Fracture Network Quantification for Enhanced Reservoir Characterization in CO_2 Storage Sites

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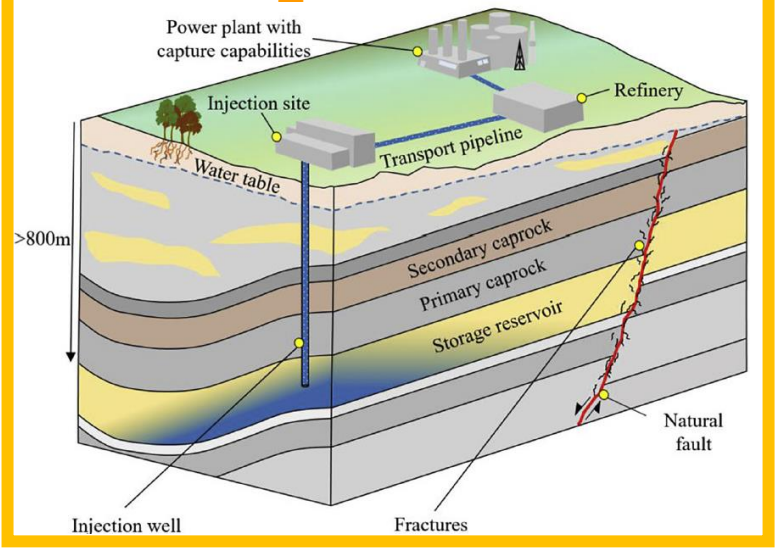
Critical Role of Fracture Network Quantification

Fracture Network Mapping for Energy System Operation/Control

SPE 214996

CO_2 storage

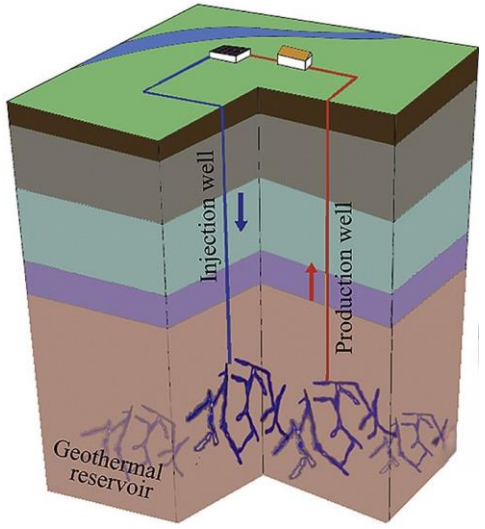


https://doi.org/10.1016/j.earscirev.2020.103390

- Assessing containment of injected CO_2
- Mitigating fluid migration risk
- Optimizing injection strategy

http://dx.doi.org/10.2139/ssrn.5071255

Geothermal

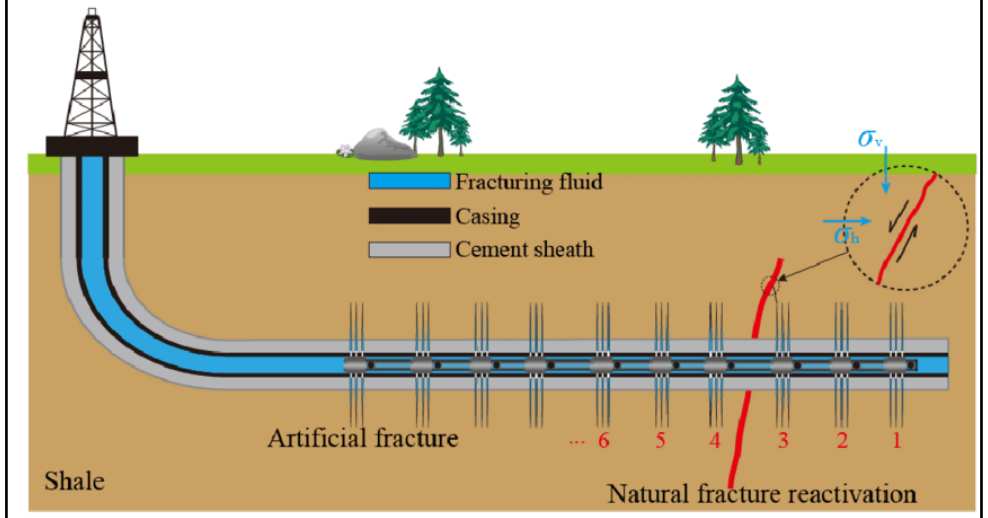


https://doi.org/10.1016/j.renene.2020.06.143

- Identification of permeable pathways
- Optimize fluid sweeping
- Optimal well placement

URTEC-3723466-MS

Hydraulic fracturing

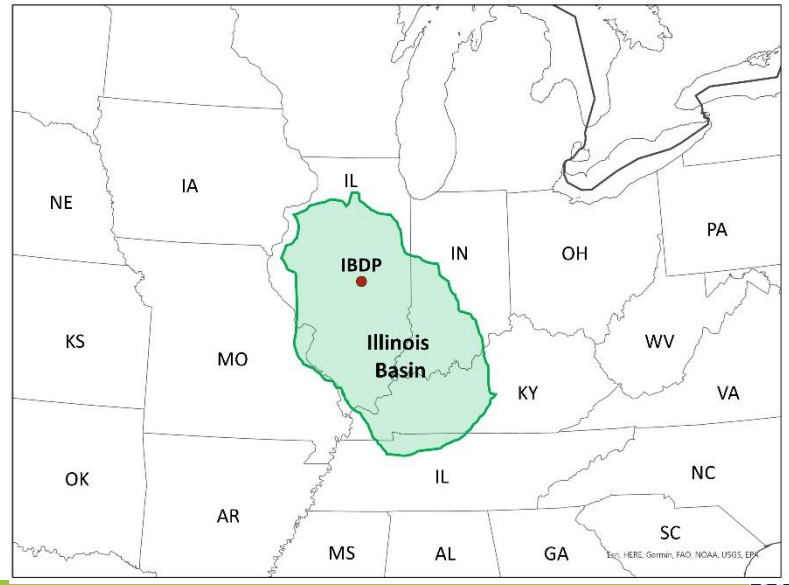


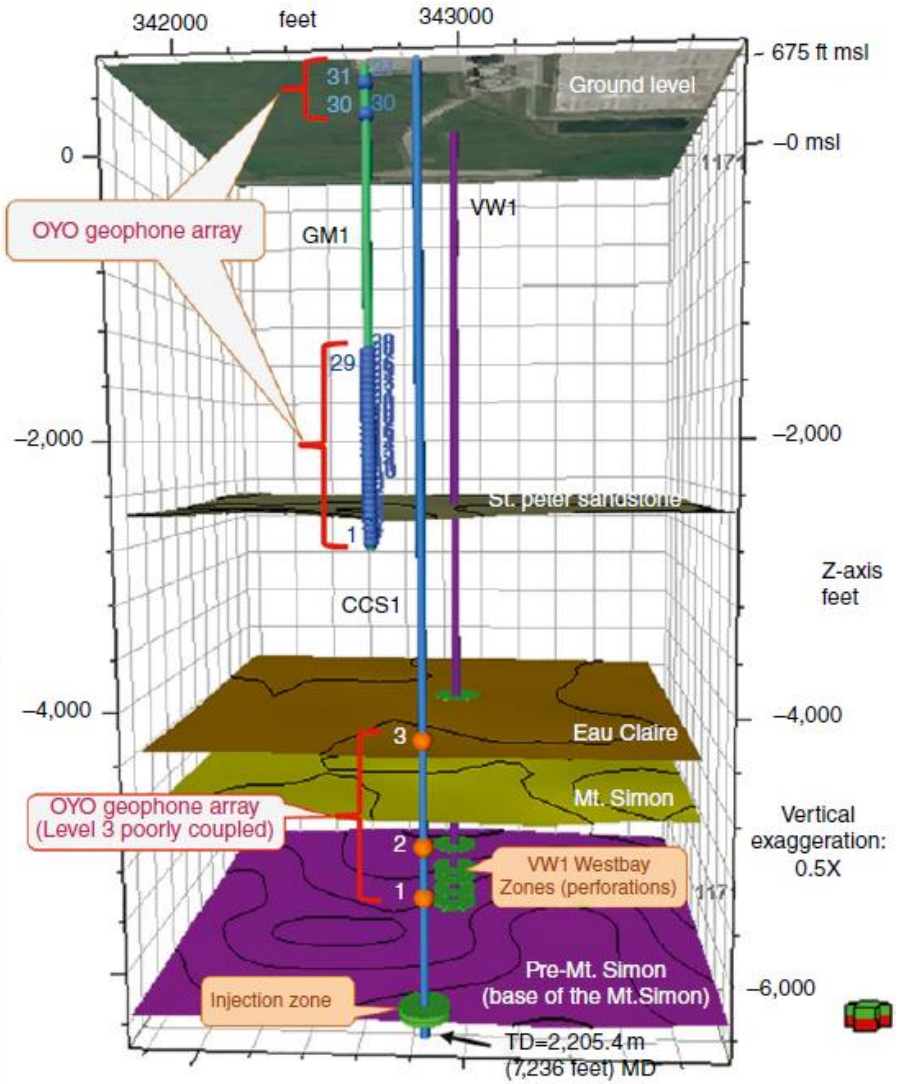
https://doi.org/10.1088/1755-1315/570/2/022011

