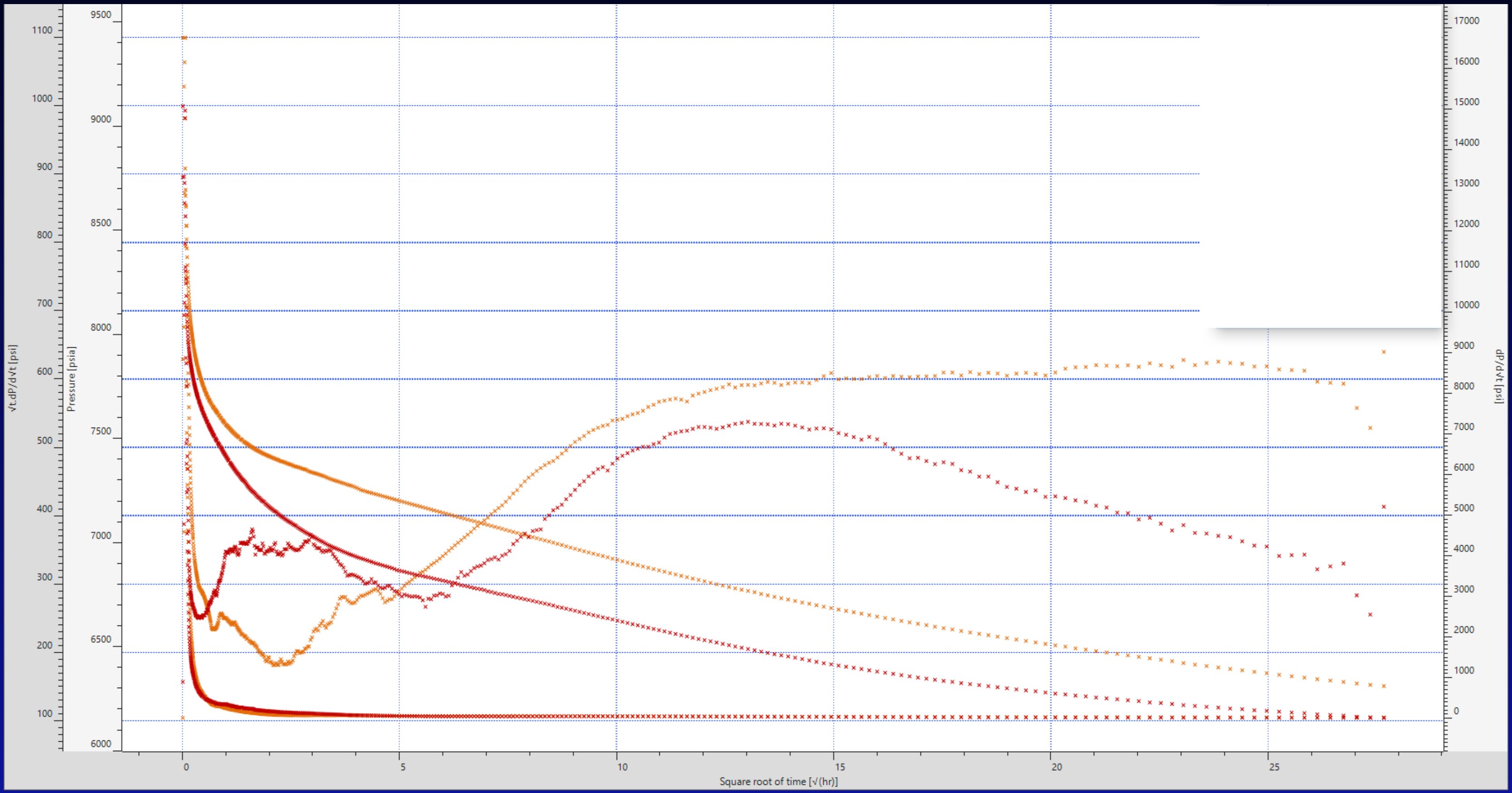
Diagnostic Fracture Injection Tests



