

# Quantitative Description Of Surface Deformation Over Typical Horizontal Fractures

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13<sup>th</sup> David S. Snipes / Clemson Hydrogeology Symposium

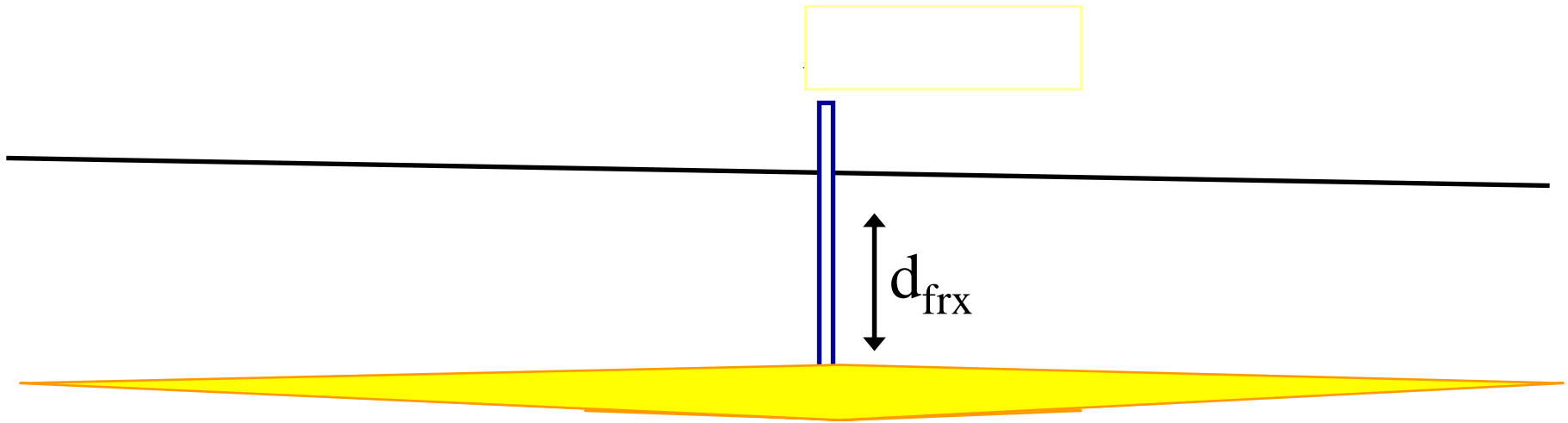
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# Creating a Fracture

