

What I learned from large block testing (mine and others)

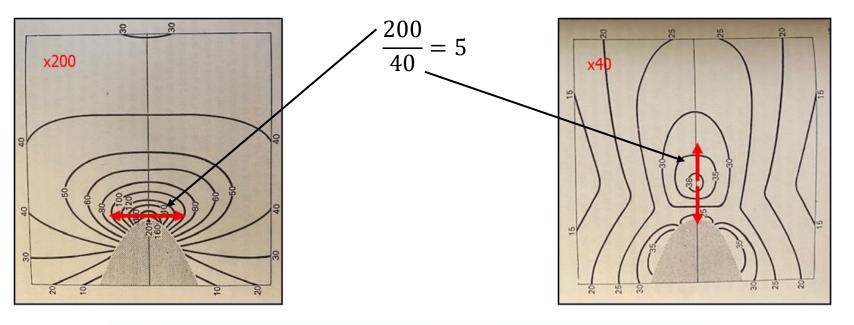
Large Block Hydraulic Fracturing in the Laboratory

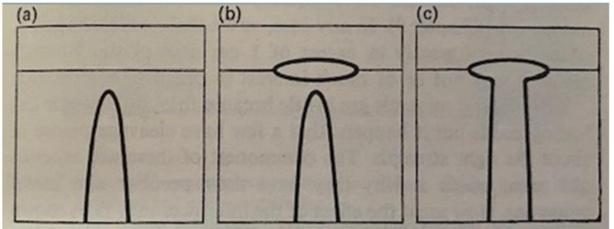
Roberto Suarez-Rivera

Sources of Toughness in Brittle Materials







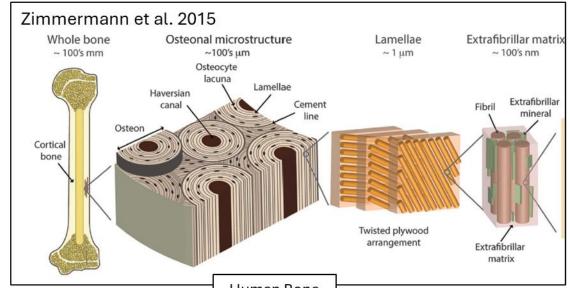


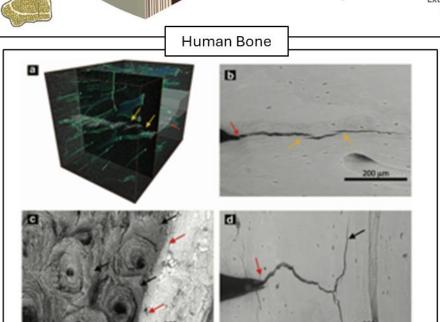
When the adhesive strength of the interface is less than 1/5 of the cohesive strength of the bulk material, the interface will be broken before the main crack reaches the interface and the crack propagation will be stopped J.E.Gordon, 1941.

Fractures in Biologic Materials





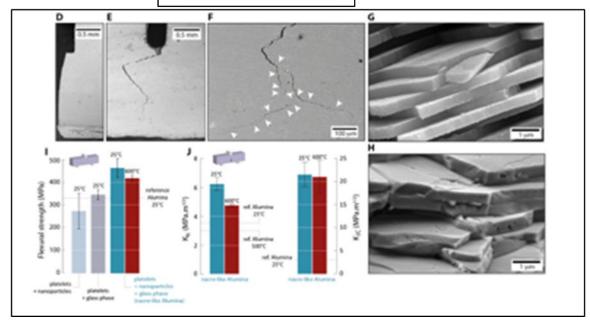






Tough Abalone Shells

Chen and Wang, 2012

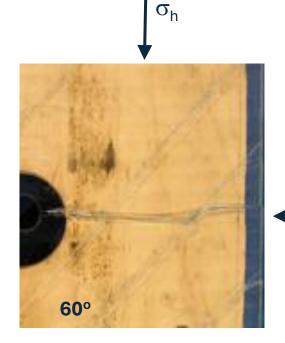


Weak Interfaces (Glass)

 σ_{H}







Fabric at 60°

- The thin bonded interfaces (fabric) are not invisible to the fracture.
- ➤ Branching or step overs were observed when the fracture crossed the interface.
- The stress contrast and the orientation of the bonded interfaces controls the degree of step over and branching.