- Optimal designing of treatment strategy
- Maximizing hydrocarbon recovery
- Minimizing environmental contamination

Road Map

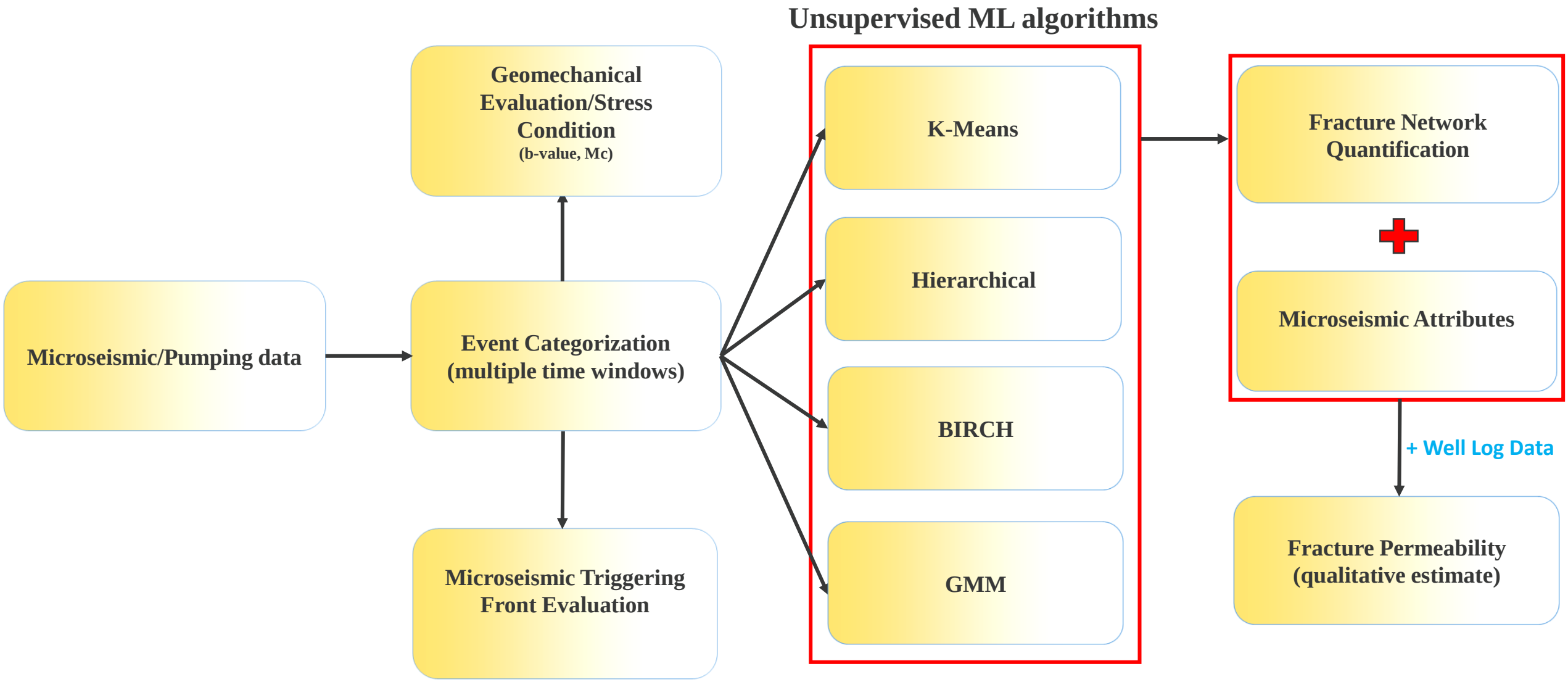
- **Goal**
  - Implementing novel methods to image fractures/faults
- **Site detail**
  - Illinois Basin-Decatur Project (IBDP)
- **Data sets**
  - Microseismic data recorded from downhole array
  - Bottomhole pressure, CO_2 flow rate, well logs
- **Methods**
  - Time-windowing
  - Physics-based ML clustering
  - Fracture network quantification
  - Qualitative permeability estimates
- **Results**





