NUMERICAL APPROACH TO INTERPRETATION OF ACOUSTIC EMISSION OCCURRING AT DIFFERENT SCALES

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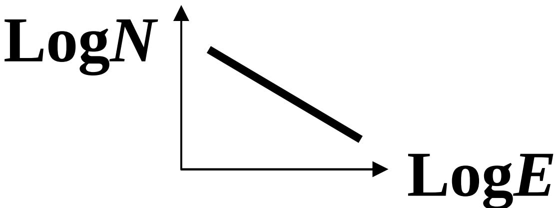
Motivation

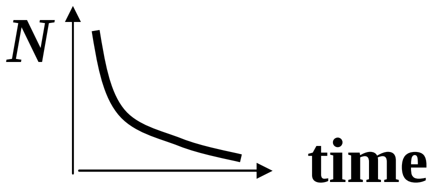
- Continuous need for the improved non-destructive monitoring techniques
- Need to characterize material's internal structure and internal processes
- Existence of a reliable numerical tool appropriate for the development

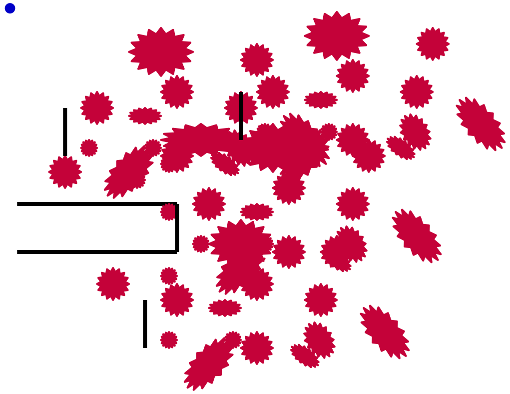
ACOUSTIC MONITORING

Data on an *individual event*:
time, location, displacement, velocity, acceleration, spectra, seismic moment, energy, stress drop, …

Data on *multiple events*:



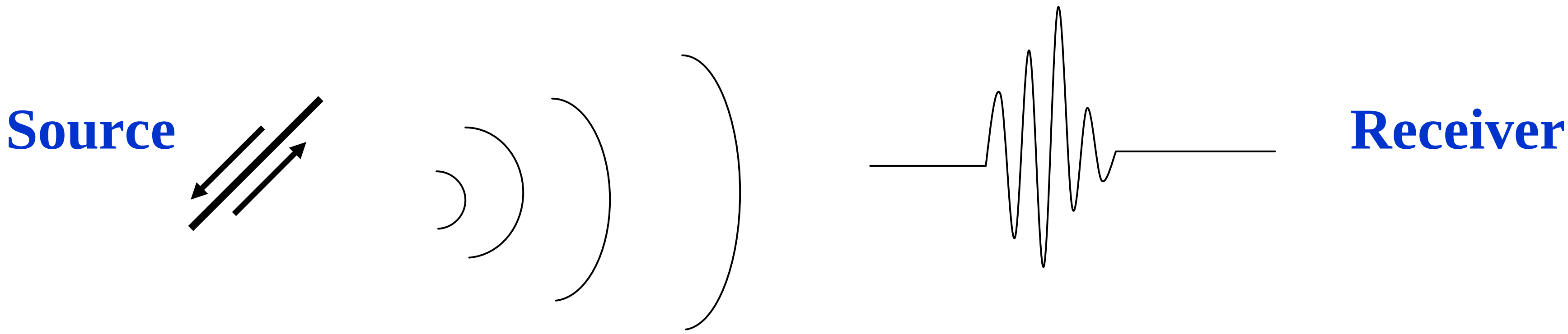




Gutenberg-Richter law, Omori's law, seismic viscosity, creep, …

Unfortunately, data interpretation and understanding are still insufficient

Numerical Modeling of Seismicity



Seismic event = instability

Basics of the Numerical Technique

- Studying a system of statistically seeded defects modeled by cracks
- In-situ changes due to a time-dependent process
- Tracing deformations on the surfaces of the cracks and registering seismic and aseismic events
- Using BIE and BEM for numerical simulations

