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Compaction, Dilatancy and Failure Mode in Porous Carbonate Rocks

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To investigate the influence of porosity change on the brittle-ductile transition, we conducted a systematic investigation of the phenomenology and micromechanics of shear-enhanced compaction, dilatancy and failure in the Solnhofen, Tavel and Indiana limestones with porosities ranging from 3% to 16%. Hydrostatic and triaxial compression experiments were conducted on nominally dry samples at confining pressures up to 435 MPa. Under sufficiently high confinement, shear-enhanced compaction was observed in all three limestones. The compactive yield behavior of Solnhofen limestone samples (with initial porosities as low as 3%) is phenomenologically similar to that of carbonate rocks, sandstone and granular materials with porosities ranging up to 40%. The compactive flow is commonly observed to be a transient phenomenon, in that the failure mode evolves with increasing strain to dilatant cataclastic flow and ultimately shear localization. It is therefore inappropriate to view stress-induced compaction and dilatancy as mutually exclusive processes, especially when large strains are involved as in many geological settings. Synthesis of our new data and published data on more porous carbonate rocks show that the compactive yield stress decreases with increasing porosity. At the same porosity, the compactive yield stress of a carbonate rock is lower than that of a siliciclastic rock. Microstructural observations show that the inelastic compaction arises from pore collapse accompanied by crystal plasticity and cataclastic processes in the solid matrix. To interpret the micromechanics of compaction and failure in these carbonate rocks, we used several versions of the plastic pore collapse model for an homogeneous material containing spherical and non spherical pores, and for a tranversely isotropic material.