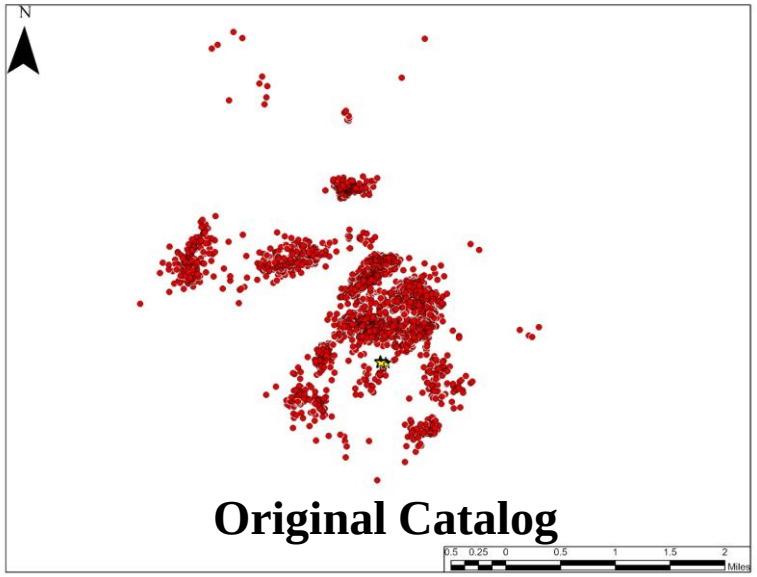
Will et al., 2014

Structured Approach to Fracture Network Quantification

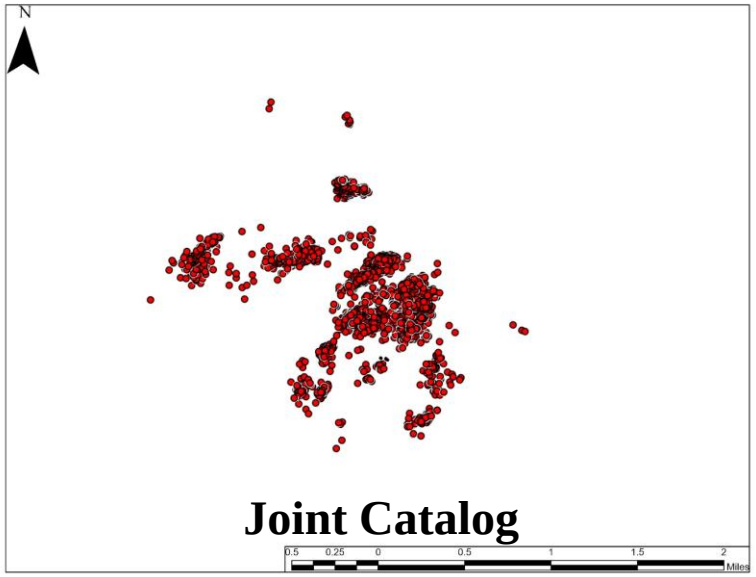


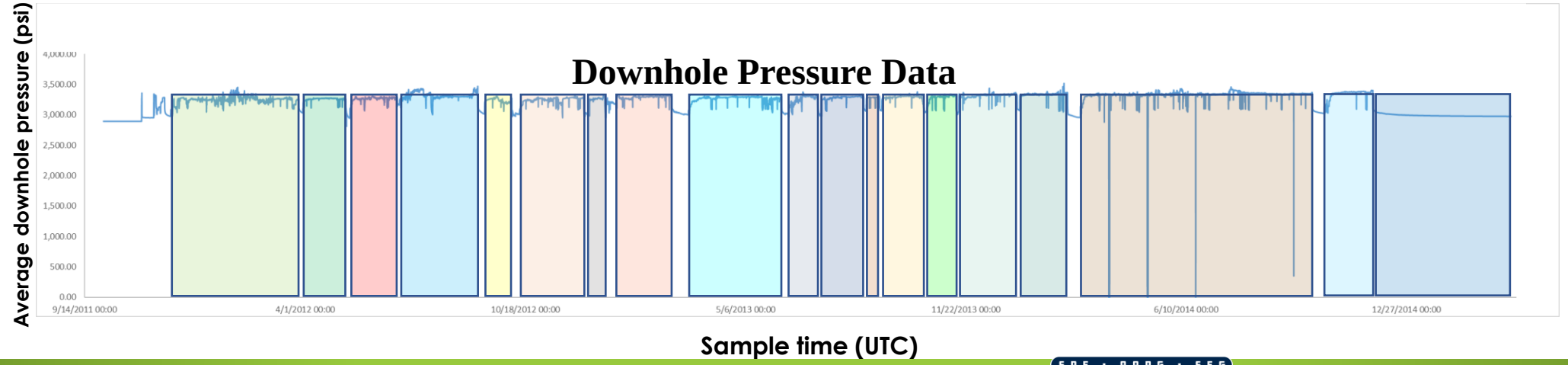
Data Assimilation

Preliminary Location



Preliminary Location + Double Difference Location

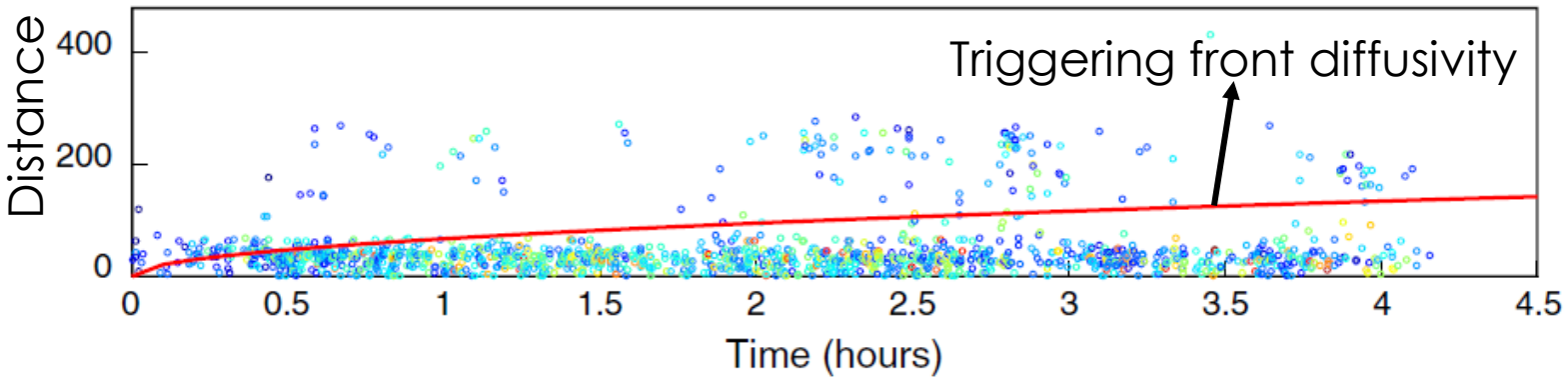


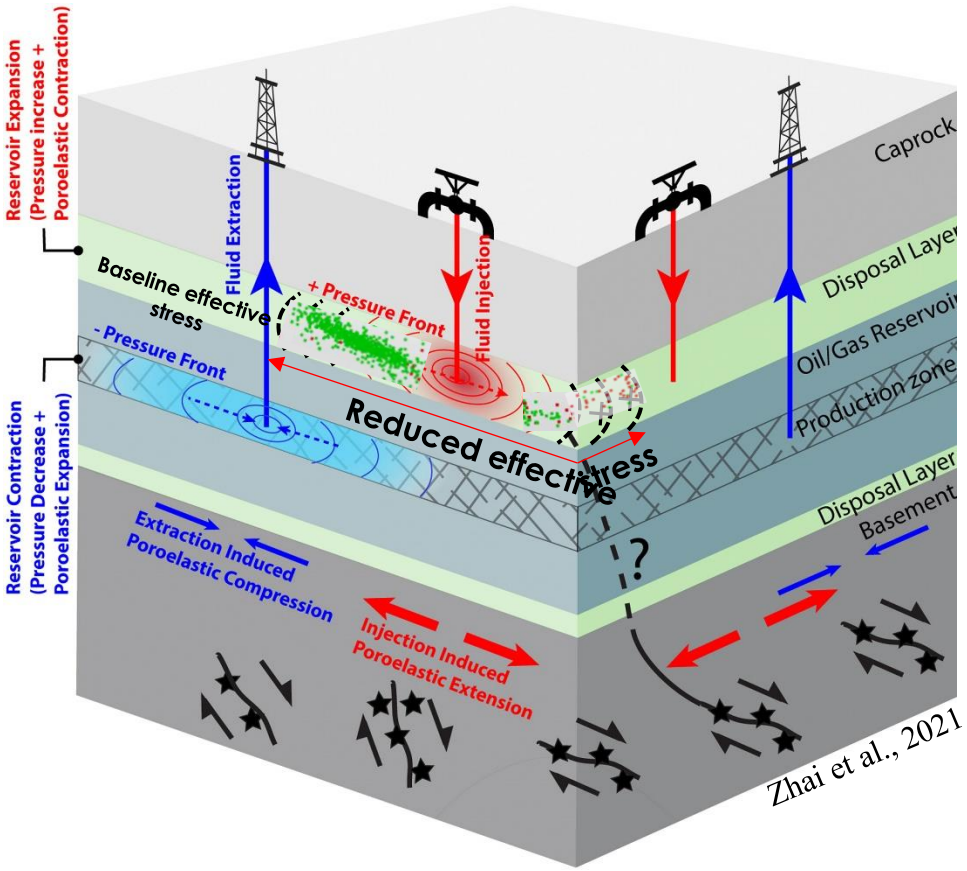


Hydraulic Diffusivity

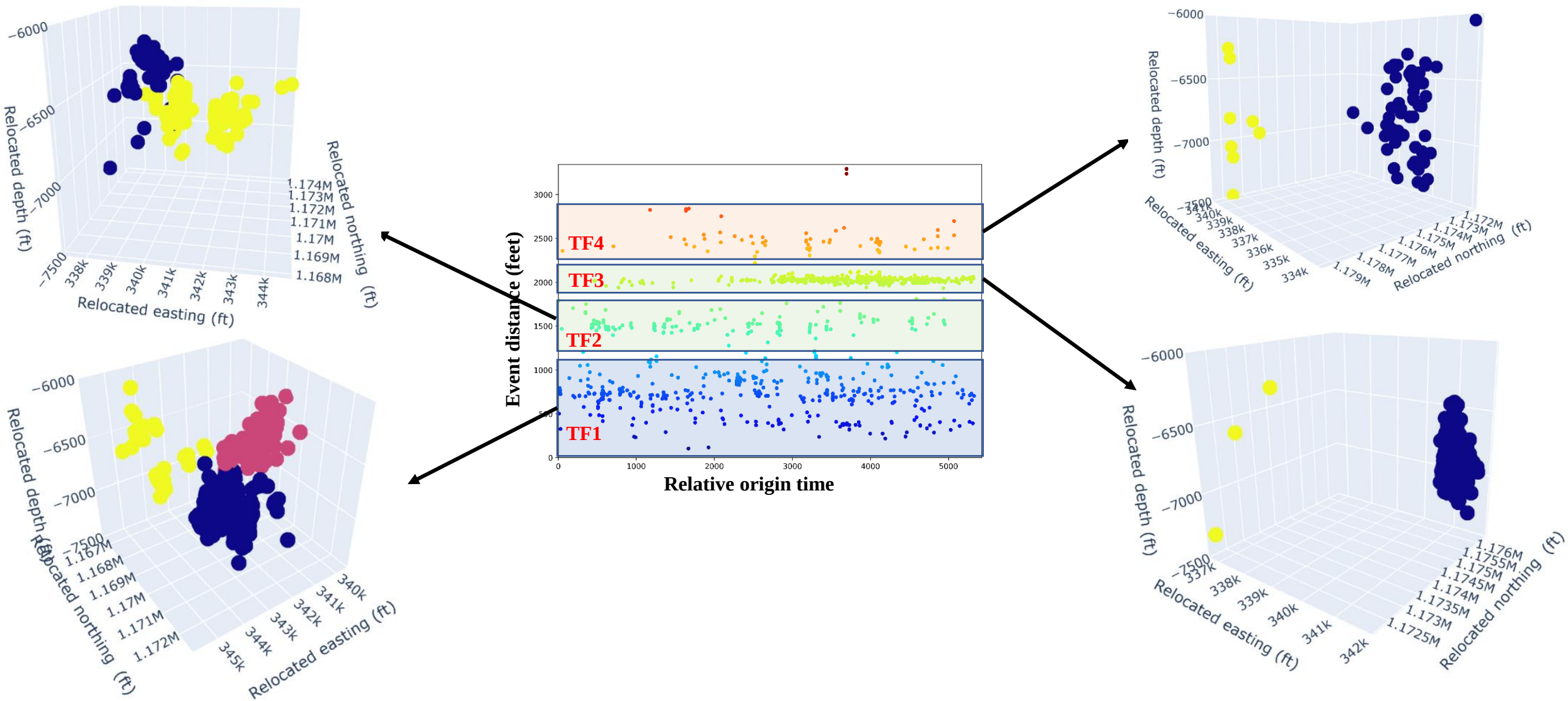
- Play a crucial role in understanding and managing high-pressure fluid injection processes
- Measure of how quickly fluids can move through the porous media
- Provides critical information about the flow behavior, pressure distribution, and fluid migration patterns during injection operations
- Derived from mapping the microseismic triggering front and can be directly linked to rock permeability

