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Ontogenesis Of Hydrofracturing: Pore Pressure Diffusion And Its Implications For Stress Dependant Matrix Permeability Stimulation

I. Ghani (1), D. koehn (2), and R. Toussaint (3)

(1) Johannes Gutenberg Universität Mainz, Geosciences, Tectonophysics, Mainz, Germany (ghani@uni-mainz.de, +49 (0)6131 3923863), (2) School of Geograyphical and Earth Sciences, University of Glasgow, UK, (3) Institute of Globe Physics in Strasbourg, Universite Louis Pasteur, France

Hydrofracturing is a common and important geological process that engineers different structures of varying scales in a variety of geological settings in the upper Crust. Many natural examples of joint and vein networks in layered rocks manifest porosity-effective stress relationships during deformation processes that are principally led by transient pore fluid overpressure.

Local stimulation of extreme pore pressure by certain fluid expansion mechanisms in reservoirs tenders the evolution of effective stress, which has been postulated to be highly sensitive to the reservoir's permeability. Changes in effective stress introduce appreciable poro-elastic response of the matrix inducing new fractures or opening/closing existing faults and fractures.

In this contribution, we investigate three aspects of time dependant dynamic mechanisms of hydro-fracturing at micro scale: (1) evolution of local effective stress by pore pressure, (2) permeability enhancement with respect to elastic deformation of host rock and (3) fracture propagation as long as fluid pressure heads the tensile strength of the rock.

The numerical scheme is a 2d coupled hydro-mechanical model, which integrates DEM and a supplementary continuum description. It resides two overlapping areas in physical space, where one represents the solid media, which constitutes a small-scale triangular discrete spring network of the software 'Latte' (Elle) and is hybridized with the other large-scale (fixed) square lattice of continuum description. A general form of the macroscopic diffusion equation of pressure is given by the compressible Navier-Stokes equation that is derived by ensuring conservation of mass of the fluid and solid media along with local Darcy's Law. Finite difference ADI method is implemented on the square lattice for the pressure discretization (hydrodynamic) in order to acquire pressure diffusion. The hydraulic head then contributes to the net force on each particle in the elastic lattice through a smoothing Tent function.

Hydrofracturing is studied with two cases, which are different with respect to the inhomogeneity in mechanical (young modulus) and material properties of an overpressure fluid regime. The modeled exercises validate the method and define the coupled problem of spatial and temporal response of the elastic matrix to effective stress evolution and vice versa due to pore overpressure. It is found that fluid overpressure in the host media contributes to the tensional/compressional stress field within the overlying rock with respect to its mechanical and lithological properties and may trigger either hybrid extension/ shear fractures or prolong extension fractures under gravity with a local stress relief. In addition, if the internal fluid pressure is the only loading, the stiff lithologies accommodate high differential stress comply brittle deformation and favor hydrofracture propagation. On the contrary soft layers behave as stress barriers and are subject to ductile deformation and host pure shear fractures.