# Fracture Properties from Seismic Waves

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# Overview

- The goal of my project is to determine if seismic waves can be used to delineate the dominant flow path in a rock fracture.
- My rock sample is a 4”x4”x4” Lucite mold of  a single fracture in Austin Chalk limestone.
- The dominant flow path between the two rough surfaces will depend on aperture size and contact area.
- Predictions will be made using image and waveform analysis.

# Procedure

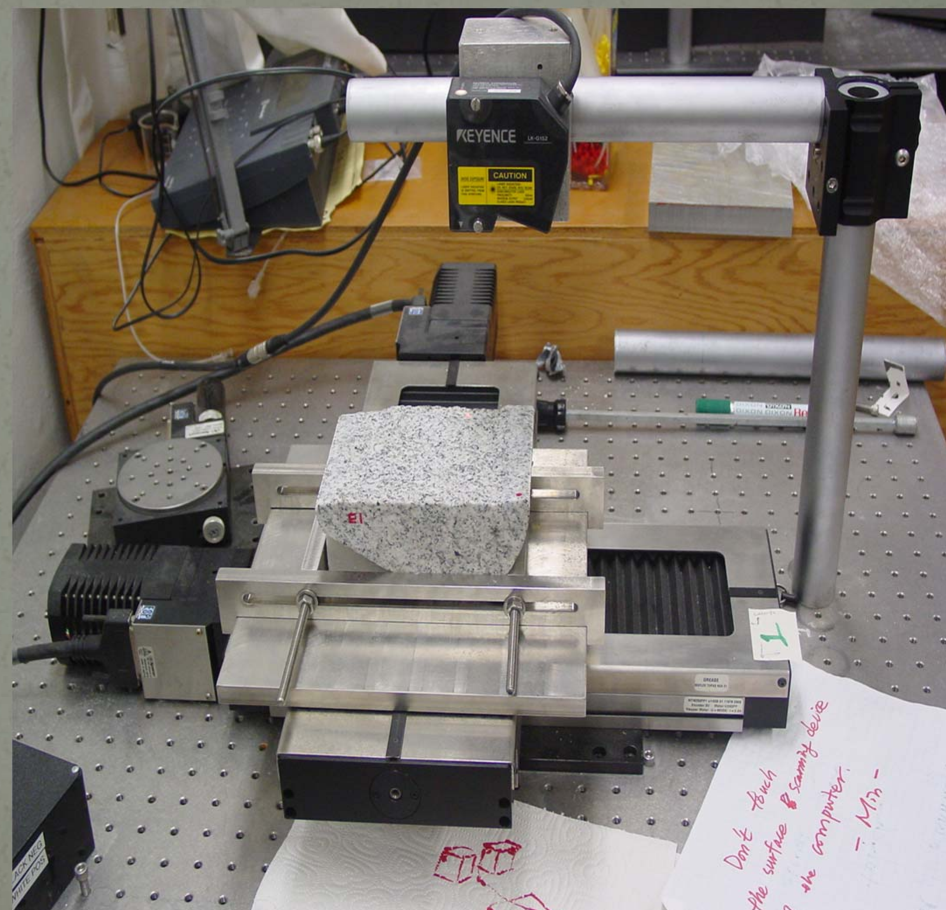
- The Lucite sample has two halves; a front and a back.
- For a control, the rough surface of each half is scanned with a laser, and an image is formed that maps the highs and lows of the sample half.
- For further control, each half is seismically scanned separately and wave data is collected of the fracture halves when there is no contact between the surfaces.
- For these experiments the reflected seismic waves were recorded for analysis, and transmitted waves were not collected.

- With the control data collected, the fracture is assembled and sealed so that no water can leak into the fracture during the experiment.
- The assembled sample is again secured and clamped in the tank and immersed in water.
- Reflection data is collected of each half while the fracture is assembled, sealed, and clamped so that the affect of contact area can be seen.
- Transmitted seismic waves through the entire sample are collected with the use of a second transducer for comparison with reflected data.

- Analyze data and make a prediction about the dominant flow path in the fracture by looking at the arrival times , amplitude, and frequency ranges of the collected wave forms. The arrival times will provide a good indication of contact area, aperture size and overall geometry.
- Verify the predicted flow path by recording the flow of fluorescent beads.
- Determine if the observed path matches the predicted path.

# Experimental Setup for Surface Roughness

- Surface roughness scans use a laser and a moving platform so that a signal can be acquired every 0.25 mm over the area of the sample.
- For a given scan, one half of the sample is secured rough side up facing the laser.
- The laser is "zeroed" on the lower left corner of the sample.
- A Labview program controls the moving platform and records data for every point on the area of the sample half.



