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Micromechanics of compaction localization: discrete compaction band formation in two porous sandstones

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Recent geologic and laboratory observations have demonstrated that strain localization may be pervasive in a compactant porous rock, particularly at stress states that are associated with the brittle-ductile transition. Such a coupling of compaction and strain localization can significantly impact the stress field and fluid transport in tectonic settings. Compaction localization is manifested by a broad spectrum of geometric complexity between two end-members: shear bands may develop at relatively high angles, and arrays of discrete compaction bands may develop subperpendicular to the maximum compression direction. A hybrid localization mode involving high-angle shear bands and diffuse compaction bands is observed in rocks with intermediate porosities.

To elucidate the micromechanical processes associated with the development of discrete compaction bands detailed microstructural observations were conducted on deformed samples of Diemelstadt and Bentheim sandstones, which have comparable porosities (23-24%) but different amounts of quartz and feldspar. X-ray CT was also used to characterize the geometric attributes of compaction bands, and our data indicate that the width and tortuosity of compaction bands in the two sandstones are similar. A methodology was developed to characterize the pore space heterogeneity from statistical variation of CT-values. Our analysis of 5 porous sandstones demonstrate that the Diemelstadt and Bentheim sandstones (which fail by development of discrete compaction bands over a broad range of pressures) have the minimum statistical variation, which imply that their pore spaces are most homogeneous. In contrast the three other sandstones with more heterogeneous pore space fail by development of diffuse compaction bands or shear bands. That discrete compaction bands are inhibited in sandstones with relatively heterogeneous pore space is in agreement with the predictions of several types of micromechanical models.