$$r_t(t) = \sqrt{4\pi D_{tf} t}$$

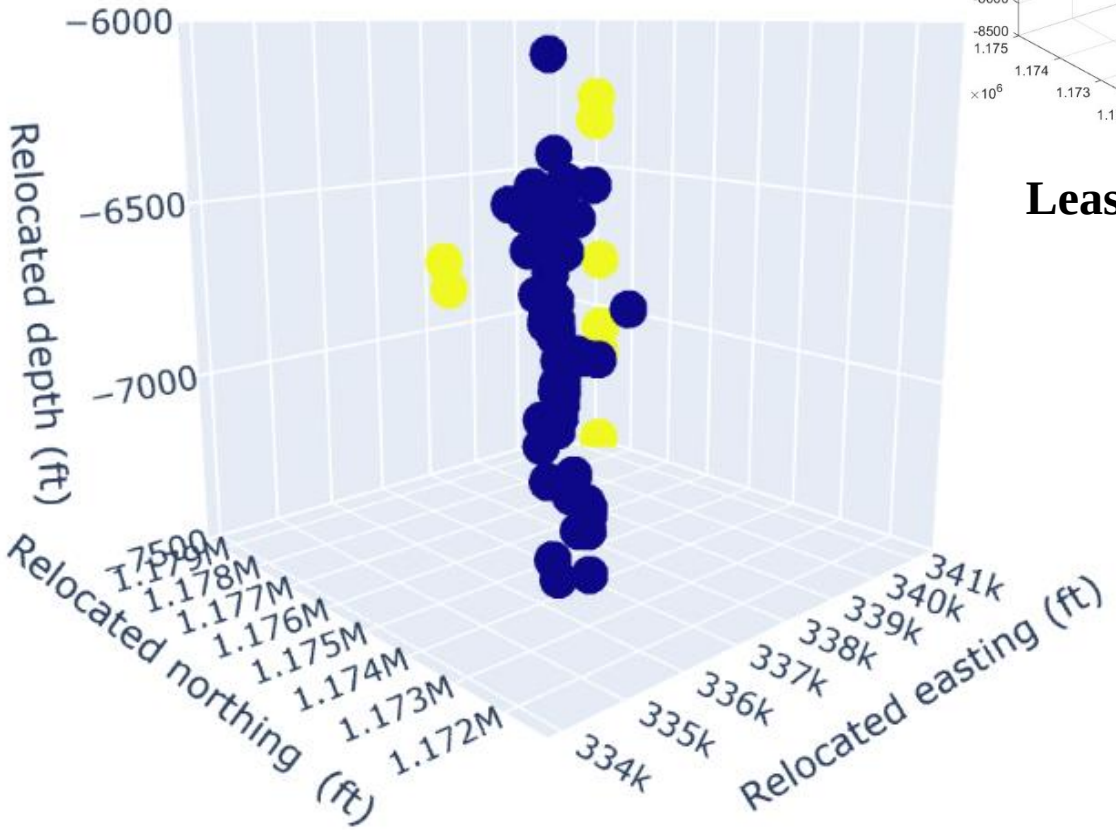




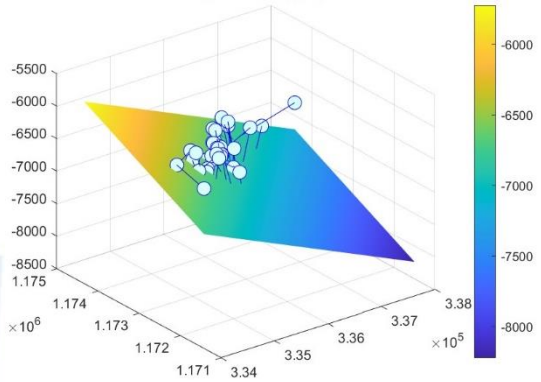
Event Clustering Using Unsupervised ML algorithms



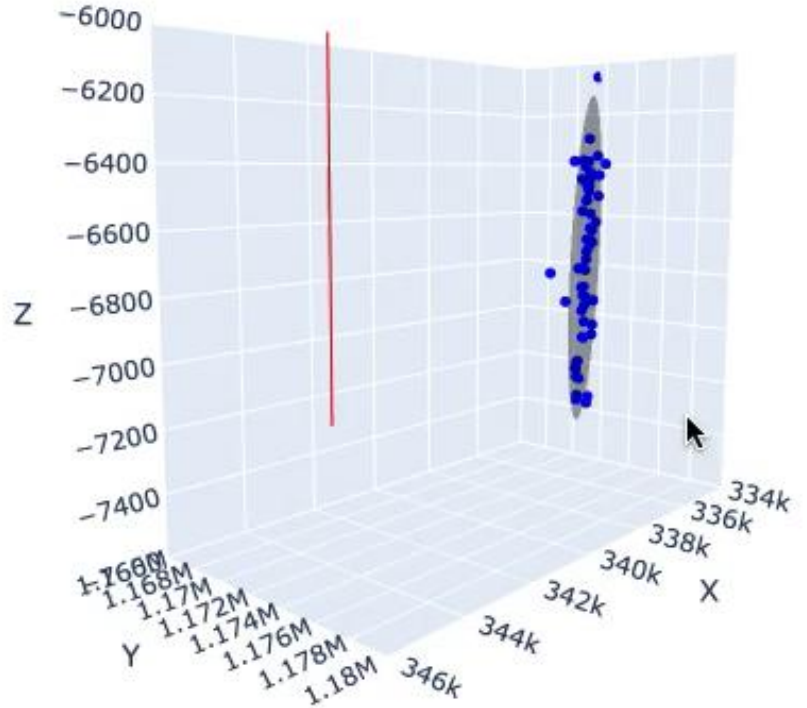
Fracture Plane Quantification Using Standard Deviation Ellipsoid