Advantages of the Numerical Technique

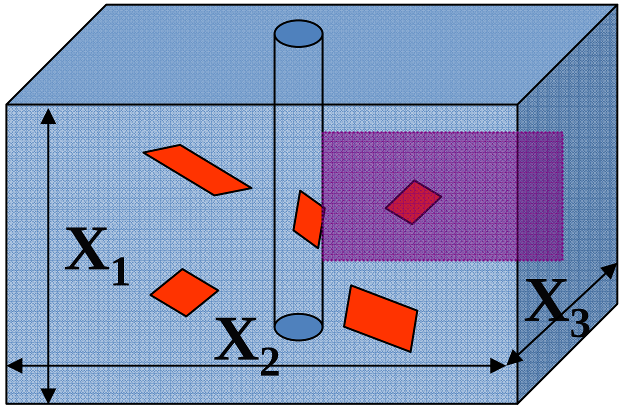
- Ease of studying up to million of defects
- ESC model allows one to simulate both unstable (seismic) and stable (aseismic, damping, or accelerating) events
- Effective solution of problems involving changes in geometry and multiple displacement discontinuities.

Simulation Output

In terms of both:

- Solid mechanics, such as stresses, tractions, strains, and displacements and
- Seismology, such as time, location, seismic moment, energy, velocity or acceleration for a single event and temporal and spatial distributions, and dependence frequency-magnitude for a set of simulated events

Time-dependent Process: Hydraulic Fracturing



Microseismicity occurs due to

a) fracture propagation and

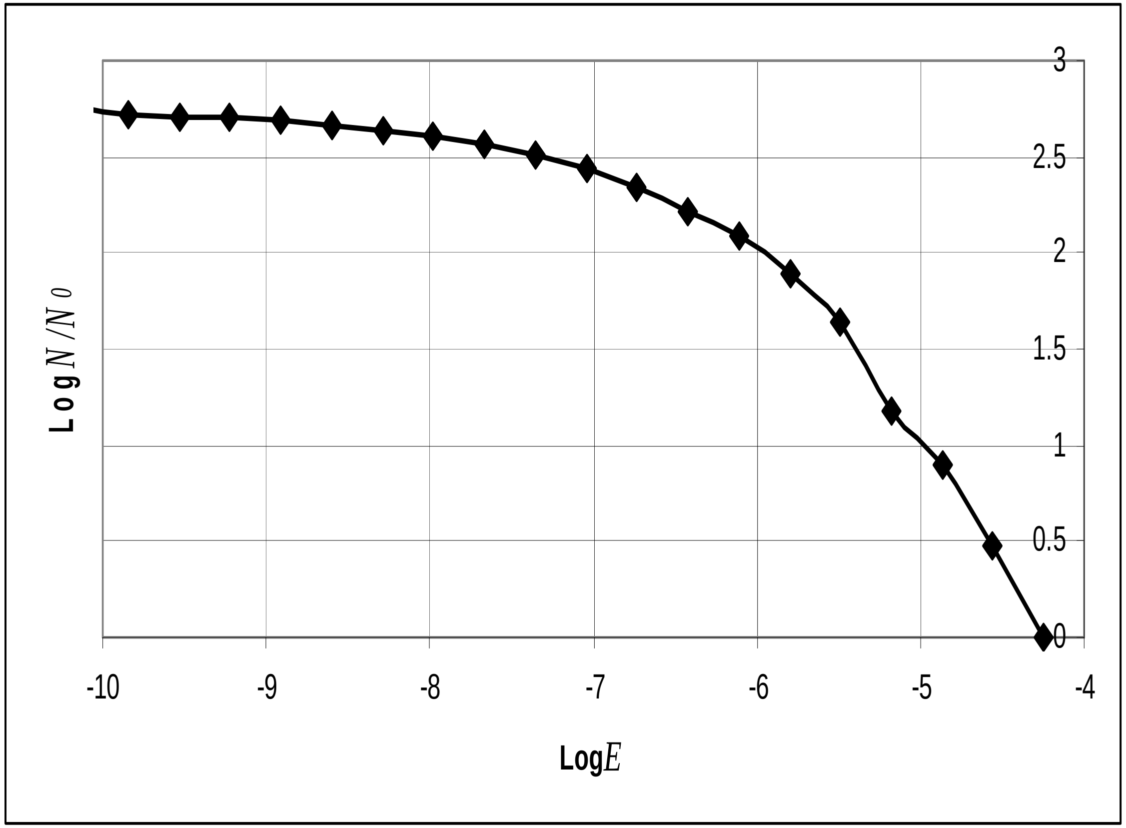
b) changes in fluid flow

Coupling between changes in fluid flow and fracture propagation is accounted for by the formulae

$$\Delta p_D(t_D, x_2) = \frac{160}{3\pi} w_D \frac{h_D}{a_D} \frac{2}{\pi} [1 + 1.515\exp(-1.15 r_D)] \left(1 - \frac{x_2}{L}\right)^{0.25}$$

$$L_D = 0.48\, t_D^{\;0.552} \qquad w_D = 0.2\pi \left[\frac{a_D / h_D}{1 + 1.515\exp(-1.15 r_D)} L_D \right]^{0.25}$$

