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Damage indicators and failure prediction in Focal Mechanism solutions

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Acoustic Emissions (AE), the laboratory analogue to seismic events, recorded during conventional triaxial deformation tests allow for an unprecedented amount of information on the evolution of fractured media within a controlled environment. This study presents the results of a new and robust derivation of first motion polarity focal mechanism solutions (FMS). 4 x 10 cm cylindrical samples of Alzo Granite (AG) and Darley Dale Sandstone (DDS) underwent systematic triaxial deformation testing (5, 10, 20 and 40 MPa) in order to investigate the relationships between increasing confining pressure, deformation and failure mode and role of pre-existing microstructure. With an average of 11 of 12 waveforms picked using a neural network for each AE, high resolution datasets are obtained that can track the evolution of deformation structure through time. Focal mechanisms are solved using a least squares minimisation of the fit between projected polarity measurements and the deviatoric stress field induced by tensile, shearing and collapse/closing type sources. Results reveal a surprisingly limited dependency on the distribution of shear fracturing in the lead up to dynamic failure. Instead, deformation is driven by the competition between the opening and closure of fractures that is strongly related to the coupling of local stress fields with pre-existing damage. Spatio-temporal trends in mechanism type and AE amplitude allow for clear identification of: a) Fracture Eucleation. This phase is characterised by broadly distributed tensile fracturing that becomes preferentially aligned as confining pressure increases; b) Fracture Growth. The onset is characterized by a discrete increase in low amplitude shearing events and cyclic fracture development that evolves from a dominance of collapse to shearing followed by tensile fracturing which then returns to collapse type. Influences in mechanism dominance due to rock type are highlighted by increased tensile fracturing in AG, which is replaced by shearing in DDS. A reduction in low amplitude tensile events at 10 MPa in both rock types further reveals a switch from axial splitting to planar localisation as confinement increases; c) Crack Coalescence. The cyclic fracture growth prior to dynamic failure and the amount of strain of this phase share a positive log-linear relationship with confining pressure, allowing to identify the potential for real-time failure prediction; d) Dynamic Failure: High amplitude events characterize the propagation of fractures. Taken together results highlight that failure of the studied samples is the result of the complex interaction between distinct regions of dilatant and compactant deformation. Although planar localisation and preferentially aligned flaws

play a more significant role at higher confining pressures, it is the initial heterogeneity or patchiness of the regions undergoing damage that control dynamic failure occurrence and the eventual fracture plane features.