

# Hydraulic Fracture in Weak Rock

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Prof. Emmanuel Detournay, Theodore W Bennett Chair Professor in Mining Engineering and Rock Mechanics in the Department of Civil, Environmental, and Geo-Engineering of the University of Minnesota (UMN), will speak on Thursday, August 5, 2021.

The topic is “Hydraulic Fracture in Weak Rock.”

## **Abstract**

Waterflooding, a method used to increase oil recovery from an existing reservoir, relies on pumping water in injector wells over a period of months or years, to drive the oil towards producer wells. The efficiency of water injection treatments to stimulate production is predicated in part on the initiation and propagation of hydraulic fractures at injection wells, to ensure a more efficient sweep of the reservoir. The mechanics of these fractures is poorly understood, however, especially in weak, poorly consolidated rocks that are also highly permeable. Indeed, the theoretical framework developed for conventional hydraulic fractures breaks down, as the treatment efficiency is virtually zero and pore pressure perturbations in the reservoir occur over a length scale that is large compared to the fracture length.

Here we consider a KGD-type model that accounts for the large scale diffusion of pore pressure in the reservoir caused by the injection. This model, which has an explicit representation of the injection well, is based on the assumption that a bi-wing fracture initiates and propagates in a region where the pore pressure is quasi-equilibrated.

The explicit representation of the injection well is required to account for the a priori unknown partitioning of the injection rate into two components, one directly from the well into the reservoir and the other into the fracture inlets.

The fracture propagation is governed by a set of equations encompassing linear elastic fracture mechanics, poroelasticity, and lubrication theory. By using source and dislocation singular solutions, the problem is reduced to two singular integral equations (elasticity and porous media flow) and a nonlinear differential equation governing fluid flow inside the fracture. This system of equations only involves field variables defined on the fracture (fluid pressure, crack aperture, and leak-off). Discretization of these equations leads to the formulation of a time-dependent nonlinear system of equations for the crack aperture at discrete locations, which is solved numerically.

A scaling analysis indicates that the solution only depends on a dimensionless time, on a dimensionless well radius, and on a poroelastic constant. The solution is shown to evolve from a small-time asymptotics, characterized by radial flow, to a large-time asymptotics, where all the fluid injected leaks into the reservoir via the fracture. Thus, at small time, the induced fracture is hydraulic invisible with the borehole pressure increasing with time. While at large time, the conductivity of the fracture is large enough that most of the fluid is attracted by the fracture, leading to a fracture-flow pattern. In this case, the borehole pressure decreases with time, as the crack propagates and the aperture increases. As a result, the peak borehole pressure reflects the transition between the two flow patterns, and not the breakdown of the formation as commonly thought.

## **Biography**

Emmanuel Detournay is currently the Theodore W Bennett Chair Professor in Mining Engineering and Rock Mechanics in the Department of Civil, Environmental, and Geo-Engineering of the University of Minnesota (UMN). He holds a mining engineering degree from the University of Liège, Belgium and MSc and PhD degrees in Geoengineering from the UMN. Prior to joining the UMN in 1993 as a faculty, he held various positions in consulting companies (Itasca, Minneapolis, MN; Agbabian Associates, El Segundo, CA) and in R&D (Dowell-Schlumberger, Tulsa, OK; Schlumberger, Cambridge, England). His expertise is in petroleum geomechanics, with two current research focuses: drilling mechanics (bit/rock interaction, self-excited drilling vibrations, drillstring/borehole interaction, and directional drilling) and mechanics of fluid-driven fractures (asymptotic analysis, scaling, numerical modeling). He has co-authored about 120 papers in refereed publications and also about 125 conference papers. He also been awarded 7 US patents and has received several scientific awards for his work. In 2016 he was elected into the US National Academy of Engineering.