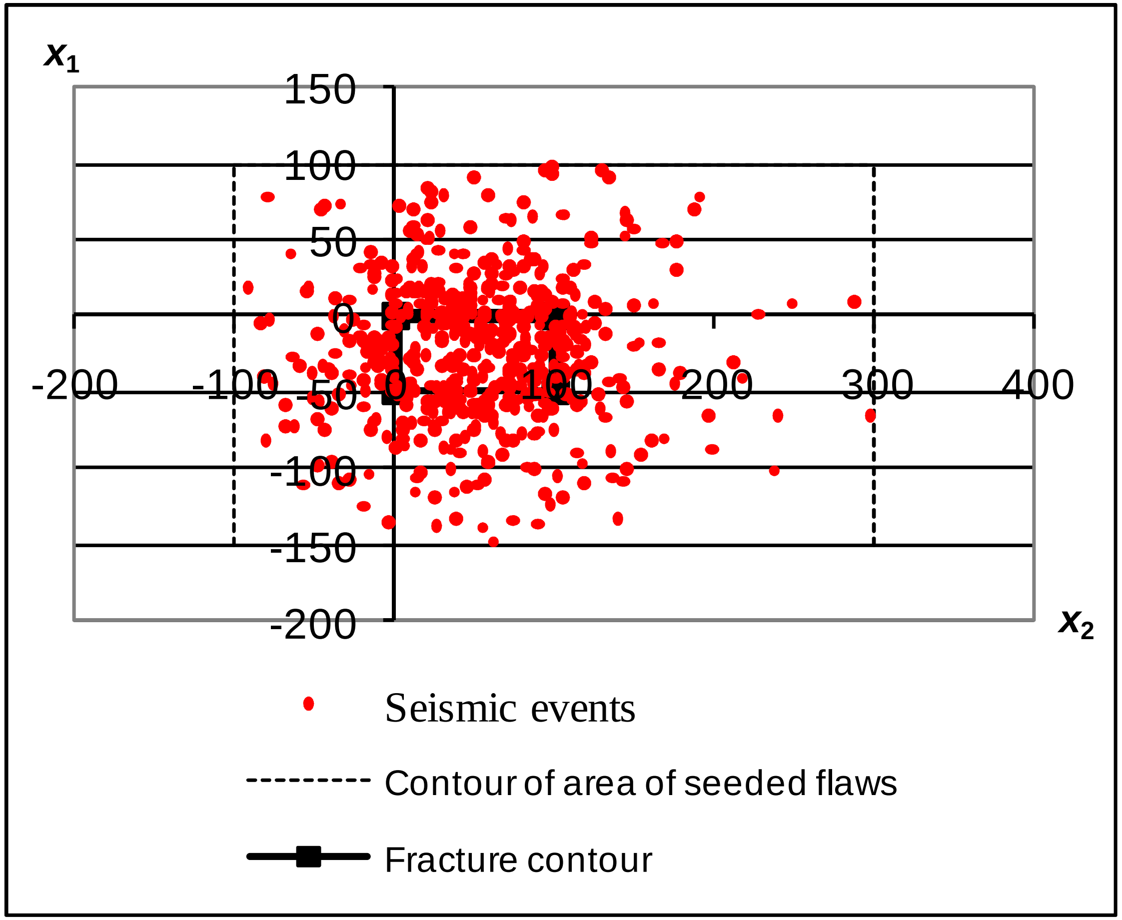
Numerical Results: Dependency of Frequency – Magnitude Type