Textural complexity implies fracture complexity



 σ_{h}

45°

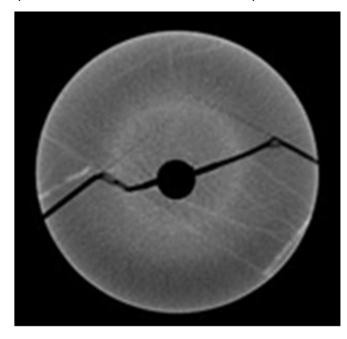
 σ_{H}

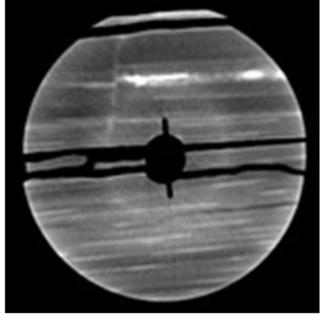
Weak Interfaces (Barnett Shale)





(TerraTek US Patent 4,152,941)





Sample is subjected to an external uniform confining stress and an internal pressure. Thin interfaces control the direction of propagation

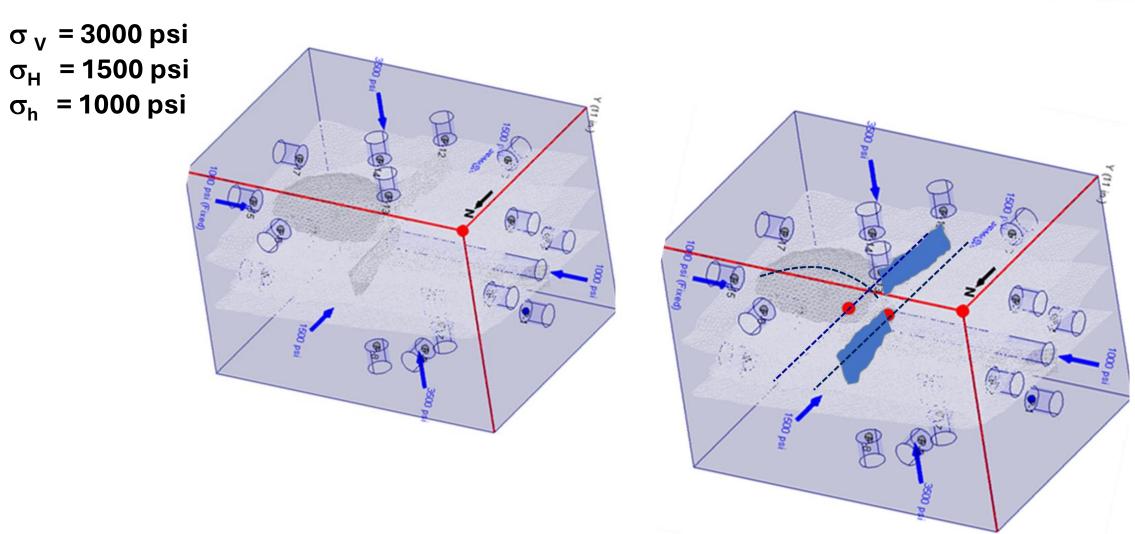
The axis of the cylindrical sample is oriented parallel to bedding (weak planes). Despite the stress concentrator, fractures follow the direction of weakness



Weak Interfaces (Mancos Shale)







Weak Interfaces (Mancos Shale)







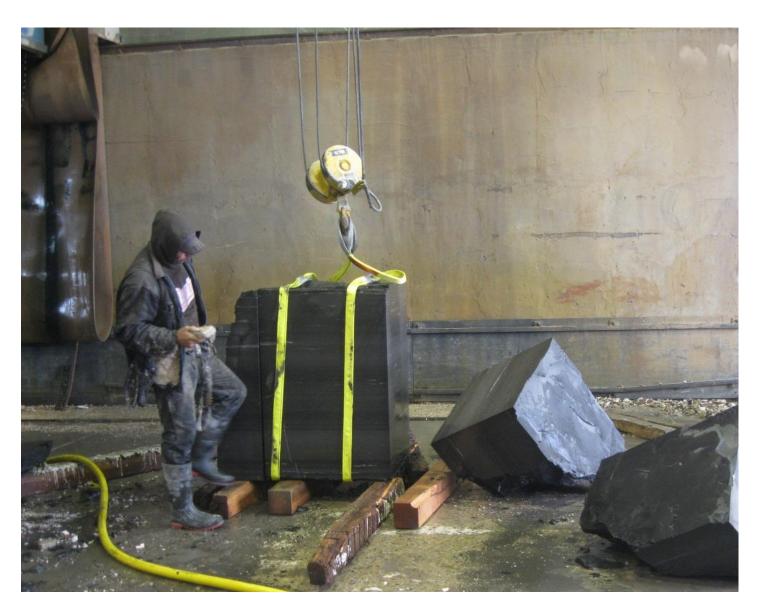
Large Block Testing (Niobrara Shale)





TerraTek 2014





Large Block Testing (Niobrara Shale)





