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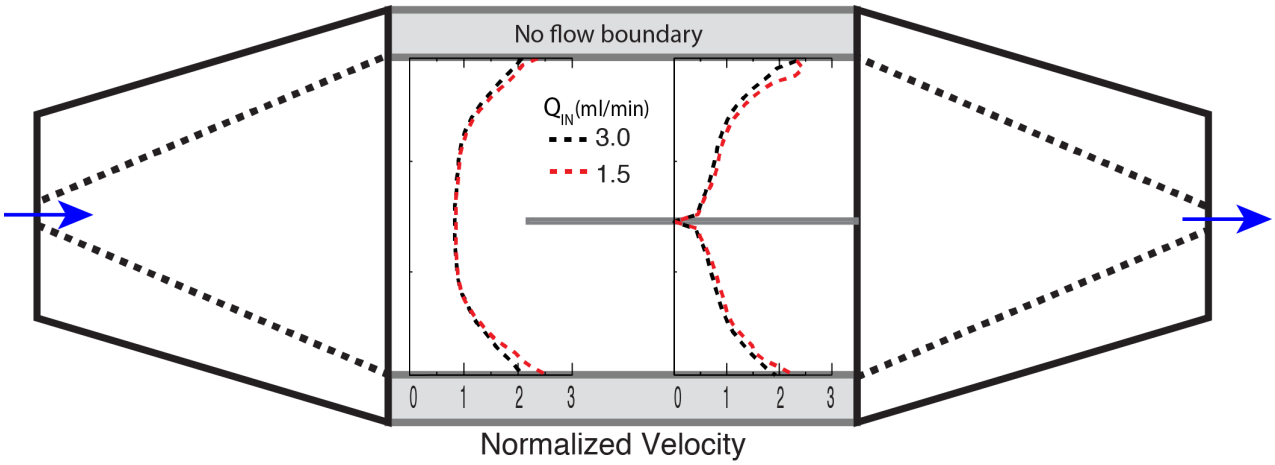
Flow of concentrated suspensions through fractures: Significant in-plane velocity variations caused by small variations in solid concentration

Ricardo Medina[1], Russell L Detwiler[1], Joseph P Morris[2,3], Romain Prioul[2] and Jean Desroches[4], (1)University of California Irvine, Irvine, CA, United States, (2)Schlumberger-Doll Research, Cambridge, MA, United States, (3)Lawrence Livermore National Laboratory, Livermore, CA, United States, (4)Schlumberger, Paris, France

Abstract Text:

Flow of fluids containing large concentrations of suspended solids through narrow fractures is important in subsurface processes where the permeability of the fracture is greater than the surrounding matrix (i.e. sand intrusion, environmental remediation, hydraulic fracturing, magma flow, and mud volcanoes). We present results from experiments in which a high concentration (50% by volume) of granular solids suspended in a non-Newtonian carrier fluid (0.75% guar gum in water) flowed through a transparent parallel-plate fracture. Digital particle-image-velocimetry analysis demonstrates the development of a strongly heterogeneous velocity field within the fracture that persists for the length of the fracture. The highest velocities were observed along the no-flow boundaries and the lowest velocities along the centerline; we carried out numerical simulations and additional experiments to elucidate this surprising result. Depth-averaged (2D) simulations using a rheological model of concentrated suspensions of mono-disperse solids in Newtonian fluids reproduced experimental observations of the velocity field when small (3%) variations in solid concentration were introduced. Such concentration variability led to significant (factor of two) velocity variations within the fracture yet negligible changes in observed pressure gradients. Two plausible explanations for solid-concentration variability are: *(i)* shearing of the fluid at the no-flow boundaries induced these concentration variations or *(ii)* they were induced by upstream boundary conditions. A second set of experiments was performed to identify which of the two phenomena caused the observed velocity variations. A narrow obstruction was placed along the centerline of the same cell; reduced velocities along the obstruction were observed, indicating that the observed velocity variations are the result of solid concentration heterogeneities that occurred in the upstream boundary and not from concentration heterogeneities developing inside the fracture. Our results suggest that small variations in solid concentration can lead to significant velocity variations such that a simple fracture-averaged conductivity may not reliably predict transport of suspended solids within fractures.



Plan view of fracture with narrow obstruction. Superimposed velocity profiles are representative of the observed flow behavior without (left) and with (right) obstruction. Velocity is highest near the no-flow boundaries, indicative of a reduced solid volume concentration near these regions.

Session Selection: Understanding coupled fluid flow, chemical reactions, mechanical deformation and transport throughout Earth's crust

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Submitter's E-mail Address: ricarm3@uci.edu
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First Presenting Author

Presenting Author

Ricardo Medina

Primary Email: ricarm3@uci.edu

Affiliation(s):

University of California Irvine
Irvine CA 92697 (United States)

Second Author

Russell L Detwiler

Primary Email: detwiler@uci.edu
Phone: 9498247125

Affiliation(s):

University of California Irvine
Irvine CA 92697 (United States)

Third Author

Joseph P Morris

Primary Email: JMorris4@slb.com

Affiliation(s):

Lawrence Livermore National Laboratory
Livermore CA (United States)

Schlumberger-Doll Research
Cambridge MA (United States)

Fourth Author

Romain Prioul

Primary Email: rprioul@slb.com

Affiliation(s):

Schlumberger-Doll Research
Cambridge MA (United States)

Fifth Author

Jean Desroches

Primary Email: JDesroches1@slb.com

Affiliation(s):

Schlumberger
Paris (France)

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