# Experimental setup for seismic scans

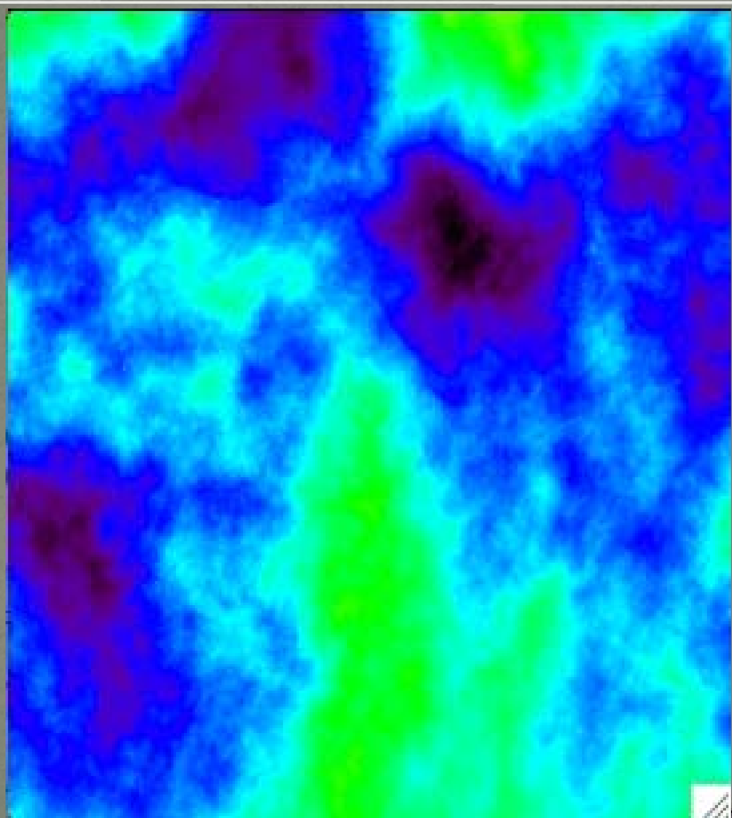
- The sample is secured and clamped in a tank and immersed in water.
- Underwater, ultrasonic transducers are mounted to overhead actuators, and hang down facing the sample.
- The actuators are controlled by computer input and the transducers return either a reflected or transmitted signal to an oscilloscope.
- The waveforms from the oscilloscope are recorded by a computer program.

# Experimental setup for Flow Path

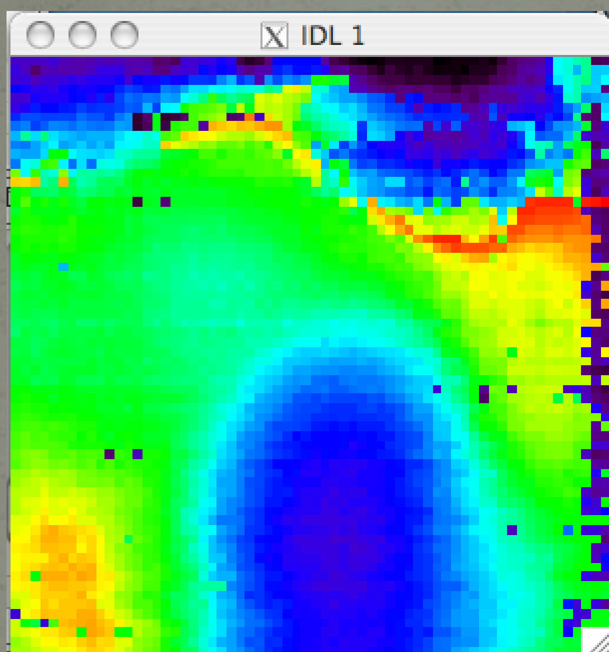
- The sealed, assembled sample is submerged in a tank of water with the same orientation as the seismic scans.
- A green laser illuminates the fracture plane.
- A syringe pump is programmed to deliver desired amounts of a fluorescent bead swarm through a needle placed directly above the fracture.
- A video camera records the path of the fluorescent beads as they fall through the fracture under gravity.

