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Numerical and sandbox modelling of various failure patterns caused by pore fluid overpressures – consequences for fluid migration

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In low permeable sediments, the fluid migration depends on failure patterns caused by shear banding, tensile hydraulic fracturing or fluidizing in non-cohesive materials. The state of stress induced by gravity and regional tectonics is not the only factor that controls the orientation and onset of failures. In overpressured sediments, the seepage forces generated by fluid overpressure gradients introduce an additional component to the effective stresses. Consequently, the principal stresses can be rotated by pore fluid overpressures. Listric normal faults are well known exemples of this stress rotation in sediments. According to this principle, we can also demonstrate that, in a tectonically inactive basin, a localized increase of the pore pressure leads to various failure patterns depending on the magnitude of the fluid overpressure already present in the sediment. In a moderately overpressured layer, a localized pore pressure increase will promote shear banding or vertical tensile hydraulic fractures whereas, in a highly overpressured sediment, it will lead to horizontal hydraulic fracturing. This phenomenon may be of great importance for the prediction of fluid flows in sedimentary basins. In this talk, our theoritical developments will be illustrated by results of analogue and numerical experiments. Our experimental technique consists in applying an homogeneous fluid pressure at the base of a 2D porous granular medium (Hele Shaw cell) in order to simulate the overpressured sediment. Then, an additional localized injection of fluid in the middle of the model induces fracturing. Numerical results come from a poro-elasto-plastic Finite Element code and from a Distinct Element code. In our Distinct Element code, the solid matrix is modeled by an assembly of elastic particles whereas pore fluid

is assumed to be continuous. This model can be used to model fluidization process, hydro-fracturing or shear banding in saturated media. It provides informations at the grain scale. Thus, we show that microscopic pore pressure gradients due to local variations of permeability modify the transmission of forces between the grains. It changes the textural properties of the granular material which progressively looses its frictional property, leading to more diffuse deformations.