Geophysical Research Abstracts
Vol. 12, EGU2010-10159-1, 2010
EGU General Assembly 2010

Modeling coupled fluid-grain deformation within fault zones

Liran Goren (1), Einat Aharonov (2), Renaud Toussaint (3), and David W. Sparks (4)

(1) Weizmann Institute of Science, Environmental Sciences and Energy Research, Rehovot, Israel. (liran.goren@weizmann.ac.il), (2) Institute of Earth Sciences, Hebrew University, Givat Ram, Jerusalem, Israel. (einatah@cc.huji.ac.il), (3) IPGS, CNRS UMR7516, Université de Strasbourg, Strasbourg Cedex, France. (renaud.toussaint@eost.u-strasbg.fr), (4) Department of Geology & Geophysics, Texas A&M University, College Station, TX, USA. (sparks@geo.tamu.edu)

Shear of faults often concentrates within a layer of “fault-gouge” - granular fragments produced by wear of the wall rock during shear. The pores between the grains are in many cases filled with fluid, and the fluid pressure in this granular layer controls the strength of the whole fault zone according to the law of ‘effective stress’. We study coupled granular-deformation and fluid pore pressure changes within a shearing layer, using a new two-scale two-phase model: the grains are modeled at the grain scale using a granular dynamics algorithm, while the fluid is simulated on a slightly coarser Darcy porous-flow scale. The formulation for the fluid is based on first principles and is general enough to account for the fluid response to both elastic and inelastic finite deformation of the granular matrix.

Using both simple analytical predictions under an infinite stiffness assumption and fully coupled simulations of shearing fluid-filled granular layers, we find that the presence of fluid influences all aspects of deformation, and introduces important physical constraints on upscaling lab results to the field scale. The analytical infinite stiffness assumption (where pore pressure responses to granular deformation, but granular deformation is not affected by pore pressure gradients) reveals that the pore pressure response may be described as visco-elastic: When fluid flow is negligible (on the deformation timescale), pore pressure responds elastically to strain within the granular layer (porosity variations), and the fluid compressibility controls the magnitude of pressurization. When fluid flow is important, pore pressure correlates to strain rate (the rate at which the porosity varies). Systems that are large enough show a mixed visco-elastic response. An important additional understanding is that pore pressure may rise even if the overall trend of the system is dilative, provided there are periods of abrupt or spatially localized compaction, and that some drainage exists.

Fully coupled simulations are also carried, where the fluid and granular phase are treated dynamically, with adequate momentum exchange terms. They reveal that the relations between granular deformation, drainage conditions, and pore pressure variations that were derived under the infinite stiffness assumption remain generally valid even when this assumption is relaxed. Coupled simulations also highlight the transition from stress-chains supported layer to fluid pressure supported layer that occurs during pressurization. This transition is accompanied by a significant reduction of the shear stress, that potentially allows the development of runaway dynamic slip. Additional insights are offered regarding the time scales controlling dilatancy hardening and the relation between pore fluid pressurization/depressurization and stick-slip motion.