# Data Analysis

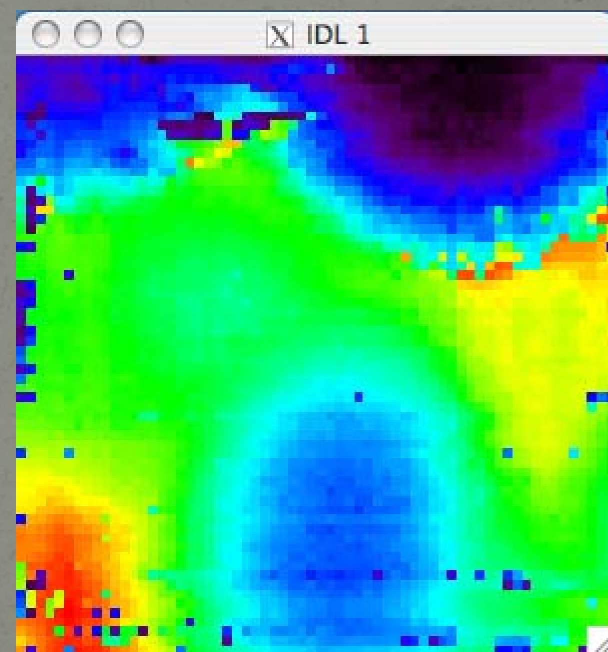
**Surface Roughness Front**



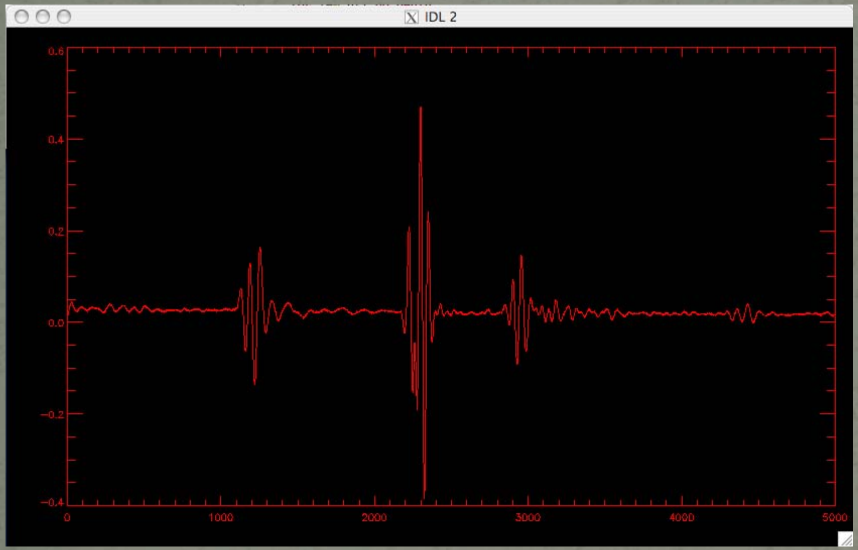
# Back half reflection



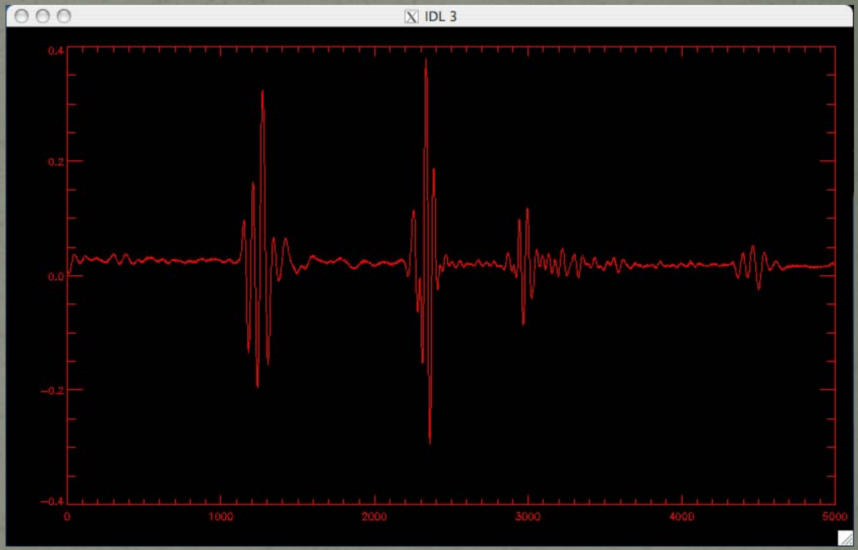

# Back reflection with fracture



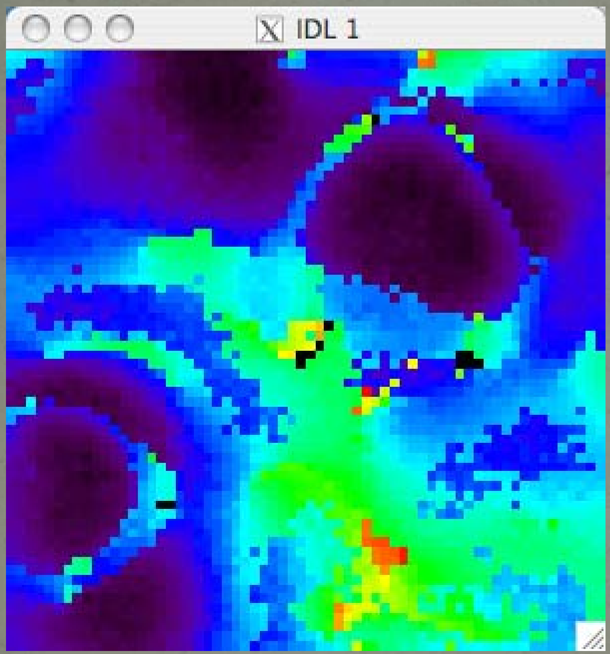