*FR<sub>x</sub>*

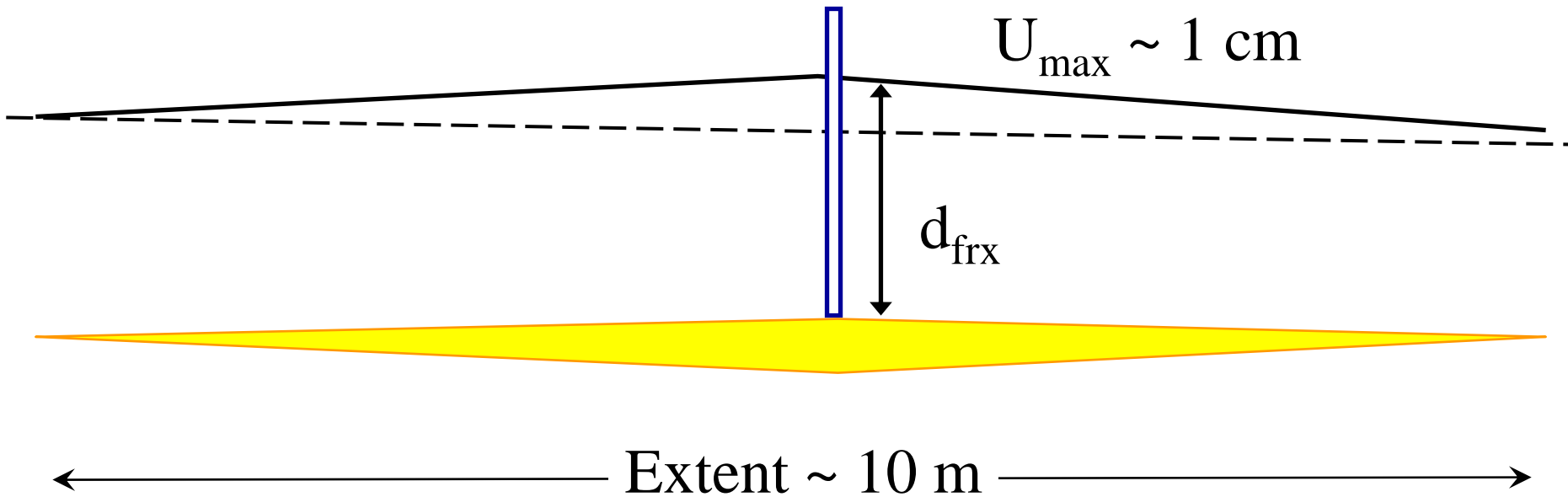


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# Surface Uplift

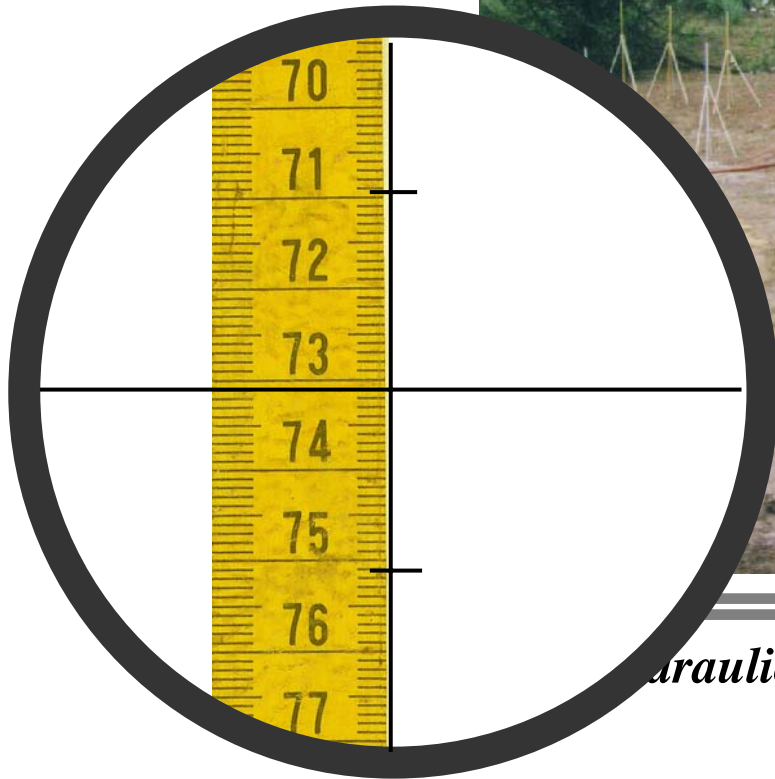
*FR<sub>x</sub>*



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# Measuring Uplift

FR<sub>x</sub>

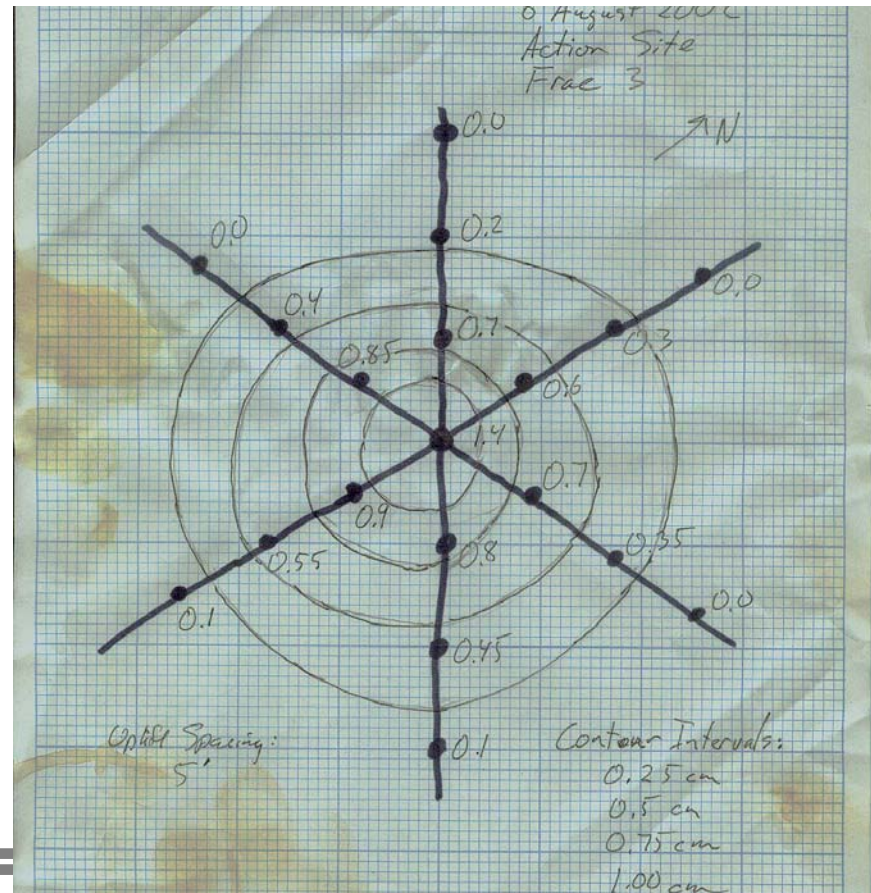


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# Qualitative Analysis

FR<sub>x</sub>

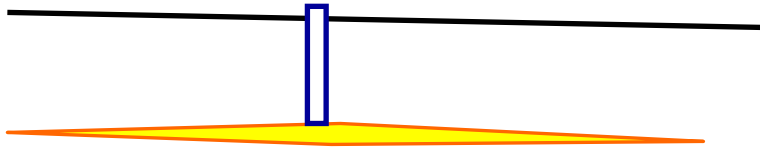
