Can stationary cnoidal waves explain periodic deformation bands in porous sandstone?

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Deformation bands are sub-seismic brittle structures found in granular materials. These structures exhibit two spatial distributions: [1] non-linear decay of spacing associated with the damage zone of a fault, and [2] periodic, constant spacing not associated with faults. Periodically spaced deformation bands are of interest as they can be pervasive through porous (>5% φ) formations and are known to impact fluid flow. Bands can act as conduits or barriers to fluid flow and are commonly identified in petroleum reservoirs. An understanding of the factors controlling their distribution is therefore of great importance.

Here, we test a novel mathematical theory postulating that material instabilities in solids with internal mass transfer associated with volumetric deformation are due to elastoviscoplastic p-waves termed cnoidal waves. The stationary cnoidal wave model for periodic compaction bands predicts that their spacing is controlled by important material properties: the permeability of the weak phase in the pores, the viscosity of the weak phase, and the inelastic volumetric viscosity (strength) of the solid grains. A semi-analytical parametric study of the dimensional non-linear governing equations yields a surprisingly simple scaling relationship, which requires testing in the field. Stronger units with higher permeability are predicted to exhibit a wider spacing between deformation bands.

We test the cnoidal-wave model on natural deformation bands from Castlepoint, North Island, New Zealand. These bands are hosted by Miocene turbidites of the Whakataki formation, which formed in tectonically controlled trench-slope basins associated with the onset of subduction of the Pacific plate beneath the Zealandian plate along the Hikurangi subduction margin. Adjacent sand- and siltstone beds exhibit significant differences in deformation band spacing. Spacing statistics derived from field mapping and laboratory measurements of host-rock permeability and strength are employed to test the scaling relation predicted by the cnoidal wave model. Inconsistencies between theoretical and observed spacing are discussed critically.