## Waveform back half reflection



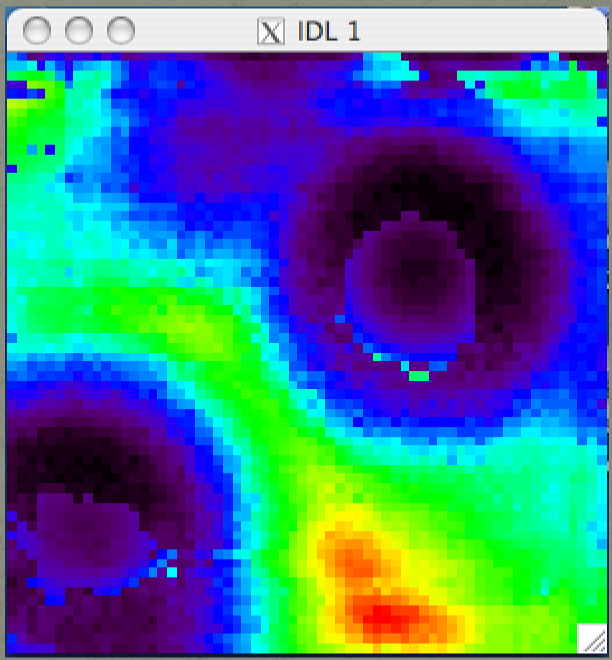

## Waveform back reflection with fracture



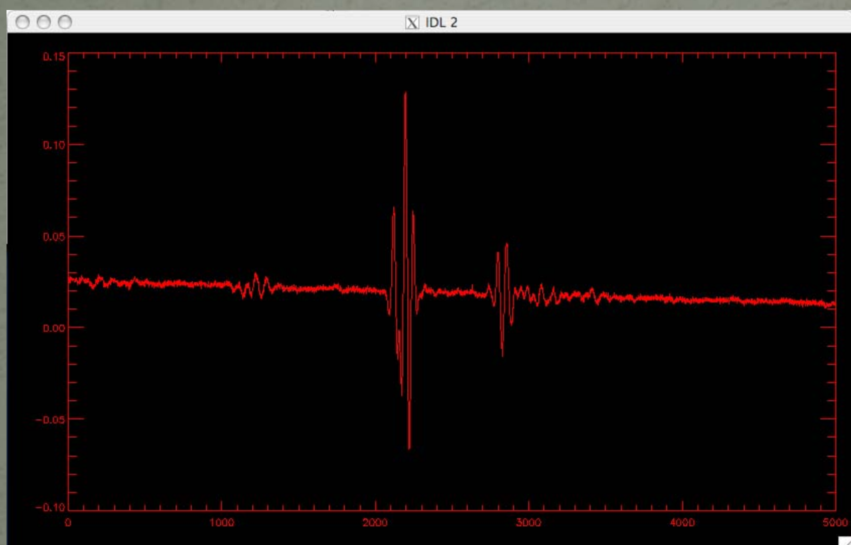
## Front half reflection



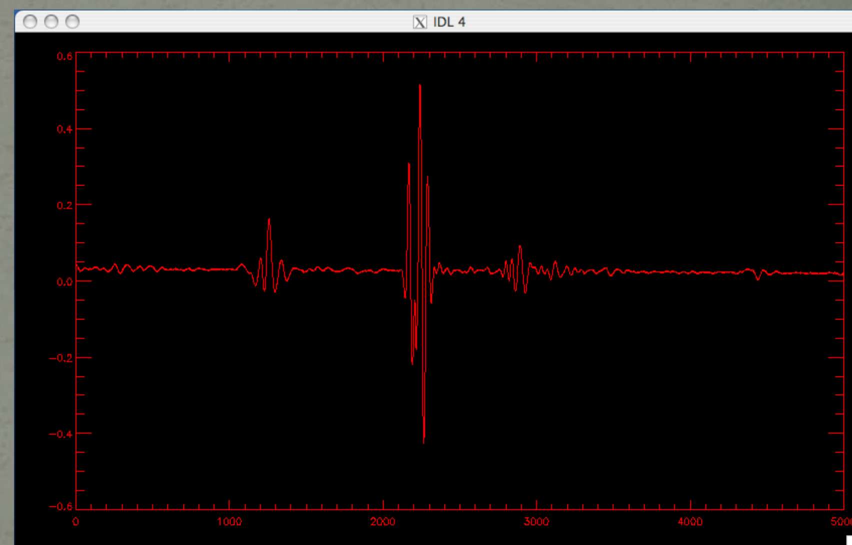