- ◆ Quick
- ◆ Easy
- ◆ No computer
- ◆ Do it in the field



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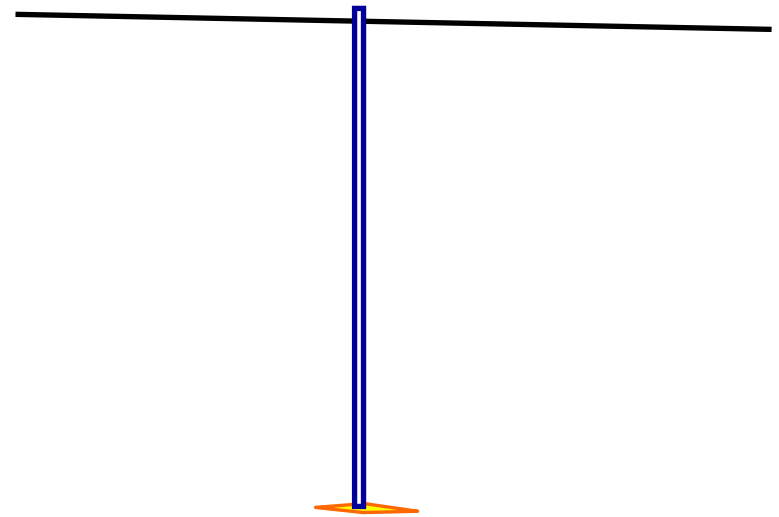
# Applicability

*FR<sub>x</sub>*



## ◆ Shallow Fractures

- » Explored
  - ✘ Excavation
  - ✘ Coring
- » Aperture & Uplift Correlated



## ◆ Deep Fractures

- » 3-D Effects ??

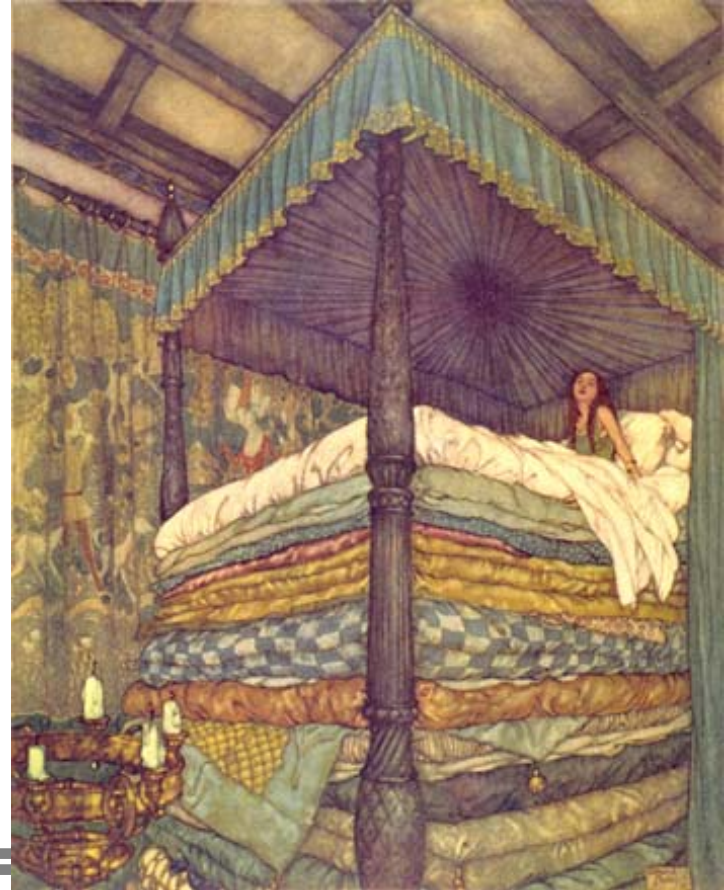
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# Princess & The Pea

