INVESTIGATION OF THE COMPACTION LOCALIZATION PROCESS IN POROUS SANDSTONE USING ACOUSTIC EMISSION LOCATIONS AND FOCAL MECHANISMS

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The physical manifestation of pre-failure strain localization in porous rock ranges from localized shearing to zones of localized compaction (compaction bands), with the observed mode depending principally on the mean stress and the third stress invariant. Recent theoretical studies (Issen and Challa, 2005) show that the full range of orientations should be observed, from pure compaction localization, where the plane of localization is perpendicular to the maximum, principal compressive stress to low-angle combined compaction and shear and finally, predominantly shearing. All modes are the result of microstructural deformation including grain boundary failure, grain breakage, and pore collapse, to produce the large plastic strains. These grain scale processes are capable of emitting bursts of ultrasound known as acoustic emissions (AE). Using techniques identical to those used by seismologists to study earthquakes, the locations and slip planes (focal mechanisms) of individual AE can be determined and used to study the micromechanical processes ultimately responsible for localization. Previous studies have determined the point of origin for thousands of AE from micromechanical failures occurring during compaction band formation, to understand the spatio-temporal distribution of the compaction localization process. These earlier efforts are expanded in this investigation by inverting for the apparent focal mechanisms associated with the AE events occurring during axisymmmetric compression tests on Castlegate sandstone with porosity ˜28%. Representative AE focal mechanisms, all of which show evidence of shear are determined during non-overlapping time periods to examine the relationship between micro-failure modes and the state of deformation. In all cases, the inferred slip vectors show remarkably consistent low-angle shearing (<20^{o} relative to the plane normal to maximum compressive stress). Thus the micromechanisms responsible for macro compaction have a significant low-angle shearing component. When considered en masse, over times that are a significant fraction of the total time required to deform the sample, the locations of AE for a sample undergoing compaction localization form a diffuse band that is dominantly normal to the maximum compressive stress. When examined more closely, using shorter time intervals, planar features are observed that are tilted relative to the dominant direction. We believe these features are zones of low angle shearing, with compaction, that are briefly active and then are replaced by other active zones. The combination of the low angle shearing at the micromechanical level, inferred from individual AE events and the observation of low angle planes of deformation, inferred from the mass behavior of AE events, leads us to conclude that we are observing the low angle combined compaction and shearing localization predicted by Issen and Challa.

Keywords: compaction, localization, geomechanics

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