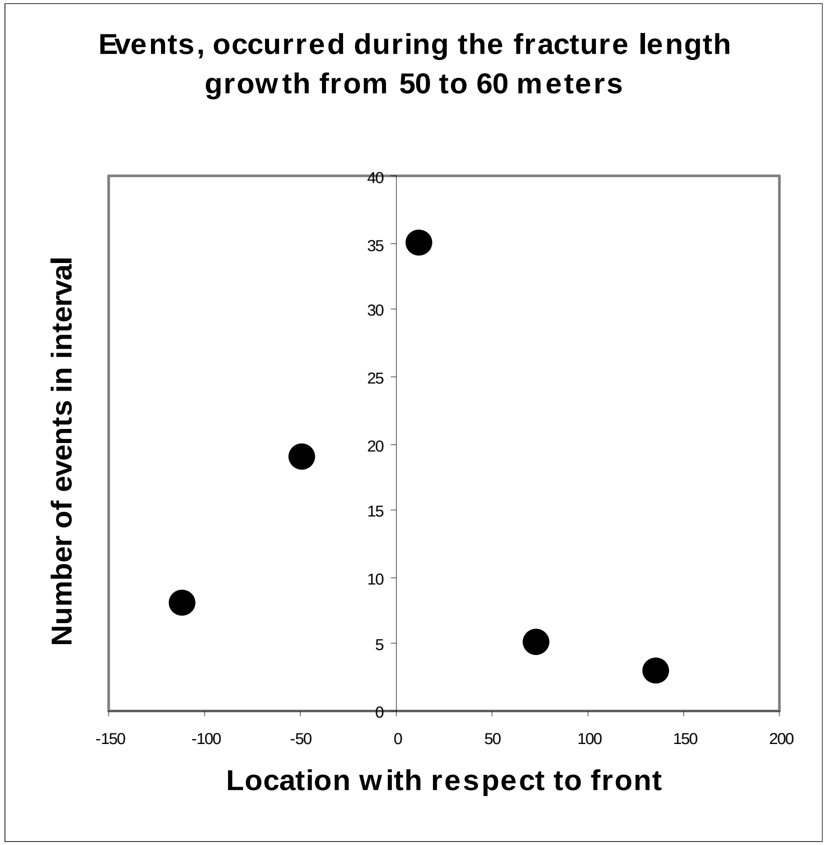
Significantly less events than in similar mining problems

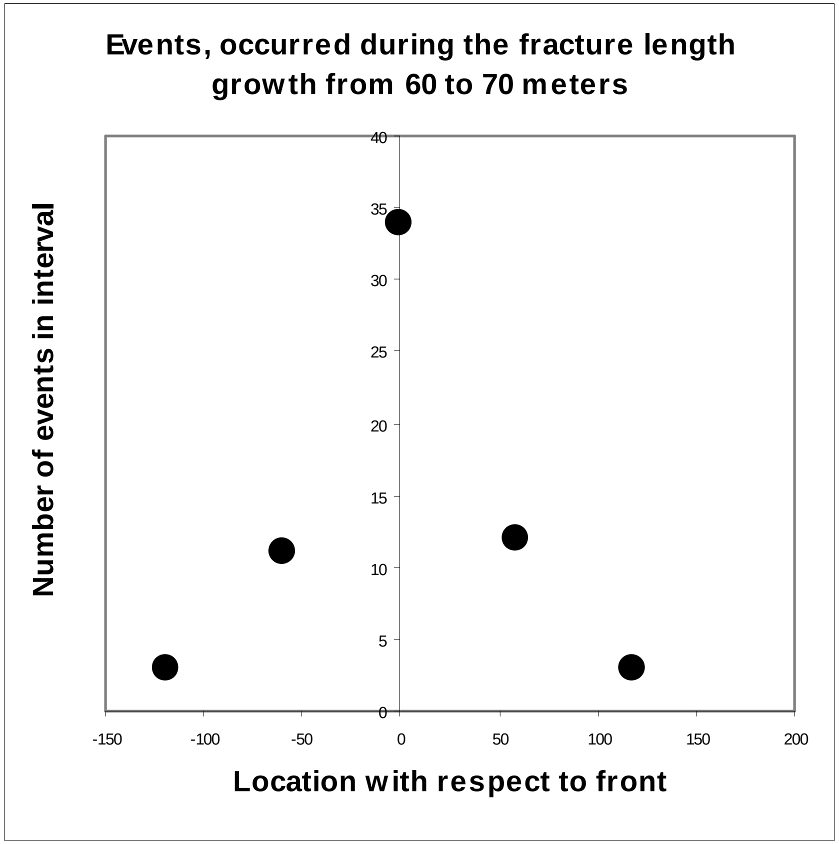
No simulated events with the magnitude exceeding -4

