Natural Fractures and Their Importance to Production

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Permeability of Fractured Rock

Scale-up & Boundary Conditions

- uniform pressure drop
 - implies orthogonal permeability upstream of fractures is infinite (flow can redirect to largest fracture with little cost in energy)





Scale-up & Boundary Conditions

- analytical relations seem unrealistic
- test with ECLIPSE (600 ft x 600 ft region)
 - 5000 psi on left, 50 psi on right
 - 1 md matrix permeability



Uniform Pressure Drop - early

WATER-K10_E100, k = 1, 01-Jan-1983





58.7

Uniform Pressure Drop – steady state (k_{eq}=3750 md)



The University of Texas at Austin

Fracture are high perm pathway

but that doesn't tell the whole story...

Percolating Fracture Network

Cap Pressure = 0 psi max in matrix



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Percolating Fracture Network

Cap Pressure = 40 psi max in matrix





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Percolating Fracture Network

Cap Pressure = 400 psi max in matrix



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Natural Fracture Characterization: Failure modes

tension vs shear

Tensile vs Shear Failure

strong bonds tensile failure

weak bonds, shear failure



Fracture normal to least compression



Fracture oblique to max compression

shear

opening mode

Ductile vs Brittle → Shear vs Tension, Monterey Formation, California Stylolites = anti-cracks dissolution no planar surfaces in carbonates



Subsurface core, TX

outcrop, Monterrey, Mexico

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The importance of crack tips

Idealization of Fracture Geometry

Or finite features with tiplines and variable displacement profile (discontinuity)?





Fracture Tips are Key to Deformation

Crack Tip Displacement Modes



Mode I Fractures



Mode I Fractures







Mode II Fracture



volcanic propagating dike source

curving path indicates changing S₃ direction

Opening Mode Fractures: Shiprock dike

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volcanic source

Mixed Mode I-II Propagation





Mixed Mode I-III Fracture





Marcellus Mixed Mode I-III



Marcellus Mixed Mode I-III



Plumose structures

evidence of opening mode and propagation history

Intermittent Growth: Plumose structure on joints



Weber sandstone, Dinosaur National Monument

Plumose Structure = propagation direction



Fractures in Shale Plumose Structure = Opening Mode



Fractures in Sedimentary Layers

Impact of bedding planes

Confined Fractures in Core: Austin Chalk



Stratabound Fractures: Height << Length



Stratabound Fractures: Height << Length



Muddy Gap, WY

Comb Ridge, Utah

St. were

and the second

Spacing Proportional to Layer Thickness

Opening mode fractures confined to thin beds

- plumose indicates opening mode
- plumose tracks propagation sequence



Stress Shadow Proportional to Frac Height





Systematic Joints in Devonian Shale, Ohio, USA



Svalbard Fractures