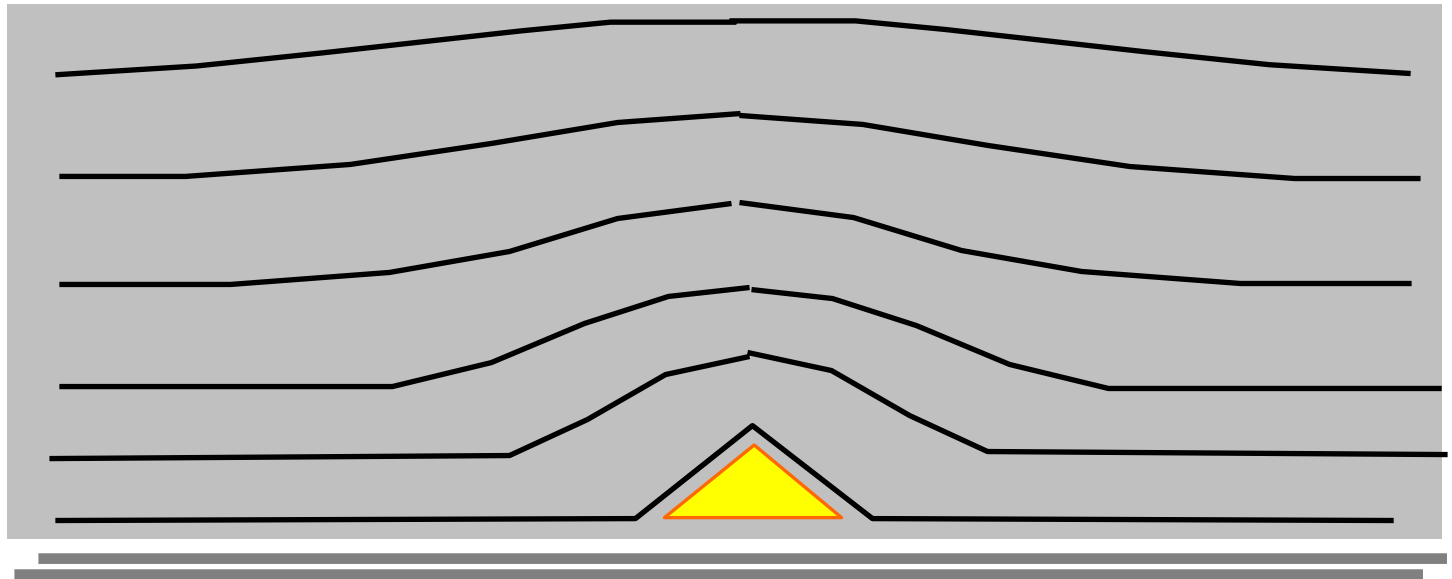
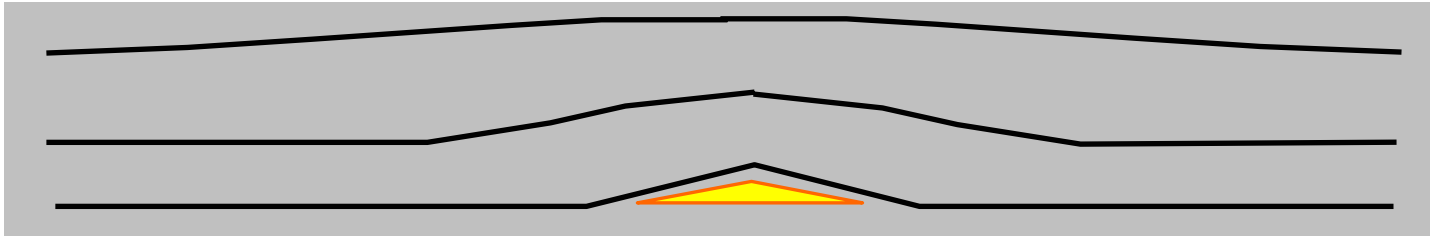
FR<sub>x</sub>