Simulated Spatial Distribution of Seismic Events



Simulated event distribution on steps of fracture propagation



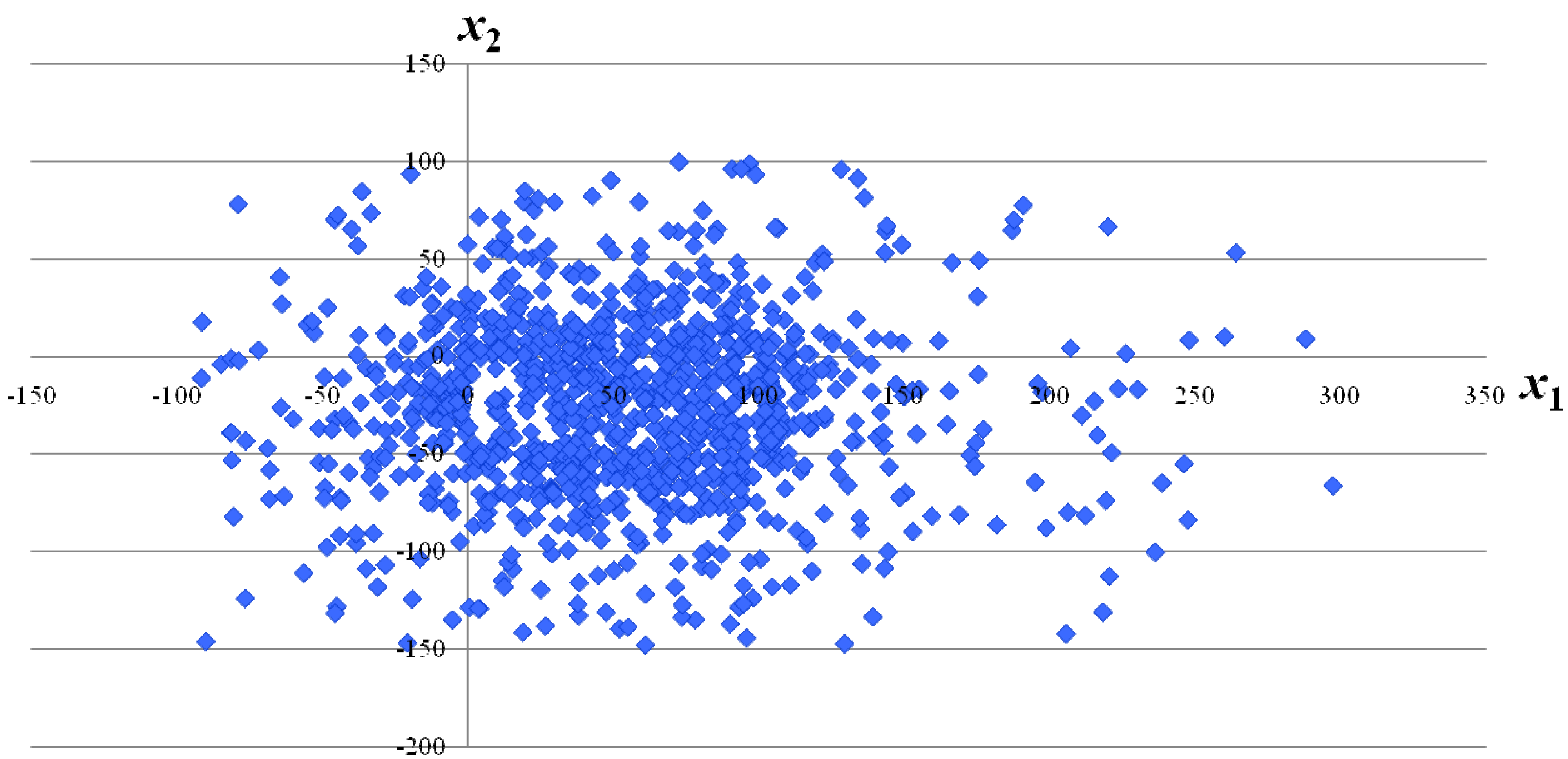


Potential for Data Inversion

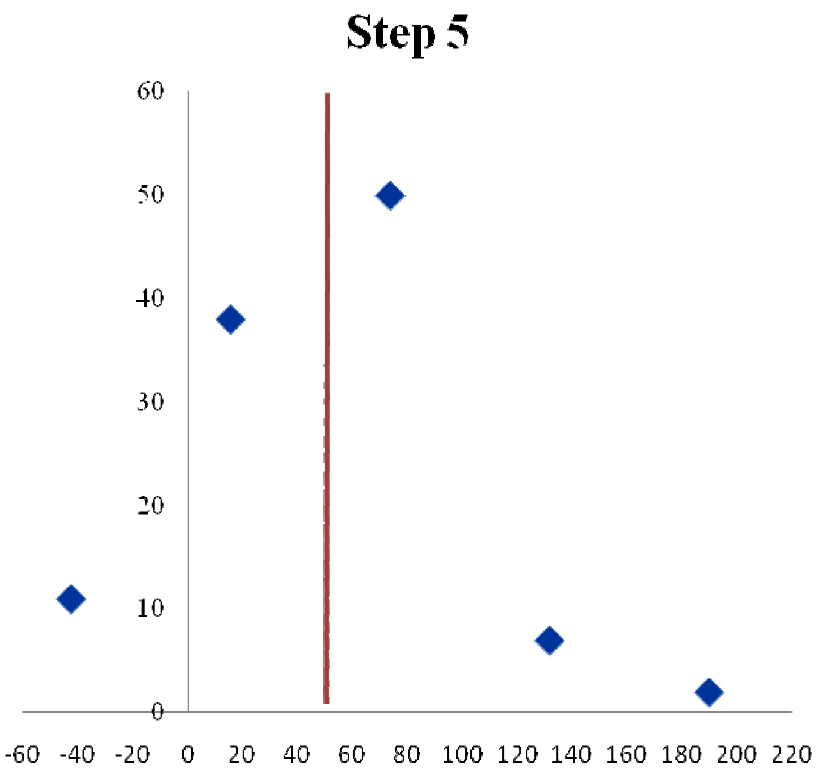
- Spatial distribution of seismic events is correlated to geometrical parameters of hydrofracture
- Fracture plane and location of fracture front can be estimated by analyzing seismicity

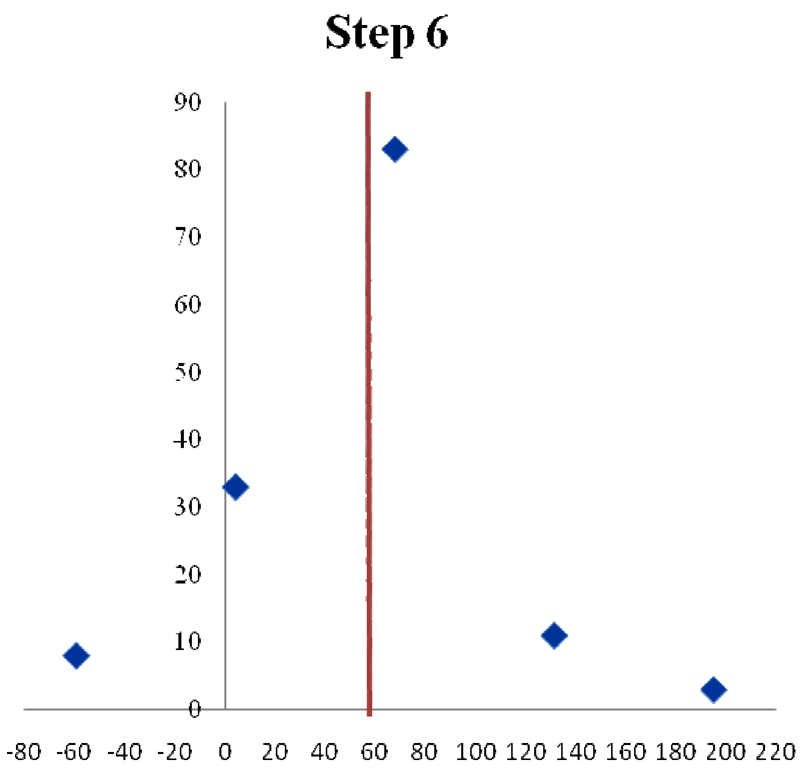
Inverted Data on the Plane and Spatial Distribution of Seismic Events

Reconstructed Fracture Plane and Events Spatial Distribution



Inverted Data on the Front on Steps of Fracture Propagation





Comparison of Simulated and Inverted Data

We see that by using only locations of simulated events, we are able to quite accurately recover:

- the final fracture plane and
- the front plane, its location, orientation and also microseismicity distribution on steps of fracture propagation.

This suggests an efficient tool to verify and to enhance existing techniques serving for interpretation of microseismic observations

Concluding Remarks

- The basics of numerical simulation of acoustic emission are common for various applications.
- Joining analysis of seismicity with numerical simulations is beneficial for acoustic emission interpretation.
- Attributes of seismicity such as grouping and spatial distribution of the events can be used to determine geometrical characteristics of the studied object and thus can contribute to the characterization of internal structure.
- Further research is required to investigate the potential of using other seismic attributes for inversion.

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Thank you!!!