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Time-dependent analyses of first motion derived focal mechanism solutions and machine learning algoritms in rock deformation laboratory experiments

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Acoustic Emissions (AE), the laboratory analogue to tectonic 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, robust, derivation of first motions calculated from AE-derived focal mechanism solutions (FMS) to analyse the induced deformation of samples of Westerly Granite, Stromboli Basalt and Darley Dale Sandstone. For each AE 12 traces were recorded. For the event location, arrival times and the polarity of the first motion were automatically picked using a combined Signal Duration and Root Mean Square (RMS) Envelope procedure. AE were organised into localised groups by minimising the RMS error between polarity signatures of each AE and these were then fitted to idealised FMS models of mode 2 shear, mode 1 shear, mixed-mode, isotropic and CLVD. Selection was dependent on the RMS error of normalised amplitudes between observed and modelled data. Results highlight time-dependent trends in the dominance of compressive, tensile and shearing events that correlate with specific deformation sequences (i.e. dynamic failure) of the samples. To complement the analysis machine learning algorithms (bootstrapped forest walks) are trained on these results to identify frequency dependent variations between the different mechanisms and improve confidence. Results for the basalt identify a shearing dominance with a strong dependence on a pre-existing fracture network for the eventual distribution, and mechanisms, of the developing failure plane. The granite, which lacks initial microfractures, has a largely isotropic distribution of tensile damage which is then dependent on the clustering of deformation-induced damage. Whilst the sandstone indicates a stronger dominance of compressive events associated with pore collapse. These data provides new insight into the potential forecasting of deformation and failure mode for different lithologies at the laboratory scale and provide support to the search of links between seismic signals and field scale fracturing processes.