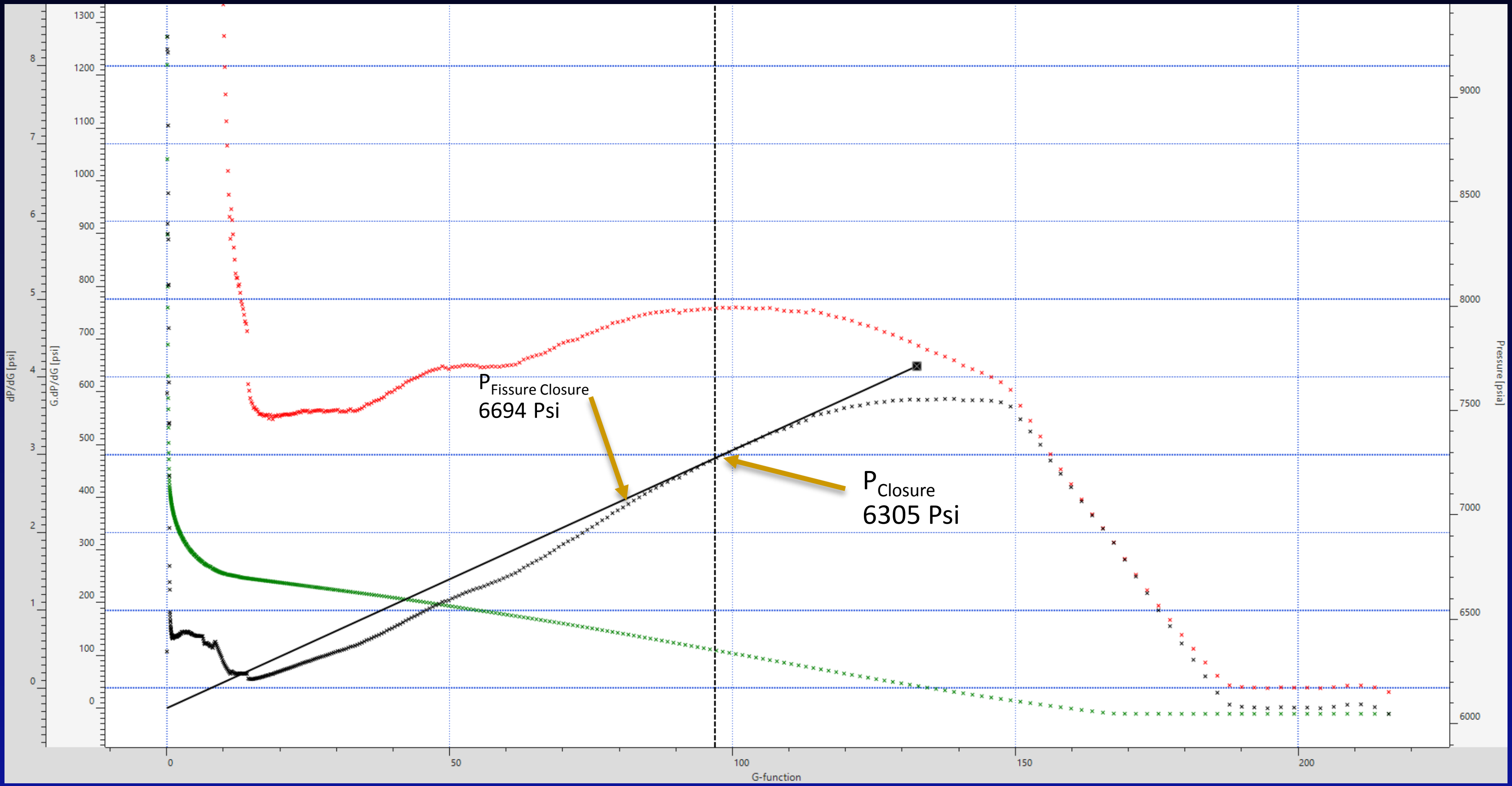
Diagnostic Fracture Injection Tests: Problem Statement



