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Evolution of Deformability and Transport Properties of Fractured Rocks Under the Action of Stress and Chemistry

Derek Elsworth (1), Josh Taron (2), Igor Faoro (1), Dae-Sung Lee (3), Jishan Liu (4), Andre Niemeijer (1,5), and Hideaki Yasuhara (6)

(1) Energy and Mineral Engineering, G3 Center and EMS Energy Institute, Pennsylvania State University, University Park, United States (elsworth@psu.edu), (2) Department of Environmental Informatics, Helmholtz Centre for Environmental Research - UFZ, Leipzig, Germany, (3) Department for Petroleum and Marine Research, Korea Institute for Geoscience and Mineral Resources (KIGAM), Daejeon, Korea , (4) School of Mechanical Engineering, University of Western Australia, Nedlands, Australia, (5) Instituto Nazionale di Geofisica e Vulcanologia, Rome, Italy, (6) Department of Civil and Environmental Engineering, Ehime University, Matsuyama, Japan

Fluids in the shallow crust exert important controls on a wide spectrum of natural and engineered phenomena. The complex interaction of stress and particularly that of chemistry exhibit important feedbacks which influence the evolution of the mechanical and transport properties of rocks. These feedbacks in turn relate crucially to the subsurface recovery of hydrocarbons from the full spectrum of conventional through unconventional reservoirs, to the recovery of hydrothermal and non-hydrothermal geothermal resources, to the secure and enduring sequestration of energy by-products, and to the earthquake cycle, for example. We report on enigmatic interactions between stress and chemistry in mediating the evolution of permeability and strength in natural and engineered systems pushed far-from equilibrium. These include the roles of excess pore fluid pressures in driving transient changes in permeability and as well as the influence of changes in chemical potential in systems driven far-from-equilibrium. These effects are shown to result in significant changes in permeability that may vary on timescales of minutes to years as feedbacks switch from mechanically-driven to chemically-driven and as the length-scale of the prototype grows. These interactions are explored through coupled modeling including feedbacks in stress and chemistry as relevant to high-carbon through low-carbon energy systems. Examples are selected to illustrate the significance of these interactions in controlling the response of hydrocarbon and geothermal reservoirs, fracture treatments and radioactive waste disposal.