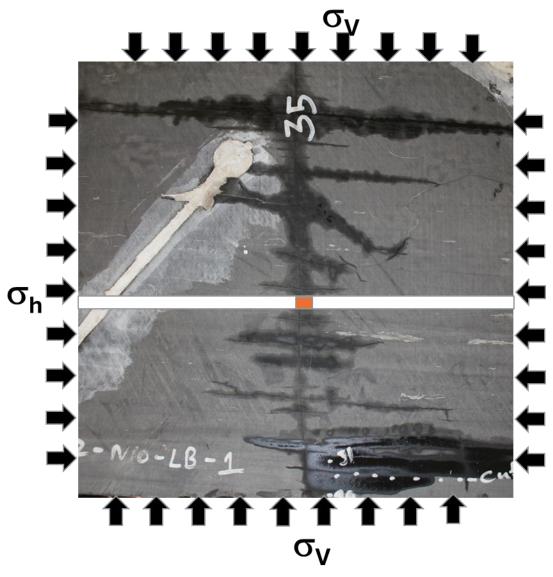




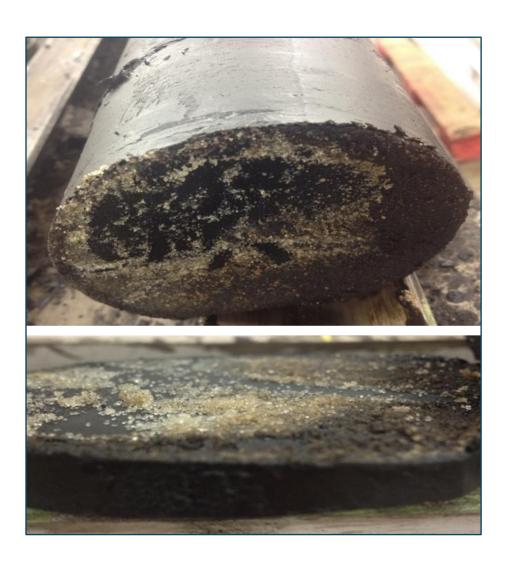
Horizontal Fracture Segments (Niobrara Shale)







IPTC-17018 • The Effect Of Rock Fabric On Fracture Complexity • Beijing, China 2013



Propped horizontal fracture in Eagleford vertical pilot well with core. (Suarez-Rivera et al., 2016 URTEC)

Horizontal Stepovers (Niobrara Shale)





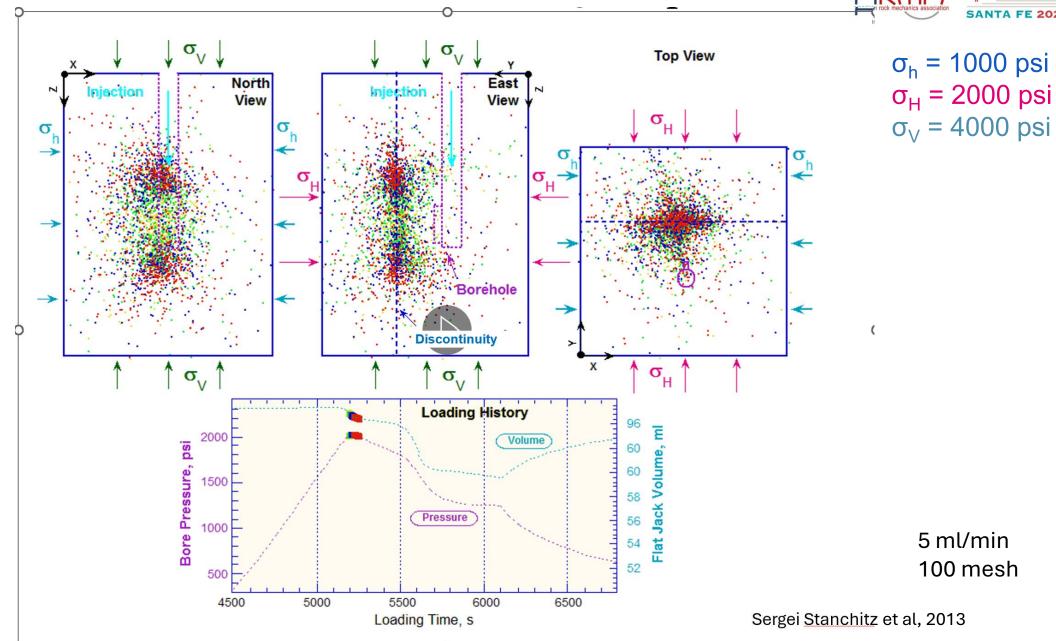


SPE166505 Regions of hydraulic fracture connectivity R. Suarez-Rivera

Weak Interfaces (Colton Sandstone – 1500 cp)



