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Borehole breakouts and sand production in porous sandstone

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We have studied the nucleation and formation of borehole breakouts in cylindrical samples of Bentheim sandstone of 50 mm diameter and 105 mm length. Central boreholes with 5 and 10 mm diameter and 52 mm depth were drilled along the axis of the samples. Grain size and porosity of sandstone were of $\approx$ 0.2 mm and 23%, respectively. Five tests on water-saturated samples were performed at 10 MPa pore pressure, and one specimen was tested dry. Sandstone samples were subjected to hydrostatic pressure increasing up to 100-140 MPa at 1 MPa/min rate. To monitor Acoustic Emission (AE) and ultrasonic velocities, twelve P-wave and six polarized S-wave piezoelectric sensors were glued to the surface of the rock. Fully digitized AE waveforms were recorded by 10 MHz/16bit Data Acquisition System (DAXBox made by Prökel), hypocenters location error was about 2.5 mm. To monitor strain in the different parts of the rock, two pairs of orthogonally oriented strain-gages and four single strain-gages were glued on the cylindrical surface of the rock. Volumetric strain was also estimated by monitoring the change in pore fluid volume. Initial compaction of samples was homogenous with elastic ultrasonic velocities increasing from 3.6 km/s to 3.9 km/s. At effective confining pressures of 66-107 MPa nucleation of borehole breakouts was accompanied by an onset of AE activity. Located AEs show planar clusters forming at the borehole surface growing in radial direction along the sample axis. For all samples breakouts grow as a single plane propagating towards the sample surface. Similar shape of breakouts in porous sandstones was recently observed by Haimson (Int. J. Rock Mech. Min. Sci. 44, 2007). Experiments performed on samples with borehole diameter of 5 mm (wet or dry) show two symmetrically oriented AE clusters on the opposite sides of the borehole. One sample with a 10 mm diameter borehole, shows initial breakouts formed with three AE clusters surrounding the borehole at about 30 % lower confining pressure. Breakout orientation is not affected by the orientation of the bedding. We estimated inelastic energy dissipated during breakout formation and propagation ranging from 20 J to 120 J. Normalizing inelastic energy by fracture area estimated from AE analysis we found inelastic energy release rates between 17 kJ/m^2 to 60 kJ/m^2. These values are very similar to recent estimates of energy release rates found for the formation of compaction bands in porous sandstones. Preliminary microstructural observations show width of breakouts decreasing from about 1-2 mm at the borehole to a few grain diameters with increasing distance from the borehole.