## Front reflection with fracture



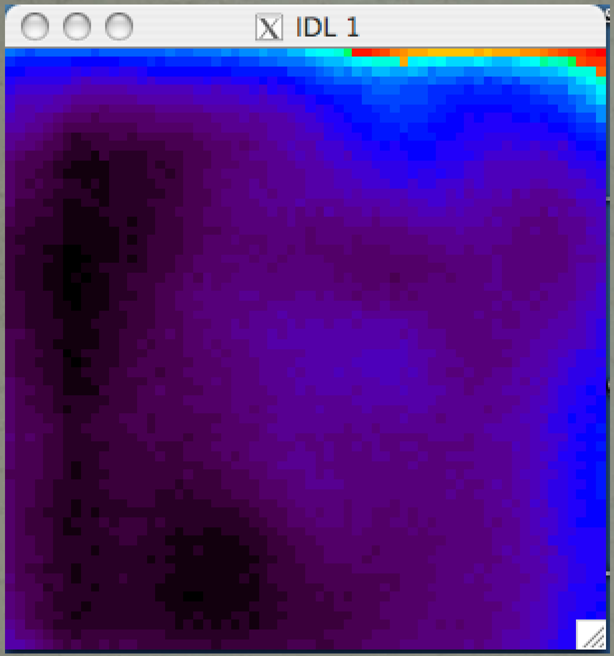
## Waveform front half reflection



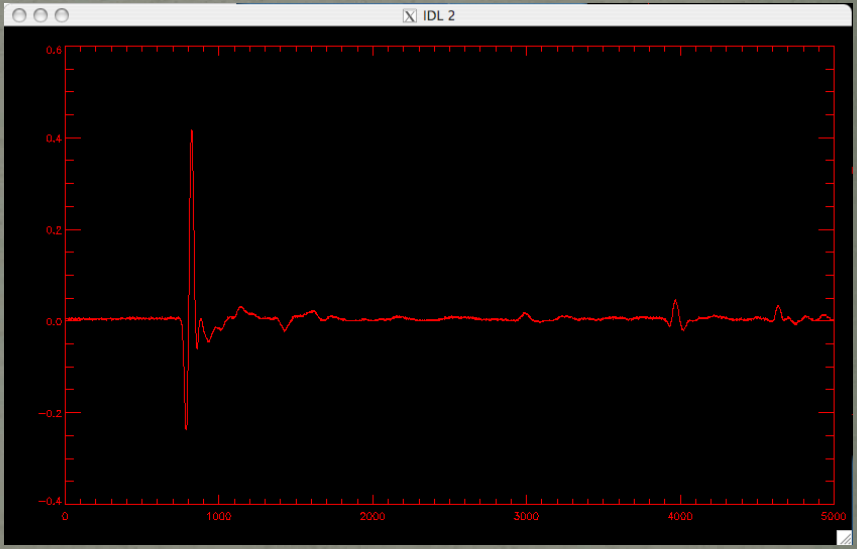

## Waveform front reflection with fracture



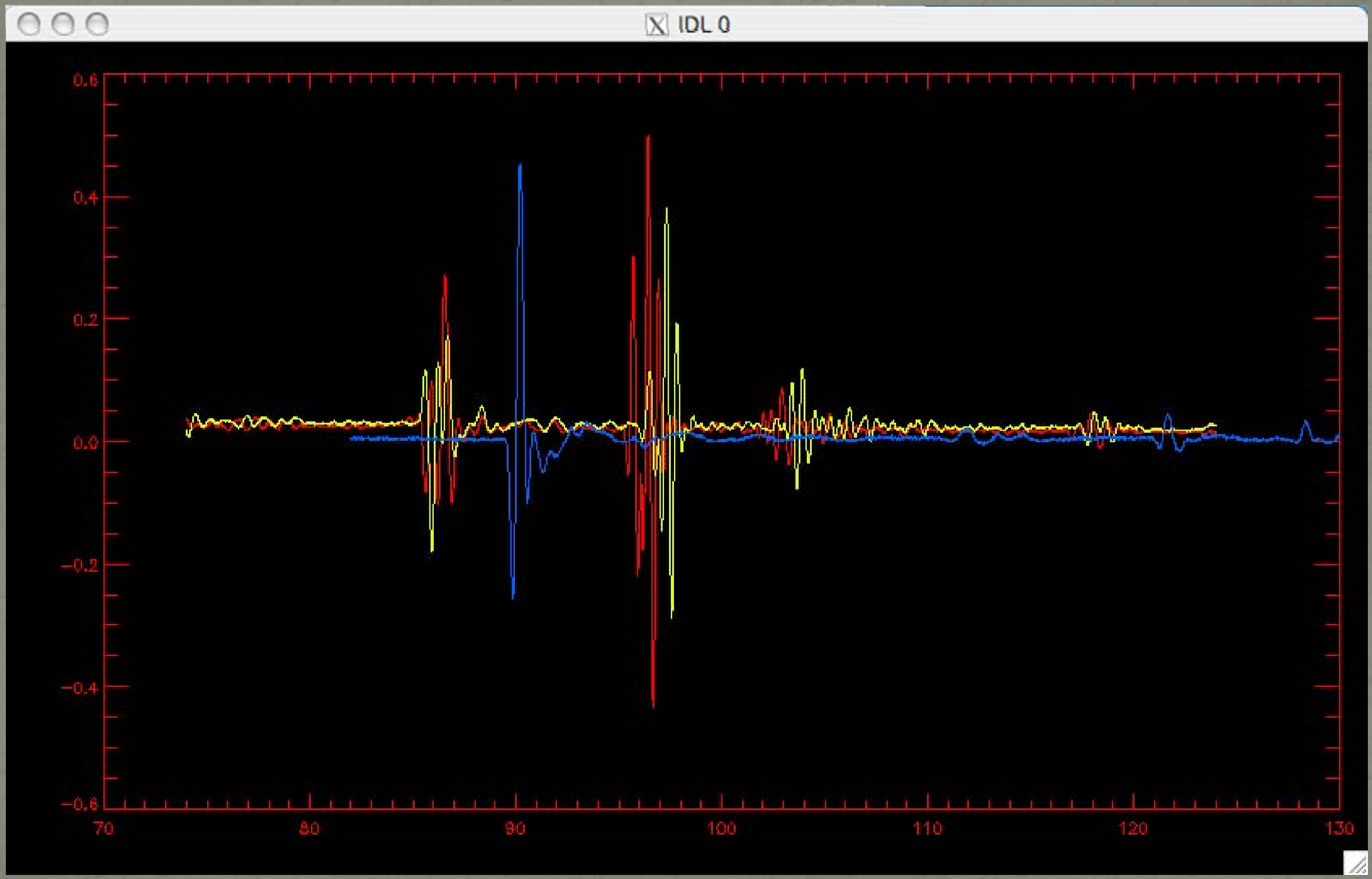