Microseismic Cluster

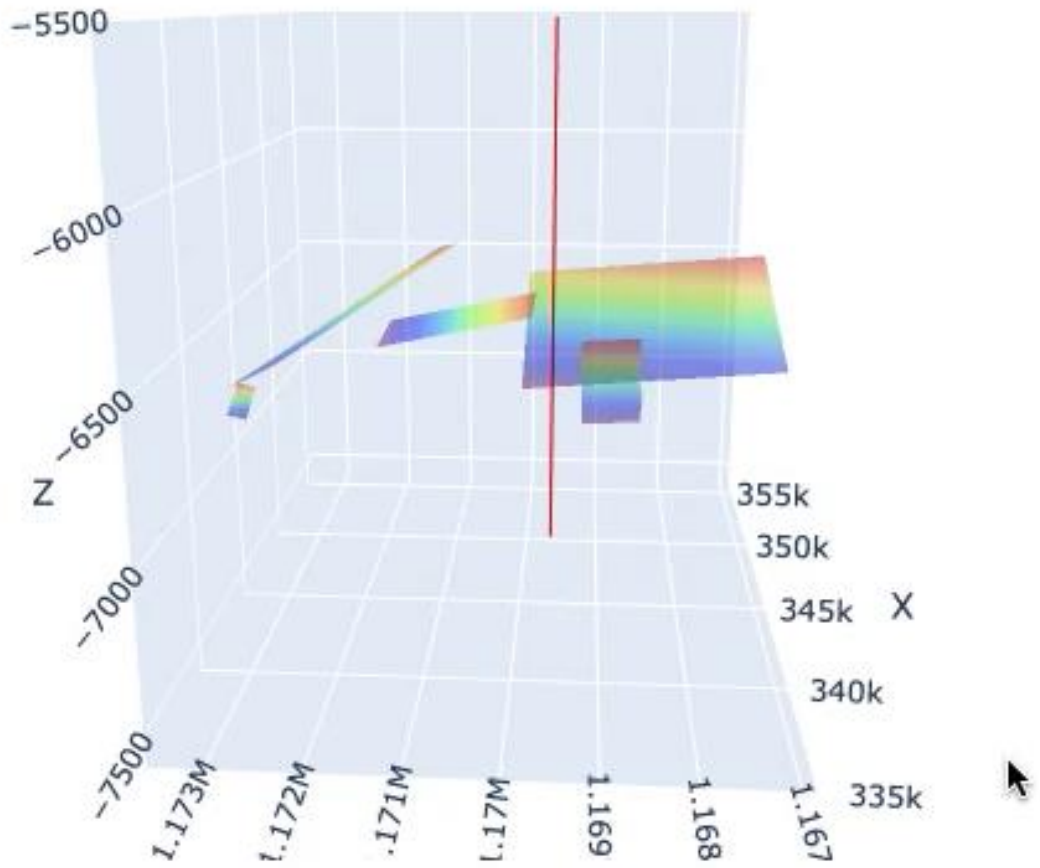


Least square plane

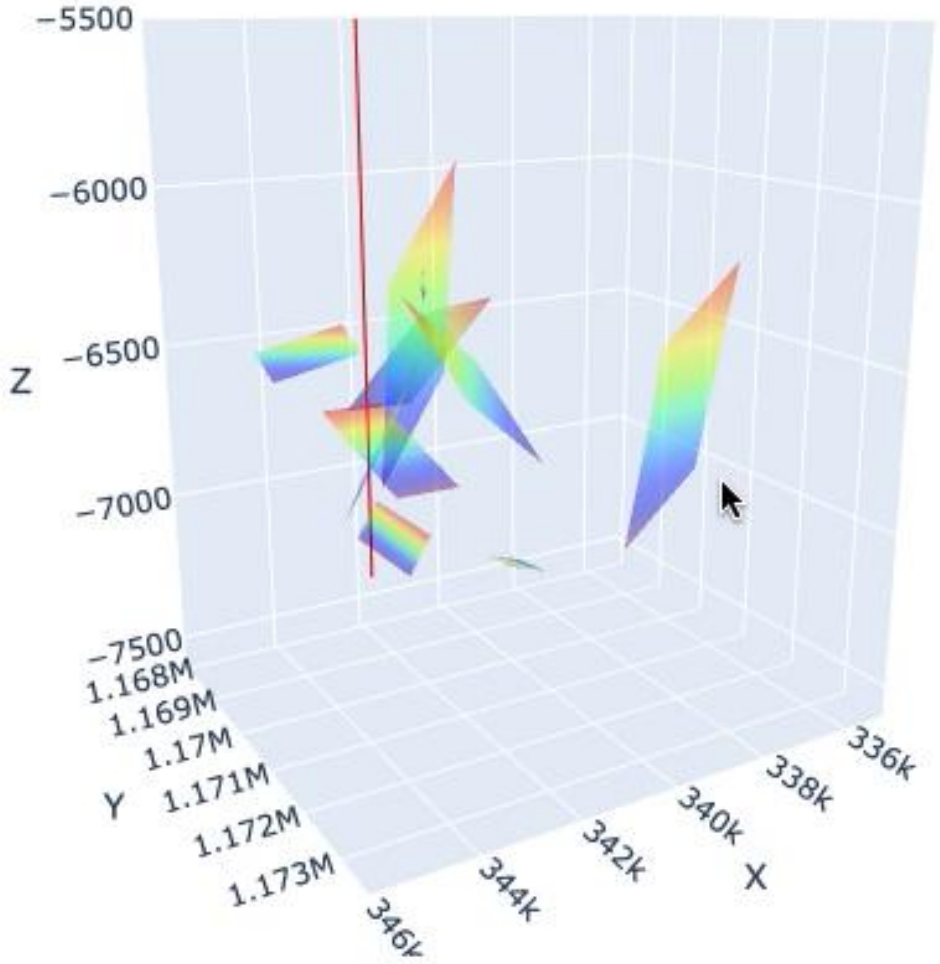


2-Standard Deviational Ellipsoid

3D Fracture Plane Distribution

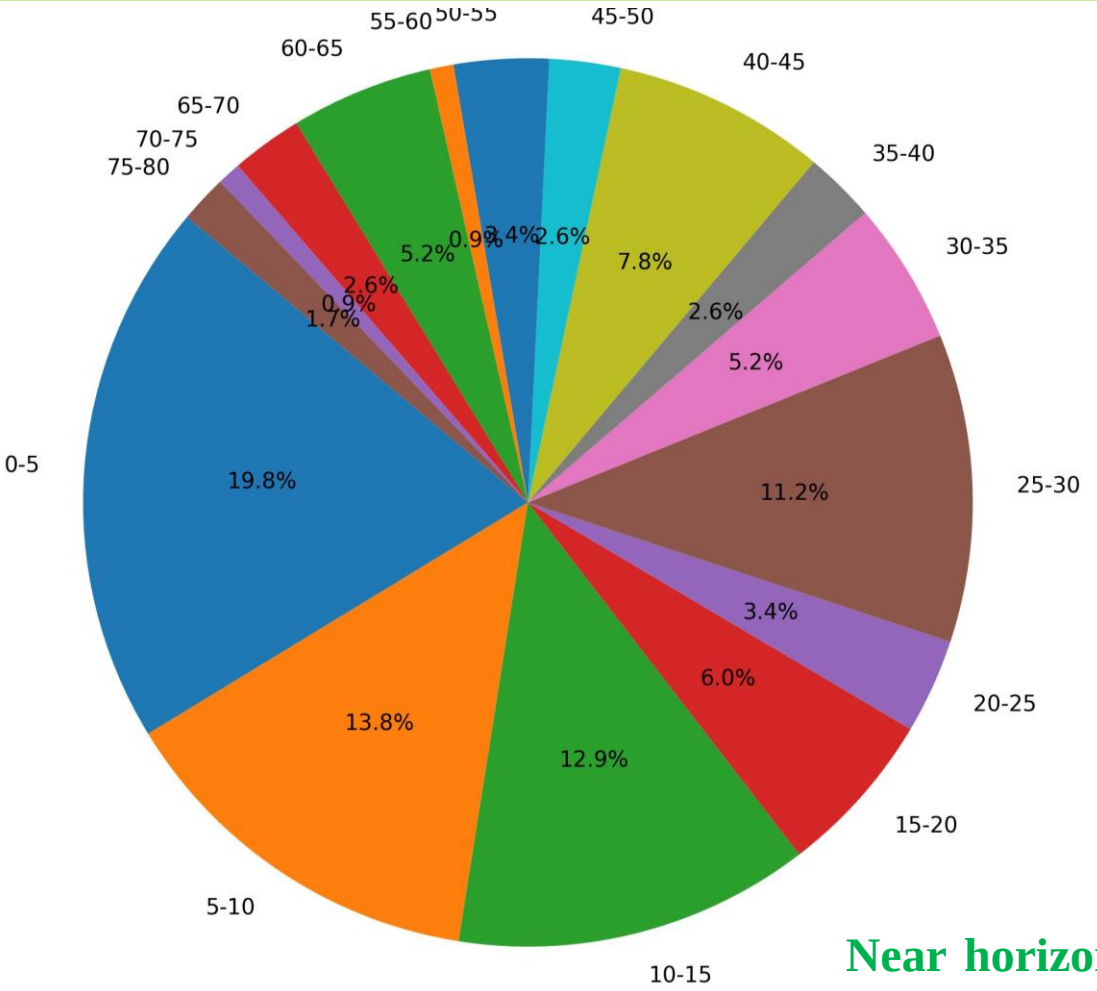


Window 3



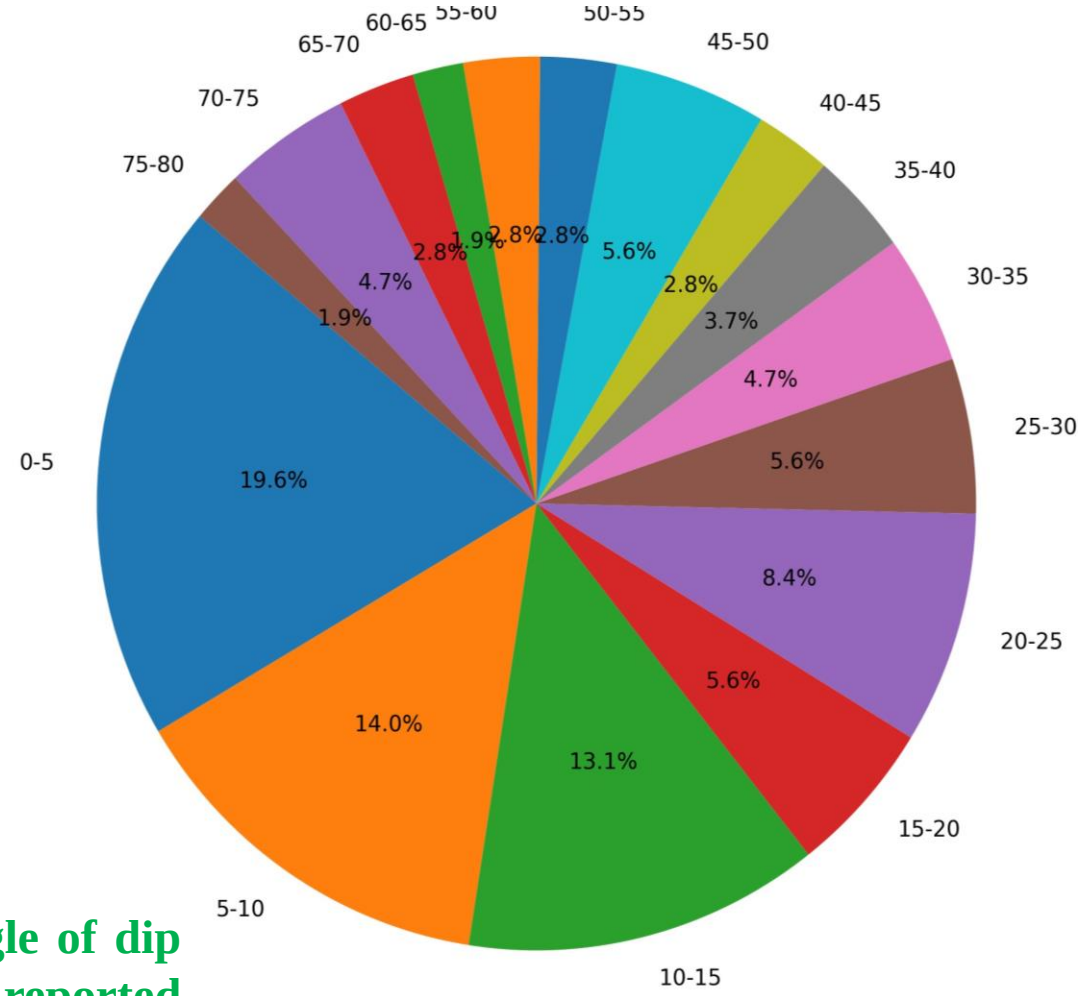
Window 9

3D Fracture Attributes (variation in dip)



