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High-performance coupled poro-hydro-mechanical models to resolve fluid escape pipes

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Field observations and laboratory experiments exhibit inelastic deformation features arising in many coupled settings relevant to geo-applications. These irreversible deformations and their specific patterns suggest a rather ductile or brittle mechanism, such as viscous creep or micro cracks, taking place on both geological (long) and human (short) timescales.

In order to understand the underlying mechanisms responsible for these deformation features, there is a current need to accurately resolve the non-linearities inherent to strongly coupled physical processes. Among the large variety of modelling tools and softwares available nowadays in the community, very few are capable to efficiently solve coupled systems with high accuracy in both space and time and run efficiently on modern hardware.

Here, we propose a robust framework to solve coupled multi-physics hydro-mechanical processes on very high spatial and temporal resolution in both two and three dimensions. Our software relies on the Finite-Difference Method and a pseudo-transient scheme is used to converge to the implicit solution of the system of poro-visco-elasto-plastic equations at each physical time step. The rheology including viscosity estimates for major reservoir rock types is inferred from novel lab experiments and confirms the ease of flow of sedimentary rocks.

Our results propose a physical mechanism responsible for the generation of high permeability pathways in fluid saturated porous media and predict their propagation in rates observable on operational timescales. Finally, our software scales linearly on more than 5000 GPUs.