- ◆ Displacement by small object dissipates over distance.
- ◆ At increased distance, detection requires greater sensitivity.
- ◆ Quantitative interpretation needed to assess object dimensions



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# Non-uniqueness of Deformation $FR_x$



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# Challenge of Analysis

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*FR<sub>x</sub>*

- ◆ Accurate measurements
  - » Better survey systems
  - » Tiltmeters
  - » GPS
- ◆ Quantitative Interpretive Method

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# Dislocation Theory

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*FR<sub>x</sub>*

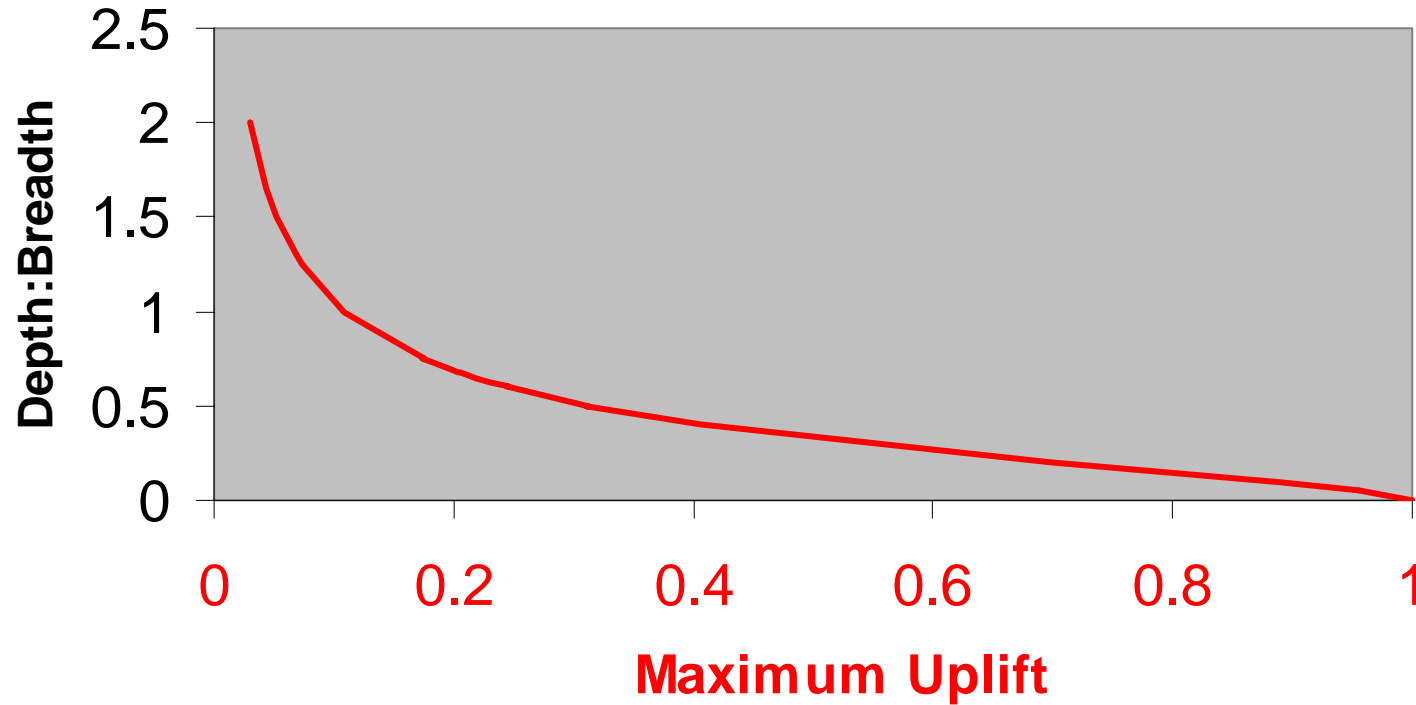
- ◆ Planar fracture
  - ◆ Multi-dimensional around the fracture
  - ◆ Arbitrary fracture orientation
  - ◆ Variable fracture aperture
  - ◆ Analytical
- 
- ◆ Davis (1983)      Yang & Davis (1986)