Hierarchical

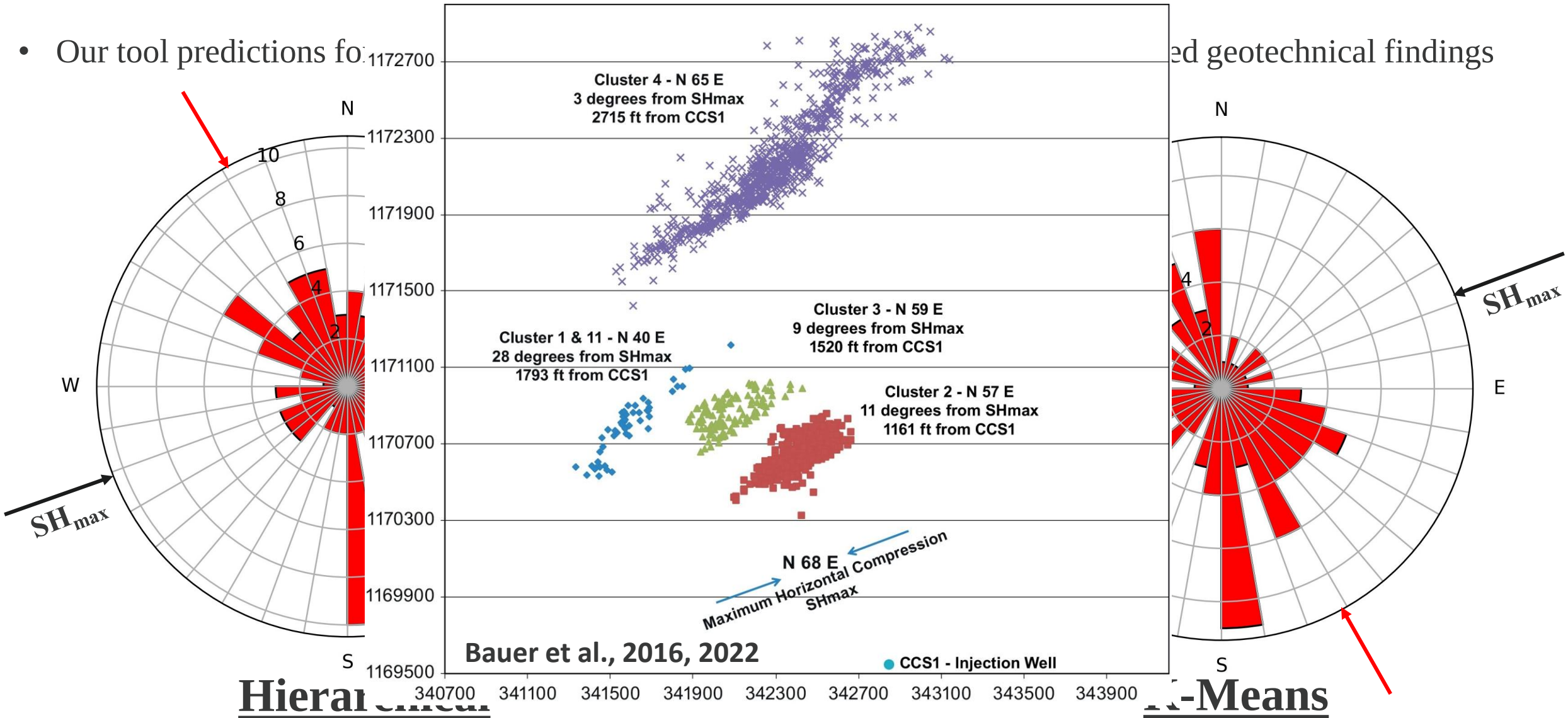
Near horizontal/small angle of dip agrees with other studies reported by using different dataset (Bauer et al., 2016, 2022)



K-Means

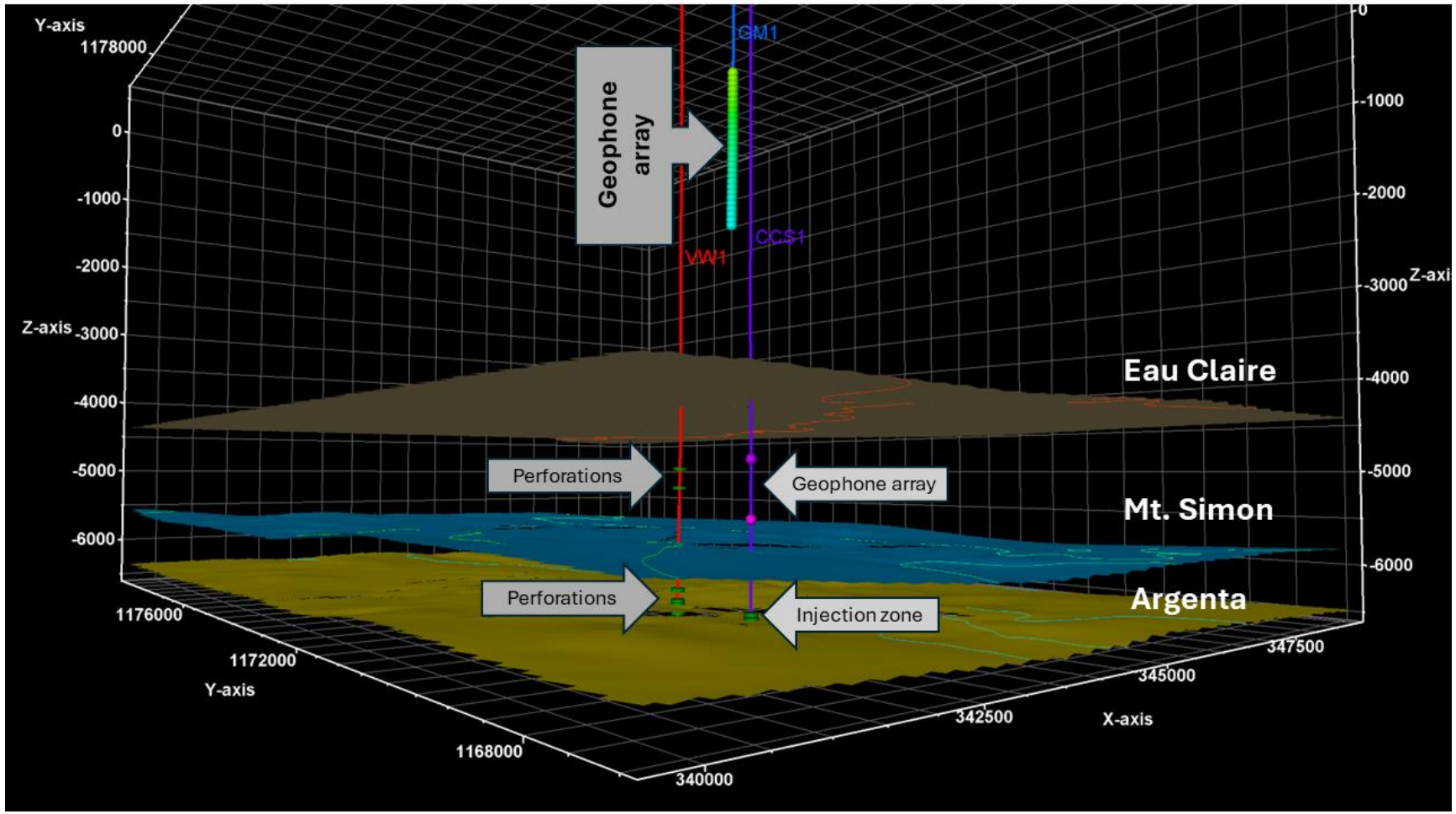
3D Fracture Attributes (dip direction)