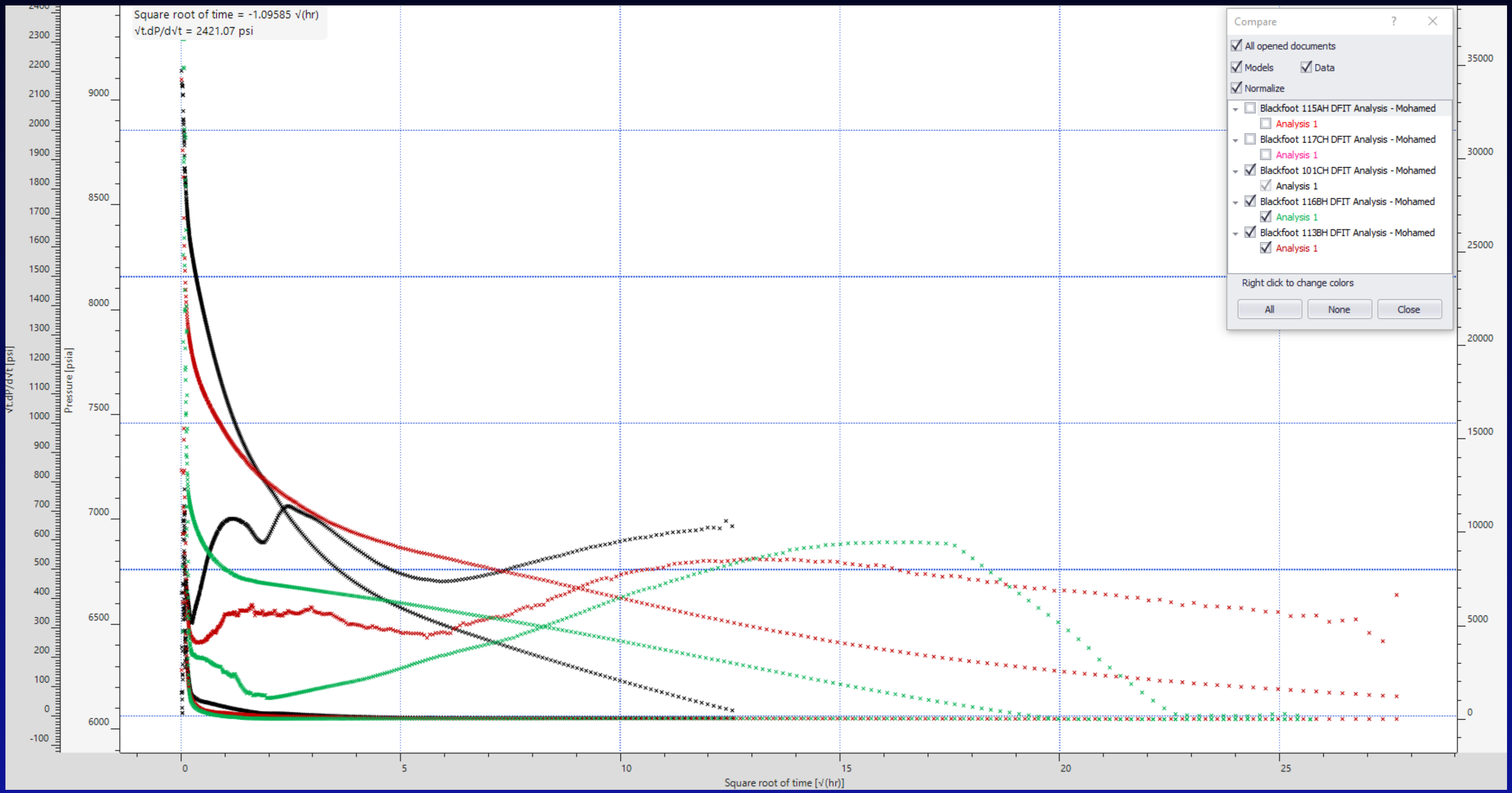
Diagnostic Fracture Injection Tests: Problem Statement