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# Attenuation of displacement

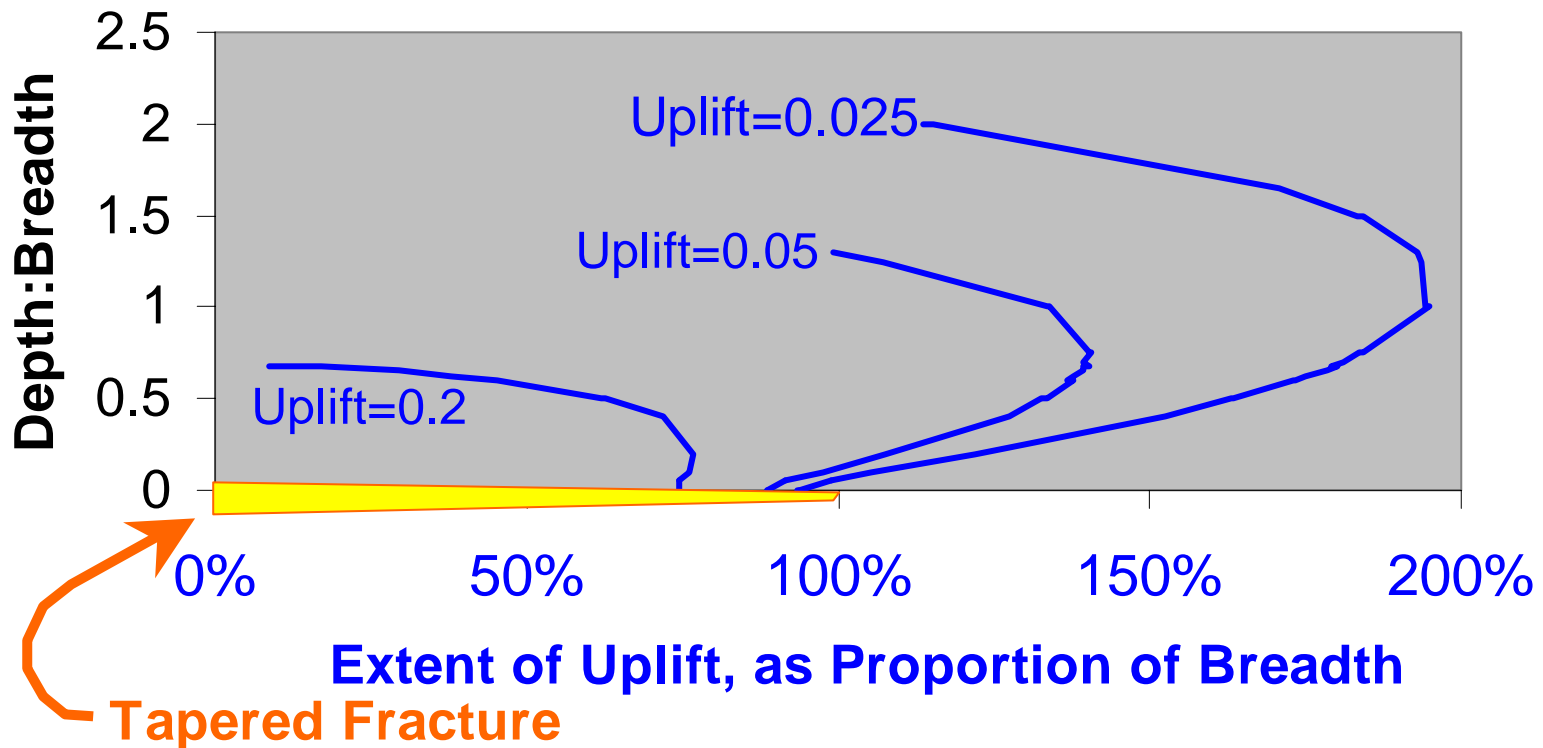
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# Area of Uplift Broadens

*FR<sub>x</sub>*



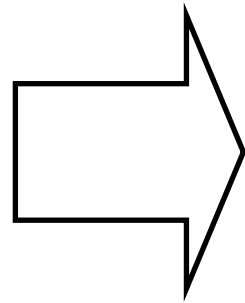
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# Inverse Applications

