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Discrete Element Modeling of Rock Deformation via Pressure Solution (PSDEM)

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Pressure solution is considered the most important ductile deformation mechanism operating in the Earths upper crust. Pressure solution (also termed chemical compaction) is a major player in a variety of geological processes, including evolution of sedimentary basins, hydrocarbon reservoirs, aquifers, earthquake recurrence cycles, and fault healing. Here we present a new numerical model of pressure solution, based on the Discrete Element Method. The new approach allows granular dissolution at stressed contacts between grains in the Discrete Element Method. The new model captures both the slow chemical compaction process and the more abrupt brittle fracturing and sliding between grains. Field observations of interactions between pressure solution features and veins, shear fractures and pull-apart are reproduced very well with the new Pressure Solution Discrete Element Method (PSDEM). PSDEM combines friction and brittle deformation with pressure dissolution on grain contacts, by allowing the grains to change size and shape as a function of the stress that is applied on their contact. A Rock is simulated as made of a collection of cohesive grains, each grain representing either a real grain or a unit of rock. Dissolution, i.e. mass loss, is represented by penetration of contacting grains into each other with a rate that depends on local conditions, while still maintaining a global balance of forces, accounting for other (elastic, frictional) material forces, and allowing large strains within the rock. This enables studying the effect of progressive dissolution on surrounding brittle deformation and stress.

We use our new model to study how the pressure solution mechanism interacts with frictional sliding, to investigate the role of stress and clays in controlling the pressure solution process. Our model shows that grain rearrangement and compaction rate driven by a combination of pressure solution and mechanical deformation depend on surface friction coefficient of grains. We also apply our model into simulation of stylolites via localization of dissolution. Simulation results show distinct brittle features, such as cracks that open between two stylolites, and a high porosity process zone at the tips of stylolites, which were observed in field studies of stylolites. These are modeled and predicted for the first time. Our new modeling tool holds a promise to provide many new insights regarding the coupling between pressure solution and brittle deformation, i.e. between mechanical and chemical compaction.