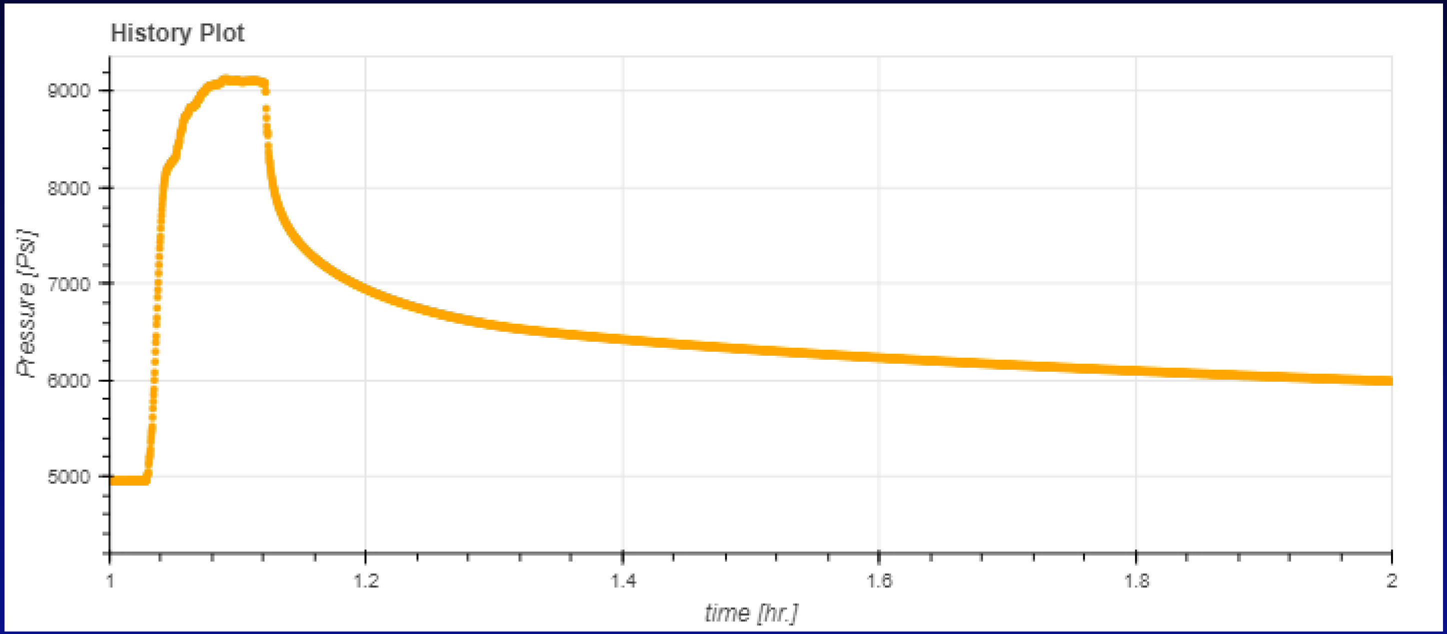
Diagnostic Fracture Injection Tests: Problem Statement



Diagnostic Fracture Injection Tests: Problem Statement



Diagnostic Fracture Injection Tests: Problem Statement



Diagnostic Fracture Injection Tests: ML Approach

Attributes/Features
Bulk Modulus
Poisson Ratio
Tensile stress
Formation height
Leak-off Coefficient
Matrix Permeability
Perf. Diameter
Perf. No.
Duration of Injection
Others??

+ Pressure Fall-off time series → Predictive model

Answers →
Data →
Machine Learning → Rules

Diagnostic Fracture Injection Tests: ML Approach

- Current Data
  - 7 wells
  - 3.5 millions rows of attributes
- SQL Database
  - Easy access for data
  - Robust mathematical operations
- Because it's a ML approach, the more data we get, the more certain we are. And the lower the uncertainty, the more we trust our model.

Attributes
Bulk Modulus
Poisson Ratio
Tensile stress
Formation height
Leak-off Coefficient
Matrix Permeability
Perf. Diameter
Perf. No.
Duration of Injection

+

Falloff points

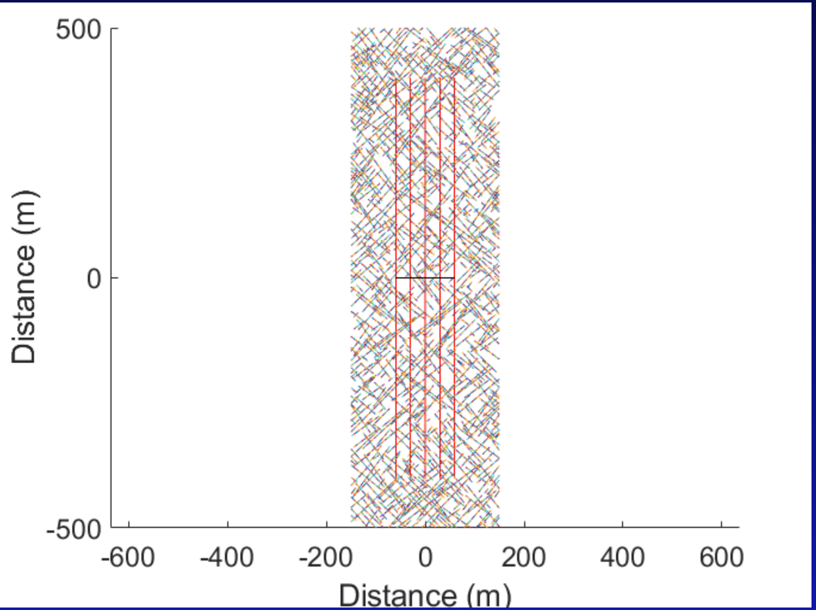
Phase II: Computational Modeling of Diagnostic Fracture Injection Tests in Discrete Complex Fracture Network.