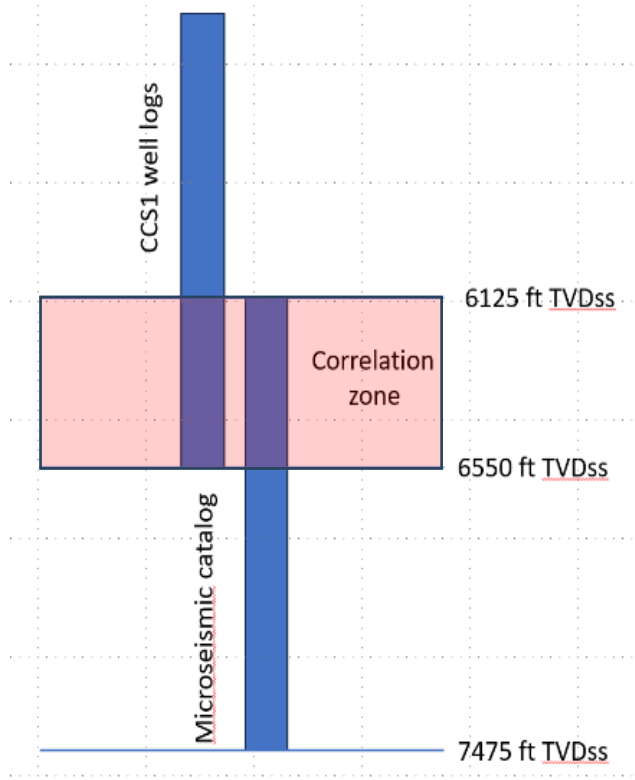
- Our tool predictions fo ed geotechnical findings



Hierar ical K-Means

Geomechanical correlation with microseismicity

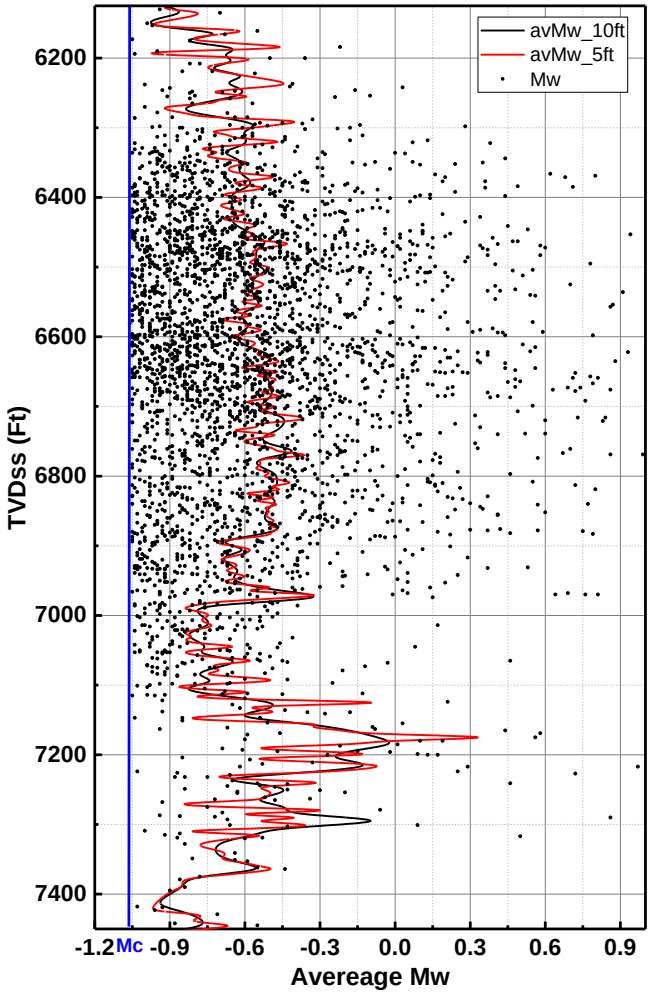


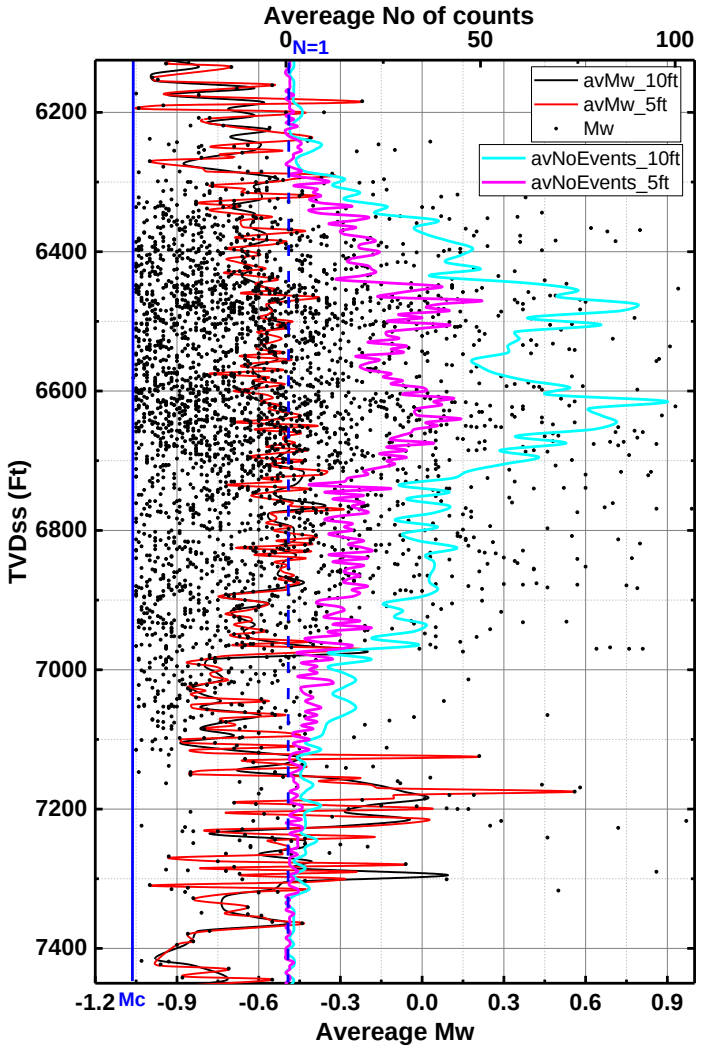


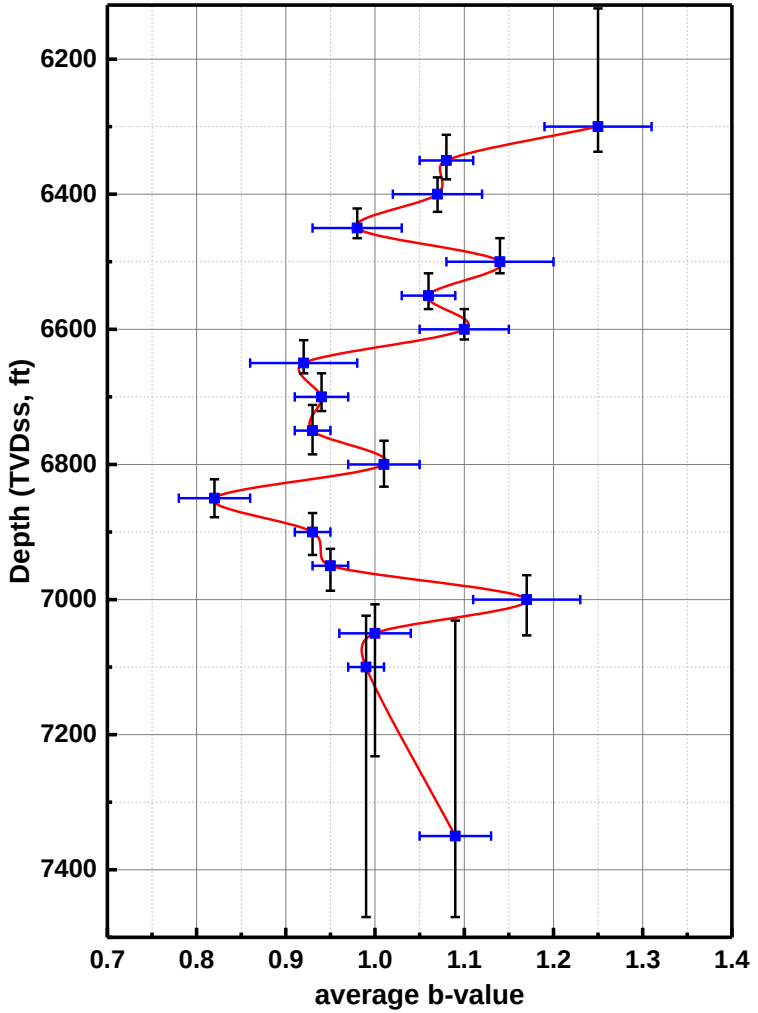
$\lambda\rho = Density\ scaled\ compression$