## Transmission



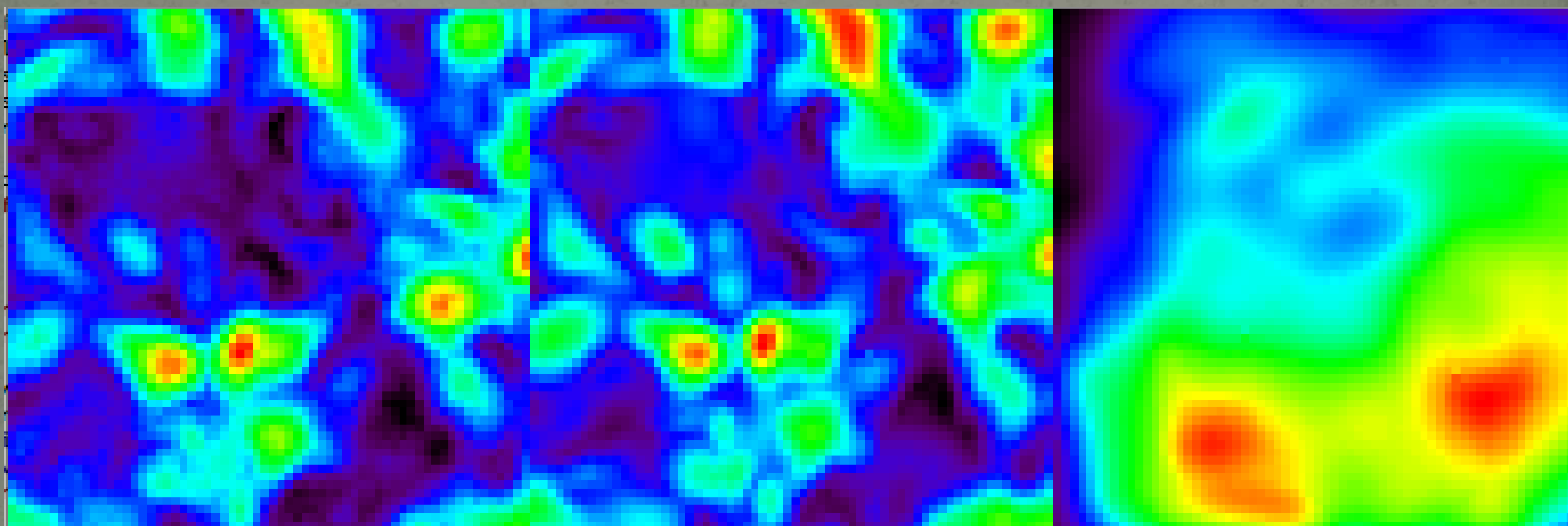

## Waveform Transmission

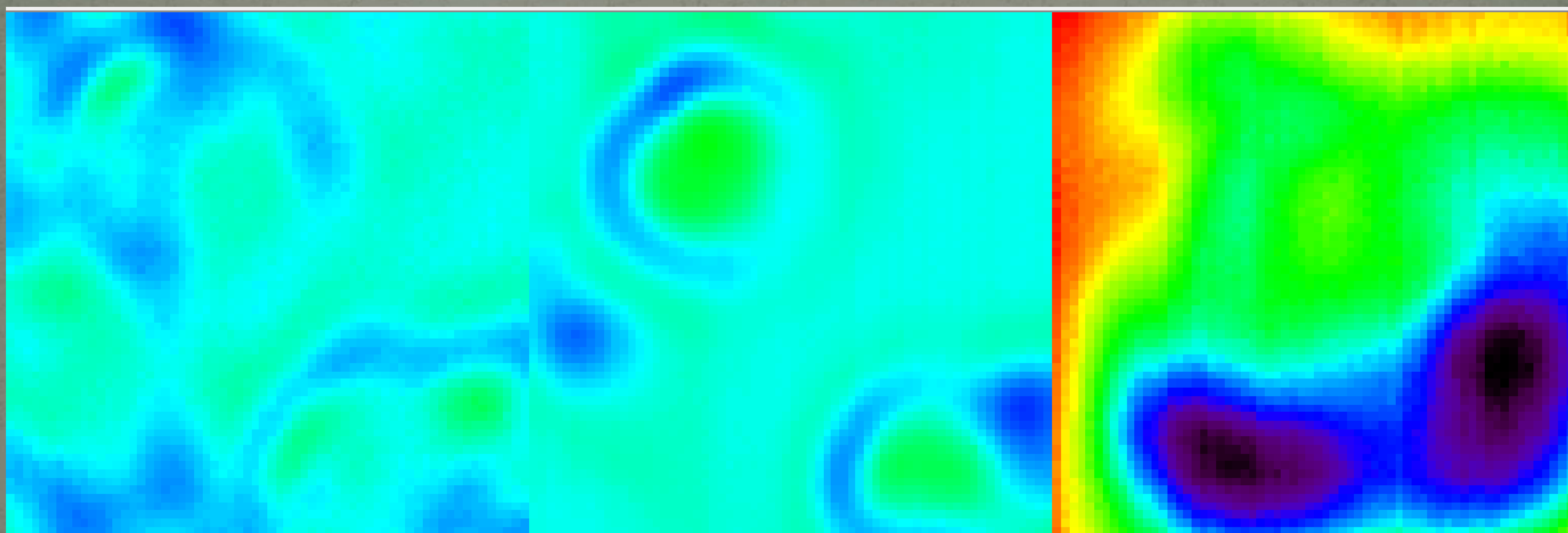


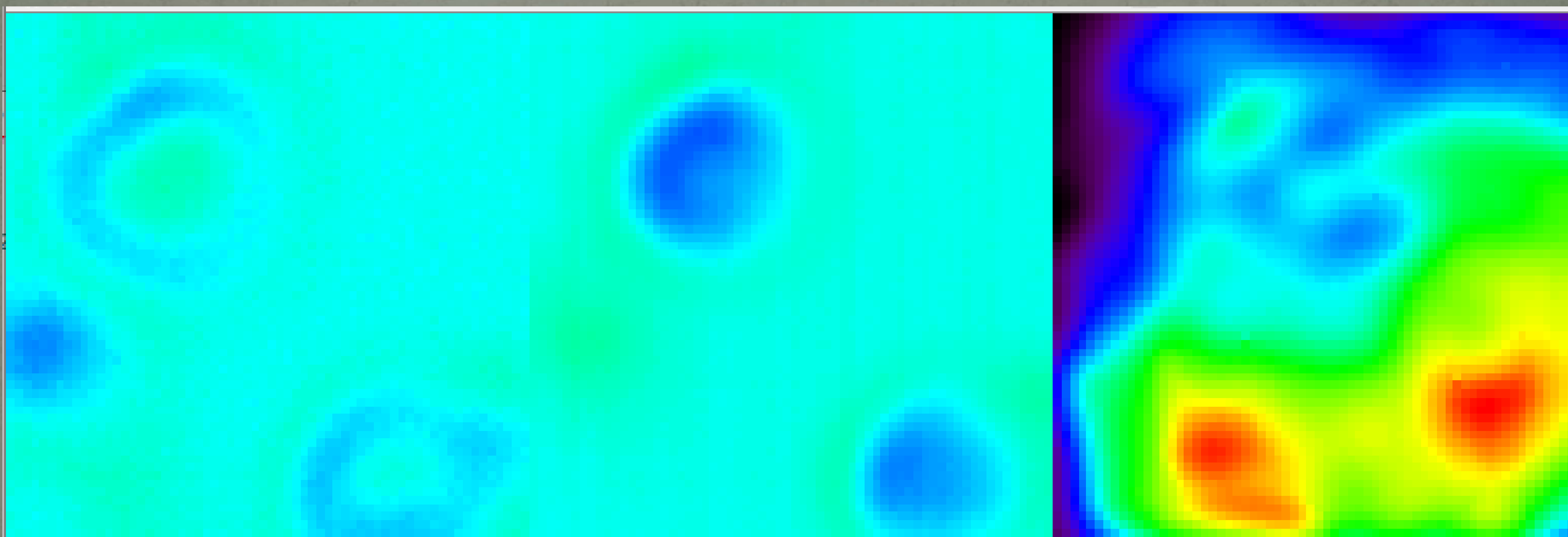
# Waveform comparison



# Amplitude