Diagnostic Fracture Injection Tests

- Objective
  - Develop a DFIT simulator to match and predict the pressure falloff after shut in.
  - Focus on the potential effect of fracture network complexity for DFIT.
  - Long term production forecasting.

Diagnostic Fracture Injection Tests

- Model description
  - Couples the fluid flow with stress induced by fracture deformation in complex 2D discrete fracture network.
  - Single phase
  - Isothermal
  - Model involves:
    - ➢Opening & propagation of new fracture
    - ➢Sliding of preexisting fracturing
    - ➢Combination of both
    - ➢Fracture closure



Diagnostic Fracture Injection Tests

- Numerical methods to calculate stresses:

  As the size and complexity of the fracture network increases, the challenge of geomechnical discrete fracture modeling grows considerably.

  - Infinite element method
  - Finite difference
    - Require discretization of the area (2D) around the fractures. Lead to a very large number of elements for complex networks.
  - Boundary element
    - Avoid the need to discretize around fractures. Require solution of dense matrices.
  - Extended finite Element Method:
    - Powerful technique for hydraulic fracturing modeling. New and have not been demonstrated on complex modeling.
  - Others ?

Diagnostic Fracture Injection Tests

- Rules:
  - Fluid-flow equations
  - Stress Calculations
  - Generating DFN

Rules → Traditional Programing → Answers
Data →

Diagnostic Fracture Injection Tests

- Rules:
  - Fluid-flow equations
    - Unsteady-state fluid mass balance equation in fracture (Aziz and Settari 1979)

$$\frac{\partial(\rho E)}{\partial t} = \nabla.\left(q_{flux} e\right) - q_{leakoff} + S_a$$

$$q_{flux} = \frac{k\rho}{\mu}\frac{\partial P}{\partial x_i}$$

$$T = ke = \frac{e^3}{12}$$

Diagnostic Fracture Injection Tests

- Rules:
  - Apertures calculations
    - Closed-fracture elements (Willis-Richards et al. 1996)

$$E = \frac{E_0}{1 + 9\frac{\sigma'_n}{\sigma_{n,Eref}}}$$

    - Hydraulic aperture

$$e = \frac{e_0}{1 + 9\frac{\sigma'_n}{\sigma_{n,eref}}} + D_{eff}\tan\left(\frac{\varphi_{edil}}{1 + 9\frac{\sigma'_n}{\sigma_{n,eref}}}\right)$$

    - Open fracture elements

$$E = E_0 + E_{open}$$
$$Ee = e_0 + D_{eff}\tan(\varphi_{edil}) + E_{open}$$

Diagnostic Fracture Injection Tests

- Rules:
  - Stress calculations

At each element the stress is specified by three components: σ_n , τ_s and τ_d

Effective normal stress must be equal to zero

$$\sigma_n^r - P + \Delta\sigma_n = 0$$

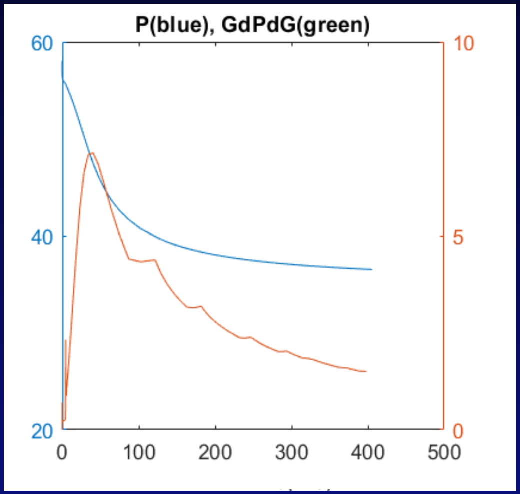
Diagnostic Fracture Injection Tests

- Data:
  - Bulk modulus
  - Poisson ratio
  - Height
  - Perf. Diameter
  - Duration of injection
  - Leak-off coefficient
  - Tensile stress
  - Fluid viscosity
  - Matrix perm
  - Perf. No
  - Injection Schedule

Rules →
Data →
Traditional Programing
→ Answers

Diagnostic Fracture Injection Tests

- Answers/Output:
  - Pressure Fall-off time series
  - G-function Plot



Rules → Traditional Programing → Answers

Data →

Phase III: Model Check

THANKS

Questions ?