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Analytical solutions and numerical modelling of non-hydrostatic compaction and decompaction

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In response to an applied stress field or pore pressure change, the pore space of a rock may compact or dilate. The analysis of compressive porosity collapse and generation of new porosity in many sedimentary, magmatic and metamorphic settings hinges upon a fundamental understanding of inelastic behaviour and failure mode of porous rocks. The inelastic response of heterogeneous materials depends both on the microstructural characteristics – such as size, shape and orientation of grains, inclusions, pores, and cracks – and on the mechanical properties of the constituents. If the rock's porosity is low and the pore dimensions are sufficiently small the simplest model of a representative element volume is an isolated thick-walled spherical shell. The spherical pore collapse model seems to have an intrinsic limitation in that it cannot consistently reproduce the yield cap for both hydrostatic and non-hydrostatic loadings with the same set of yield parameters. The model consistently underestimates the differential stress required to initiate shear-enhanced compaction: while this first envelope fits the hydrostatic data of critical pressure, it consistently falls below the experimental measurement of differential stress. The modelling does not predict the experimental results quantitatively perhaps because actual stresses around the pores are not well approximated by hydrostatic ones. In the non-hydrostatic case, additional problems may arise due to oversimplifying treatment of the yielding domain as the circular perimeter of the spherical pore. The non-hydrostatic applied stress field induces stress concentration in the vicinity of the spherical pore, and permanent deformation occurs within non-spherical domain where the local stress field satisfies a specified yield condition. To arrive at better agreement with the laboratory data the spherically symmetric model should be modified to account for differential stress or shear-enhanced compaction or decompaction. Here we analyze the yield behaviour of thick-walled spherical shell

and cylindrical tube under far-field non-hydrostatic loading. We compare numerical solutions with classical and newly derived analytical solutions. Special emphasis is on quantifying of difference of material response in compaction compared to the decompation processes.