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Spatio-temporal seismicity patterns associated with anisotropic propagation of discrete compaction bands in Diemelstadt sandstone

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We report results from conventional triaxial deformation tests performed on samples of Diemelstadt sandstone conducted under a confining pressure sufficient to induce compaction bands. Diemelstadt sandstone is a visibly anisotropic rock with an initial porosity of 23% and a mean grain diameter of 0.3mm. We have quantified the pore-space anisotropy of this material by: (a) measuring radial elastic S and P waves as a function of azimuth around orthogonally cored samples, and (b) measuring the magnetic susceptibility anisotropy (AMS) of samples saturated with ferrofluid. Elastic wave velocities show anisotropies of 7% and 3% for P and S waves, respectively, while the AMS measurements show that the pore fabric approximates to an oblate spheroid, with the isotropy plane parallel to the bedding plane. Consequently, we have performed experiments on samples cored both normal and parallel to the isotropy (bedding) plane.

Previous studies of compactive deformation have concentrated on the growth of a sequence of compaction bands through the volume of the sample. By contrast, here we have concentrated on the nucleation and temporal evolution of single compaction bands in rock samples. Throughout our experiments we used full wave-form acoustic emission (AE) locations from 12 transducers to record the propagation of individual compaction bands in orientations parallel to and normal to the plane of pore-space isotropy. This allowed us to compute a propagation velocity for the compaction bands, which took several minutes to traverse the sample. We also computed the seismic bvalue as a function of time from recorded AE events, using the maximum likelihood method of Aki, in order to examine the scale of cracking associated with compaction band growth.

Consistent with our previous observations (Townend et al. 2006, Eos Trans. AGU, 87 (52)), we found samples deformed parallel to the bedding plane to be stronger than those deformed normal to it, with the compaction band geometry showing a more tortuous growth in the bedding-normal direction. This pattern of behaviour is also consistent with the very large reductions (3 orders of magnitude) in permeability observed during compaction band formation. A more gradual permeability reduction is observed during compaction band growth normal to the isotropy plane, commensurate with the increased resistance to compaction band development in this orientation.