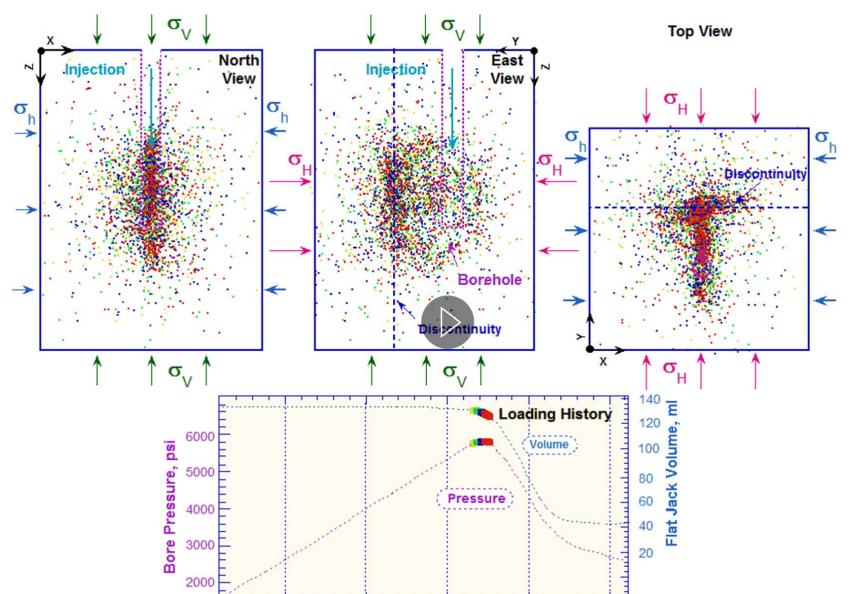




Weak Interfaces (Colton Sandstone – 2.5Mcp)







600

Loading Time, s

700

800

500

400

 $\sigma_{h} = 1000 \text{ psi}$

 σ_H = 2000 psi

 $\sigma_V = 4000 \text{ psi}$

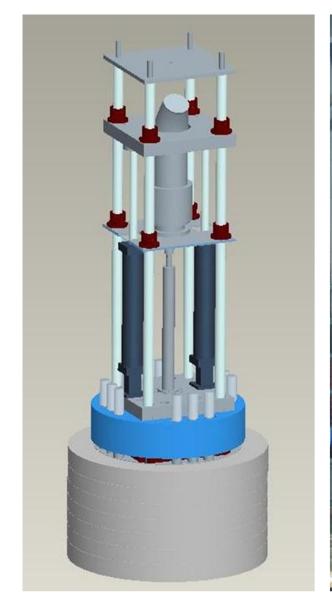
30 ml/min 30/60 Bauxite

Sergei Stanchitz et al, 2013

Near-Wellbore Effects (Mancos Shale)

















Near-Wellbore Effects (Mancos Shale)





 $\sigma_h = 3500 \text{ psi}$

 $\sigma_{H} = 5000 \text{ psi}$

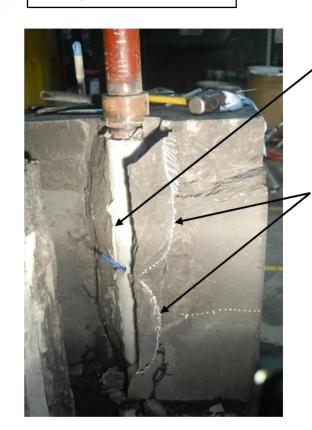
 $\sigma_V = 2750 \text{ psi}$

3-in OD Csg.

Intersection of longitudinal & transverse fracs

Transverse frac

Longitudinal fracs



Primary longitudinal first fracture

Transverse fractures turning into a longitudinal fracture?

Block is stressed prior to drilling. Perforating (2.25 in gun with 3 changes phased ±30 deg) with top/down orientation

L. Behrmann, 2010

Summary





1.- Weak Interfaces Influence Fracture Toughness

- Layered rocks with weak planes exhibit increased fracture toughness.
- The ratio of adhesion strength (tensile strength of the weak planes) to cohesion strength (tensile strength of the rock matrix) determines whether fractures are arrested or propagate less easily.

2.- Horizontal Fractures Can Occur Despite Vertical Stress Dominance

- Large block tests and field observations confirm that horizontal fractures form even under a dominant vertical stress.
- This is due to the significant difference between vertical and horizontal tensile stresses at weak interfaces (Gordon, Grasselli) and local variations in in-situ stress due to rock heterogeneity.

3.- Complex Near-wellbore Fracture Geometries Are Expected in Hydraulic Fracturing

- Longitudinal and transverse fractures frequently appear in experimental settings that simulate drilling, perforation, and fracturing.
- These types of fractures should be considered as realistic outcomes in field operations.

4.- Fracturing Behavior Under Non-Principal Stresses

- Though fracturing from inclined wellbores is uncommon, results suggest that weak interfaces and perforation orientation strongly influence fracture initiation and growth.
- This applies to both horizontal and vertical wells when shear stresses are present in the reservoir.





Thank you