$\mu\rho = Stiffness$

Microseismic Pseudologs (CCS1)

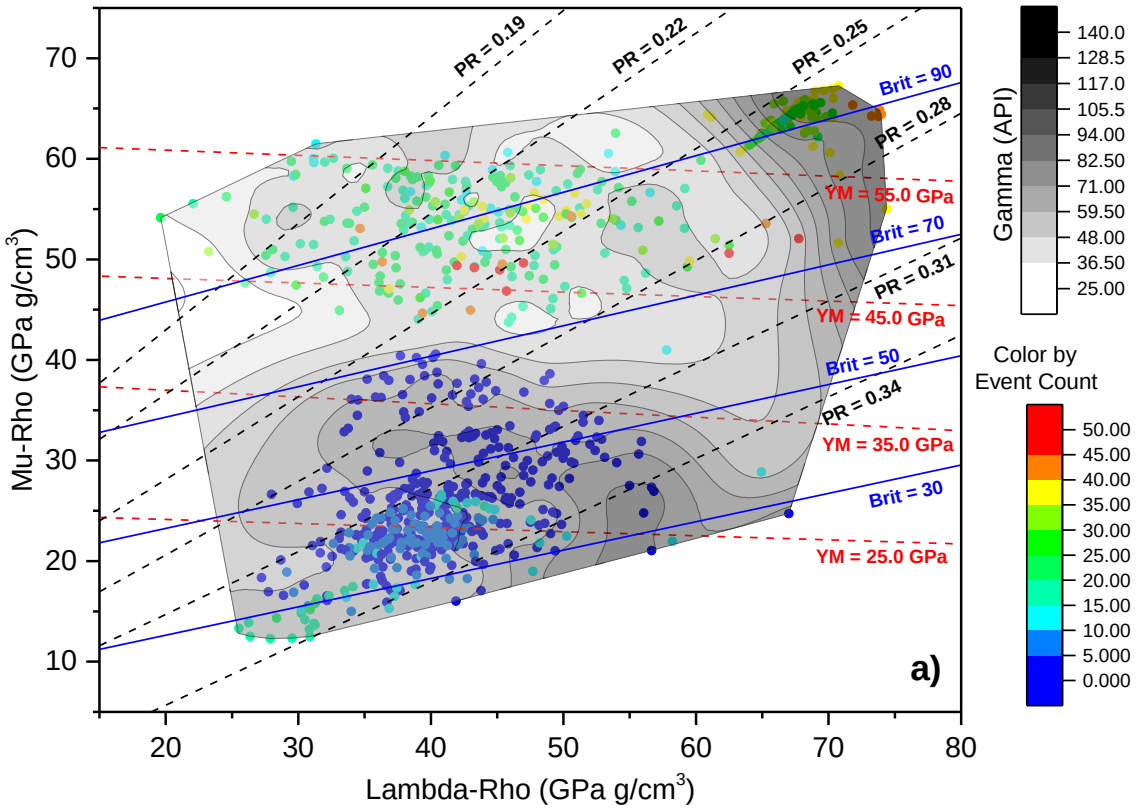




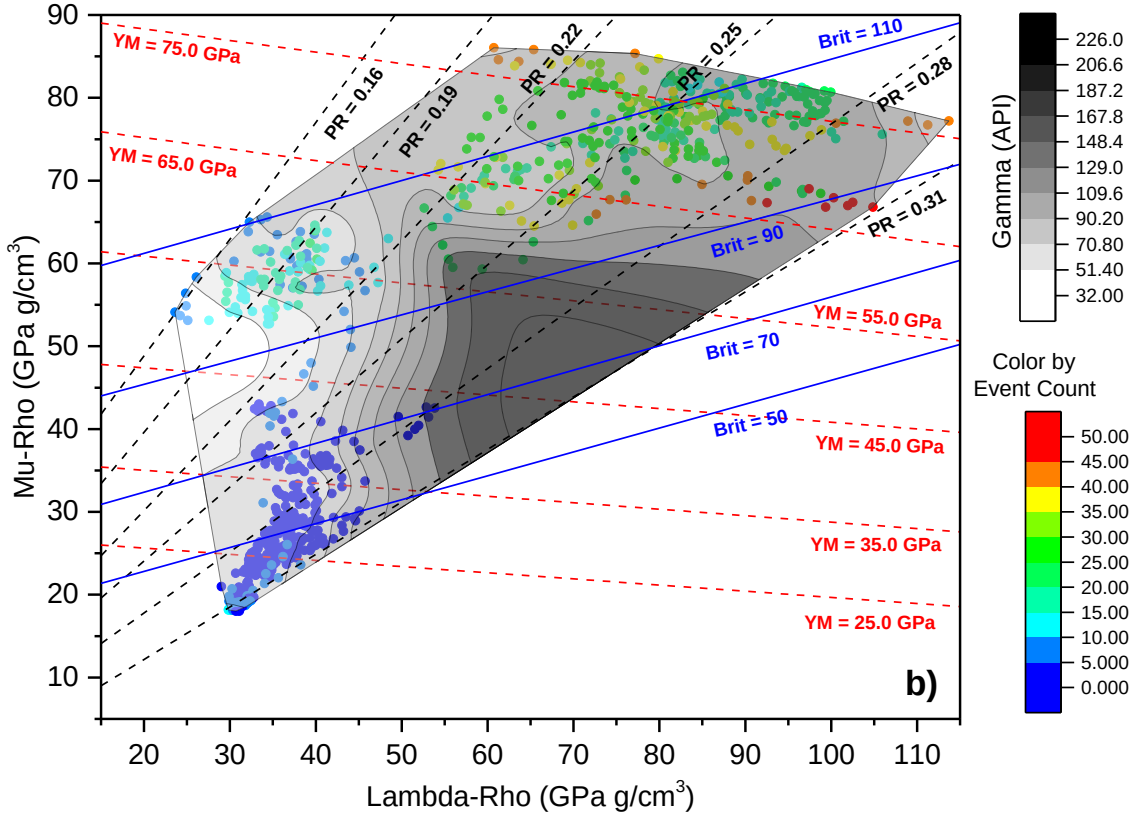


Geomechanical correlation with microseismicity

- ↑ PR ↓YM: ↓ Event count
- ↓ PR: ↑ Event count
- ↑ PR ↓YM: ↑ Resistance to fracture ↑ Amenable to deformation



CCS1



VW1

Take Away Points

- Developed a machine-learning-based solution for fracture network quantification using recorded microseismic events.
- Successfully applied the tool to the Illinois Basin – Decatur Project (IBDP) dataset to characterize reservoir-scale subsurface fracture network.
- Identified dominant fracture planes associated with CO_2 injection-induced microseismic activity that are in complete unison with the orientation of preexisting stress condition.
- Estimated qualitative permeability changes along fracture planes based on event magnitudes.
- Our technique provides a data-driven alternative to conventional Discrete Fracture Network (DFN) modeling approaches.
- The technique is highly scalable and transferrable beyond CO_2 storage, including geothermal energy and hydraulic fracturing projects.

Questions??

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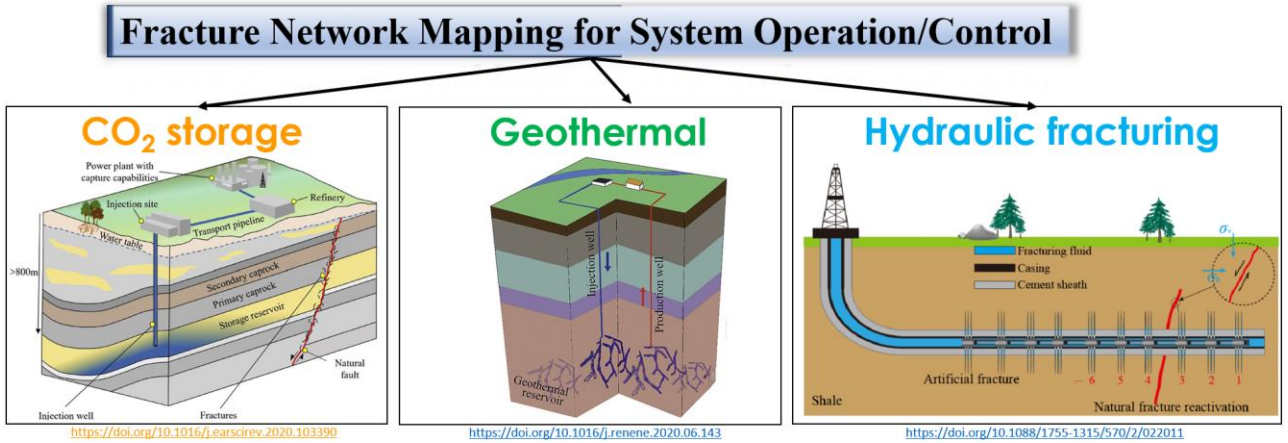

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