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Shear-enhanced compaction in viscoplastic rocks

V.M. Yarushina (1) and Y.Y. Podladchikov (2)

(1) Yale University, Dept.. of Geology and Geophysics, New Haven, United States (viktoriya.yarushina@yale.edu), (2) University of Lausanne, Institute of Geophysics, Lausanne, Switzerland

The phenomenon of mutual influence of compaction and shear deformation was repeatedly reported in the literature over the past years. Dilatancy and shear-enhanced compaction of porous rocks were experimentally observed during both rate-independent and rate-dependent inelastic deformation. Plastic pore collapse was preceding the onset of dilatancy and shear-enhanced compaction. Effective bulk viscosity is commonly used to describe compaction driven fluid flow in porous rocks. Experimental data suggest that bulk viscosity of a fluid saturated rock might be a function of both the effective pressure and the shear stress. Dilatancy and shear-enhanced compaction can alter the transport properties of rocks through their influence on permeability and compaction length scale. Recent investigations show that shear stresses in deep mantle rocks can be responsible for spontaneous development of localized melt-rich bands and segregation of small amounts of melt from the solid rock matrix through shear channeling instability. Usually it is assumed that effective viscosity is a function of porosity only. Thus coupling between compaction and shear deformation is ignored.

Spherical model which considers a hollow sphere subjected to homogeneous tractions on the outer boundary as a representative elementary volume succeeded in predicting the volumetric compaction behavior of porous rocks and metals to a hydrostatic pressure in a wide range of porosities. Following the success of this simple model we propose a cylindrical model of void compaction and decompaction due to the non-hydrostatic load. The infinite viscoplastic layer with a cylindrical hole is considered as a representative volume element. The remote boundary of the volume is subjected to a homogeneous non-hydrostatic load such that plane strain conditions are fulfilled through the volume. At some critical values of remote stresses plastic zone develops around the hole. The dependence of the effective bulk viscosity on the properties of individual components as well as on the stress state is examined. We show that bulk viscosity is a function of porosity, effective pressure and shear stress. Decreasing porosity tends to increase bulk viscosity whereas increasing shear stress and increasing effective pressure reduce it.