Comparison







# Swarm Movies

## Swarm in tight fracture

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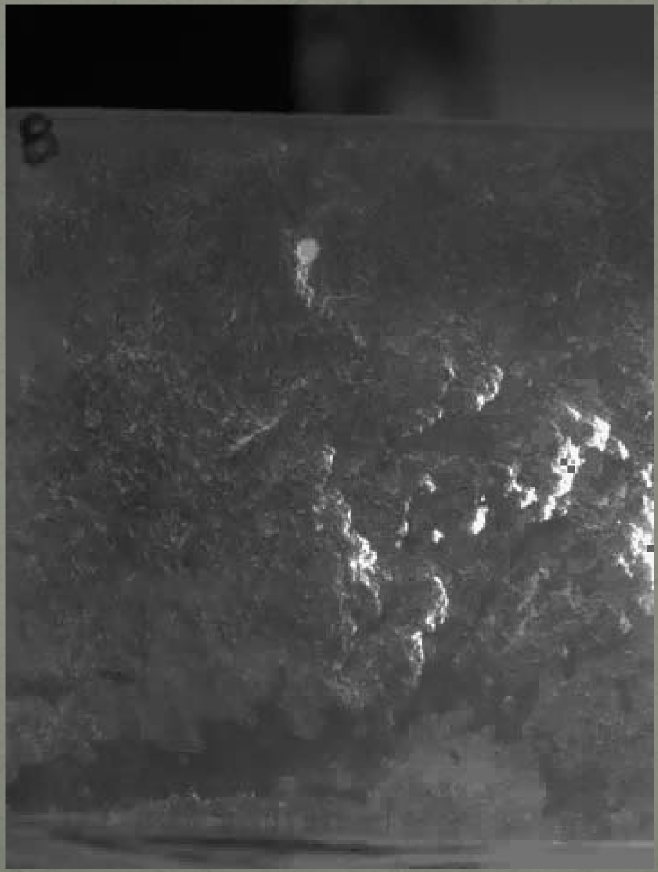
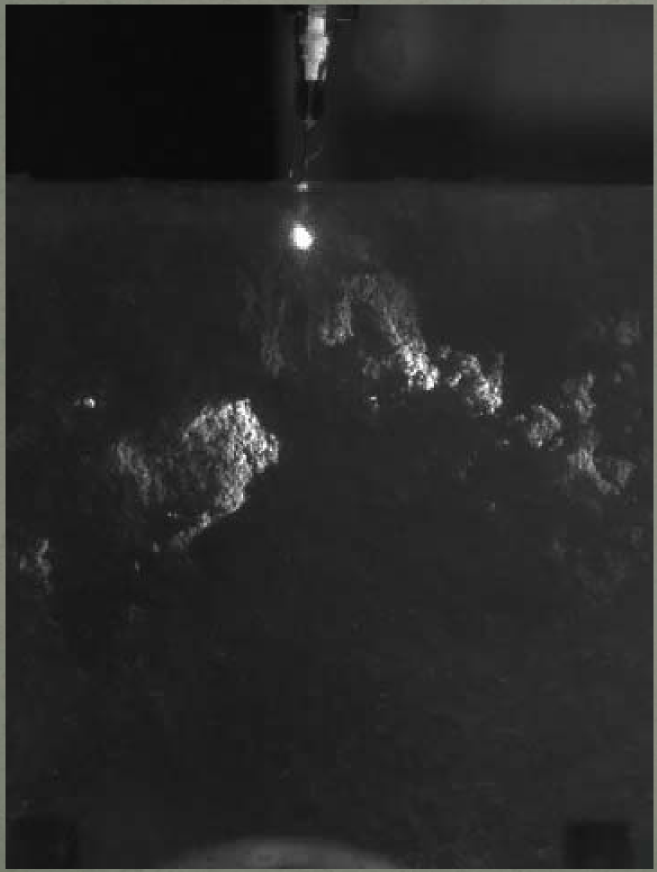
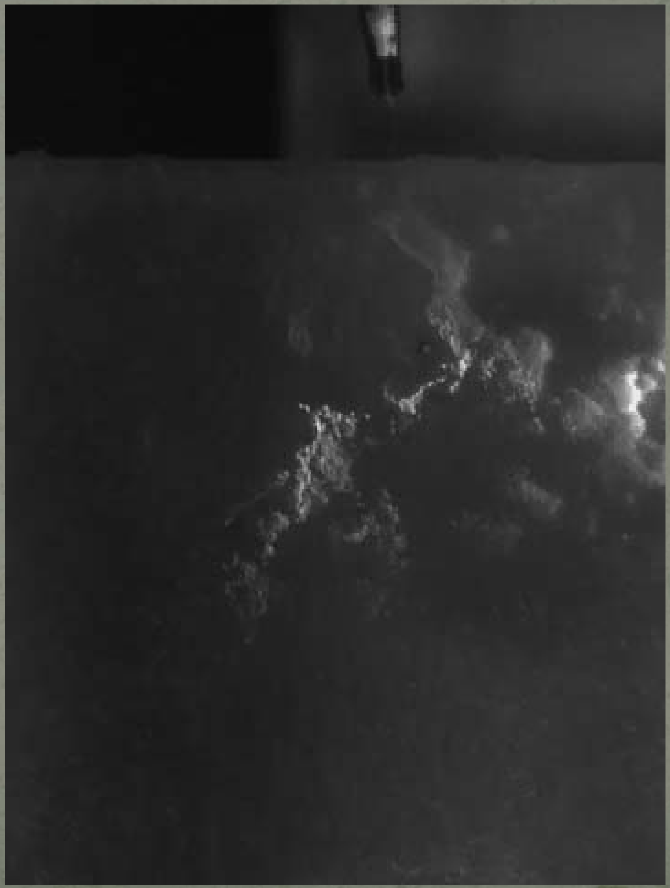


