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Modelling coupled fluid flow and solid deformation with the viscoplastic rheology

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The coupling between fluid flow and solid deformation plays important roles in earth dynamics at different timescales and length-scales. Related processes include, magma migration and focusing in the Mid-Ocean Ridges, fluid migration after slab dehydration in the subduction zone, channelized fluid flow observed as seismic chimney in the continental margin, as so on. Here we study how localized fluid channels can develop through asymmetric compaction and decompaction processes of the solid matrix by solving coupled two-phase equations with viscoplastic rheology. Previous studies produced fluid channels with decompaction weakening, while negative effective pressure (P_t-P_f) is inevitable due to the simplified rheology formulation. We develop a viscoplastic rheology formulation that considers the effects of shear stress and plastic failure on the volumetric deformation, consistent with experimental data.

Our model results show that this new rheology can produce channelized fluid flow without negative effective pressure in the model. Our numerical results also clarified that it is the flow instability of the coupled two-phase system that cause the formation of fluid channels. The ratio between shear viscosity and bulk viscosity determines how fast the flow instability develops and manifests. The geometry of the Reservoir, on the other hand, can affect where the channels form. We further study the effects of different background and reservoir porosity, different rock layer, permeability exponents, decompaction weakening factor, and so on. These results provide a better understanding of the two-phase system and its potential applications in geological environments.