Hydromechanical Modeling of a Fault Gouge Using a Discrete Element Method Approach

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Résumé

Fault zones play a crucial role in regulating subsurface fluid flow and mineralization. Their dual ability to act alternately as barriers or conduits is governed by complex interactions between multiphysics processes (thermal, hydraulic, mechanical, chemical) operating across multiple spatial and temporal scales within their structure. Focusing on the gouge scale, this work aims at investigating the hydromechanical behavior of faults using a discrete element method (DEM) approach coupled with a pore-scale finite volume (PFV) scheme. Similarly to the approach proposed by Nguyen et al. (2021), the DEM is used to model the gouge material while the PFV method is used to model the fluid flow within the pore space. Both numerical schemes are coupled in the sense that any deformation of the solid phase affects the fluid flow and, conversely, any variation in pore pressure induces deformation of the medium. Discrete models of fault gouges have proven successful in reproducing key fault behaviors, such as stick–slip dynamics in fluid-saturated gouges (Dorostkar et al., 2017), and frictional healing observed in slide–hold–slide sequences (Ferdowsi and Rubin, 2021). Nonetheless, some gaps remain in our understanding of the physics behind the mechanisms controlling the interplay between fault reactivation and fluid migration. In this study, we investigate the capability of our discrete model to capture fault instability in presence of fluid and to provide grain-scale insights into key features of fault behaviors by: 1) elucidating the physics behind the phenomenological rate-and-state friction laws, and 2) understanding the origin of permeability changes during fault reactivation.

Mots-Clés: Fault gouge, DEM, Hydromechanical behavior, rate and state friction, Permeability changes.

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