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*FR<sub>x</sub>*

*Set of  
Surface  
Data*



*Fracture  
Location  
Orientation &  
Dimensions*

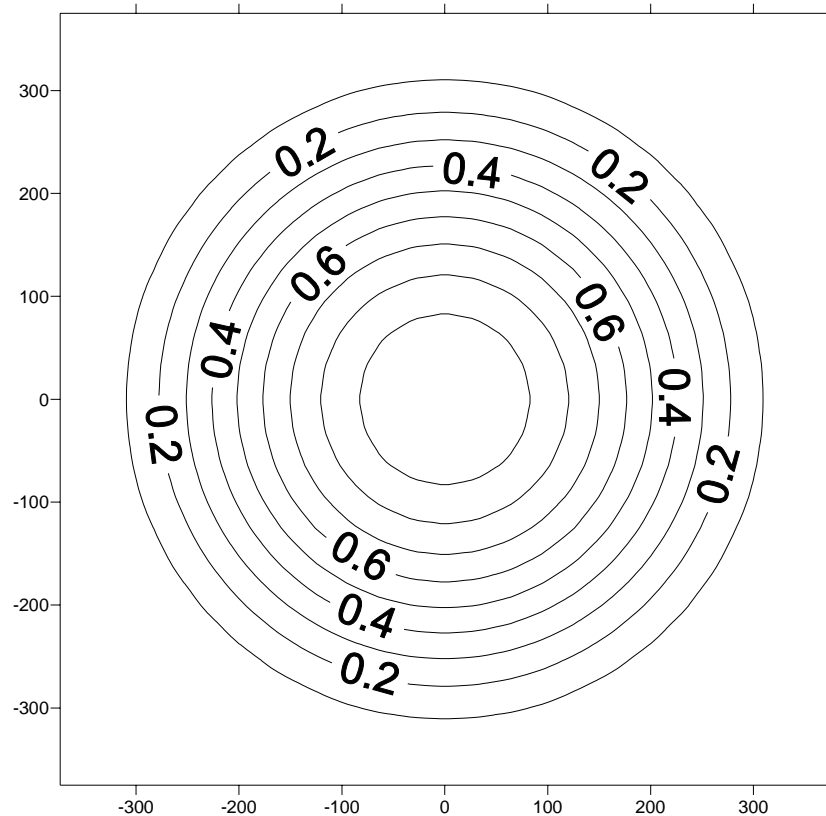
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# Hypothetical Fracture

FR<sub>x</sub>

- ◆ Dip: 5°
- ◆ Azimuth: East
- ◆ Depth: 750
- ◆ Diameter: 750
- ◆ Max Aperture: 1.0

