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Nonlinear Creep, Decompaction Weakening and Mechanical Channeling Instability

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We propose that a mechanical flow channeling instability, which arises because of rock weakening at high fluid overpressure, facilitates segregation and transport of fluids and melts. To characterize the weakening effect the ratio of the matrix viscosity during decompaction to that for compaction is treated as a free parameter R. Two-dimensional numerical simulations with this rheology reveal that solitary, vertically elongated, porosity waves with spacing on the compaction length scale initiate from minuscule porosity perturbations, a geometry that increases fluid fluxes by a factor of 1/R. The waves grow by draining fluid from the background porosity, but leave a wake of elevated porosity that localizes subsequent flow. Wave amplitudes grow linearly with time. Such waves may provoke the elastic response necessary to nucleate, and localize the melt necessary to sustain, more effective transport mechanisms. The numerical results can be understood in the context of an analytical solution of the compaction equations that is completely general with respect to the constitutive relations used to define the matrix rheology and permeability. This solution combines the porosity dependence of the rheology and permeability in a single hydromechanical potential, which can be used to construct phase diagrams depicting the conditions for smooth pervasive flow, wave propagated fluid or melt extraction and matrix disaggregation (veins or dike formation).