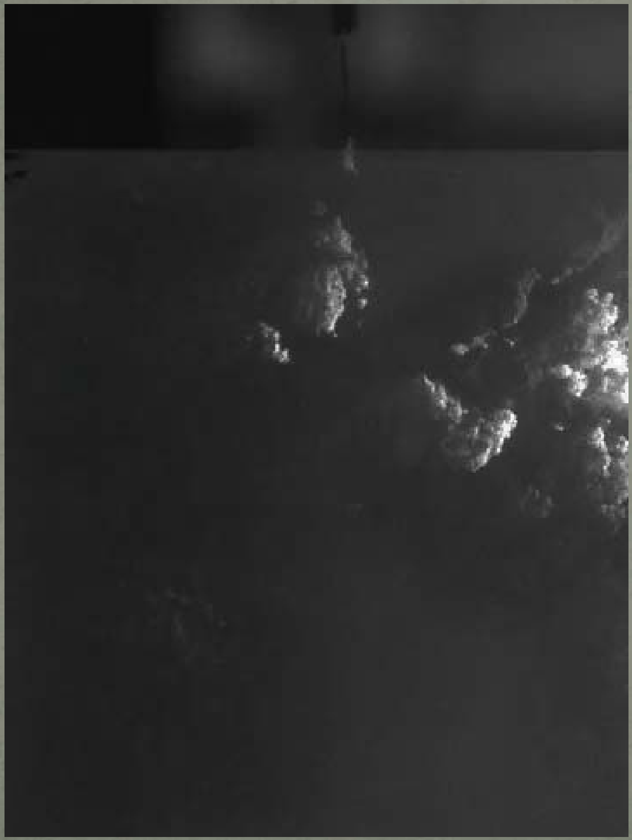
Swarm with wall 10 mm apart



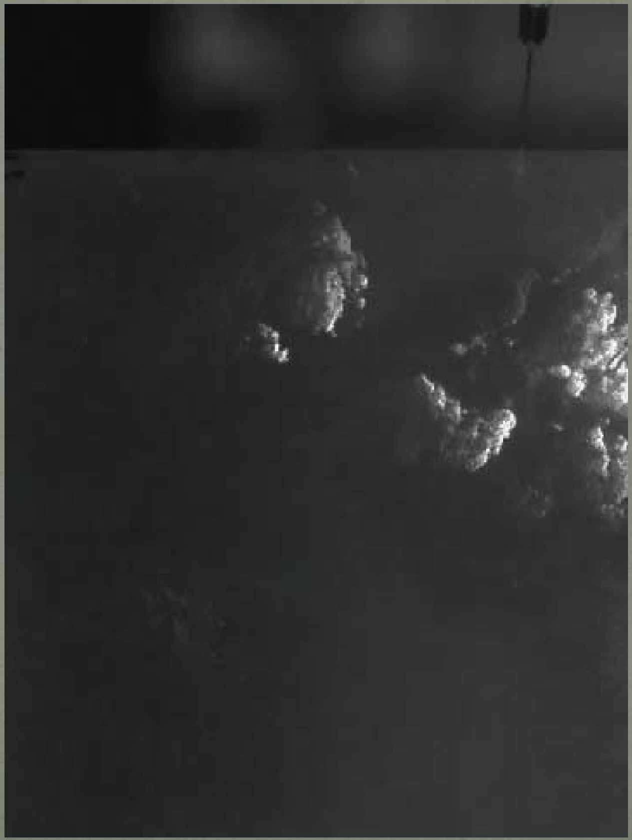
Swarm with walls 5 mm apart



## Swarm in 3 mm gap



## Swarm in 3 mm gap



# Conclusion

- Determining the dominant flow path was difficult from the amplitude data. First arrival data gave a reasonable image of the geometry of the fracture.
- Need more transmission data and further analysis of reflection data to make the best prediction.
- The swarm experiment was modified because the wall separation was too small.
- New procedure is to perform the swarm experiment first, then acquire seismic data of the sample.