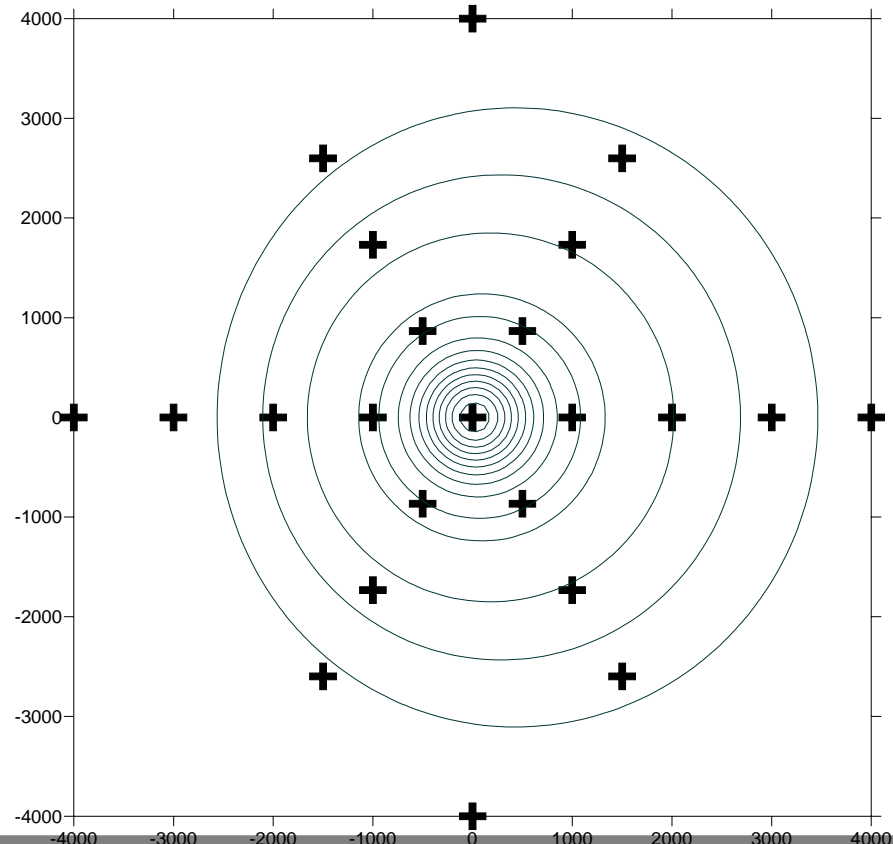


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# Hypothetical Uplift

FR<sub>x</sub>

- ◆ Maximum Uplift  
0.11
- ◆ Maximum tilt  
160  $\mu$ R
- ◆ Asymmetric
- ◆ Off-center

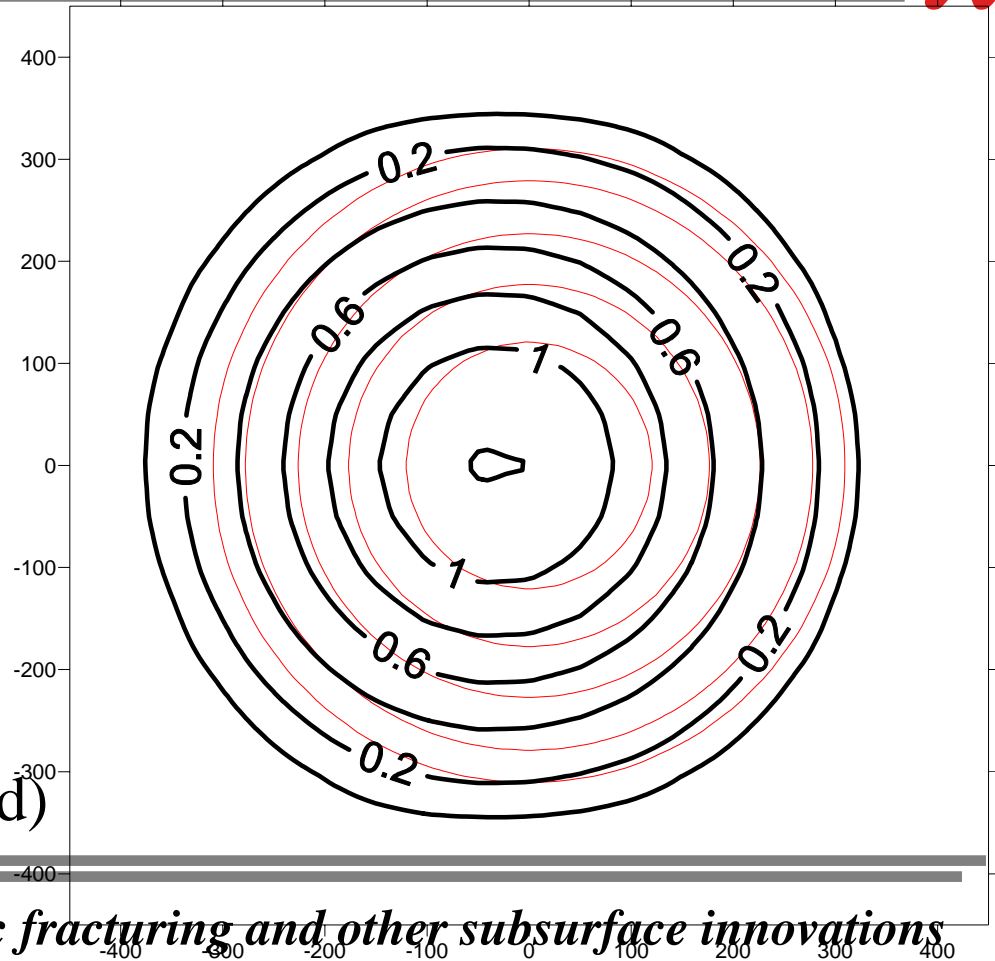


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# Inverse Results

FR<sub>x</sub>

- ◆ Dip:  $5.01^\circ$
- ◆ Azimuth: N115 ° E
- ◆ Depth: 752
- ◆ Diameter: ~800
- ◆ Max Aperture: 1.21
- ◆ Off-center
  - » (hypothetical frx in red)



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# Conclusions

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*FR<sub>x</sub>*

- ◆ Qualitative evaluation suitable for shallow fractures
- ◆ Deeper fractures can be monitored from surface
  - » If data are good
  - » If Quantitative method is used

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