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A postmortem approach via X-ray computed tomography and thresholding to investigate fracture network evolution in Onagawa shale

Eranga Jayawickrama[1], Jun Muto[1], Osamu Sasaki[2], and Hiroyuki Nagahama[1]
[1]Tohoku University, Earth Science, Japan (eranga.j@tohoku.ac.jp)
[2]Tohoku University Museum, Japan

A postmortem technique is introduced to investigate the fracture connectivity evolution under elevated confining pressures via a sensitivity analysis. Three Onagawa shale samples are deformed under brittle, ductile, and transition conditions, by increasing the confining pressures. Brittle deformation is characterized by longitudinal splitting of the sample at 3% axial strain, and the onset of transition from brittle to ductile deformation is between 4% ~ 5% axial strain. The ductile deformation is characterized by a distributed conjugate fracture network and strain hardening. In completion of the deformation, the samples are scanned in a commercially available X-ray CT machine. The grayscale values of the primary 2D images were reversed, stacked, and surface rendered to obtain the 3D volume distribution of the fractures. Reversing and surface rendering allowed the acquisition of volume and surface data of the fractures along with their direct visualization. Further, utilizing a residual analysis, the voxel value density distribution that fabricated the fracture network is extracted (Residual histogram). Thresholding of the residual histogram generated volume segments of the final fracture network demonstrating the sensitivity of the fracture network to the choice of threshold. Voxel volumes of fractures alone are obtained by thresholding post-peak voxel values of the residual histogram and consecutive post-peak thresholding shows that the generated volume segments of the fracture network can be utilized to interpret, possible nucleation sites after strain localization, propagation of fractures, and coalescence. Fracture connectivity is quantified by means of relative entropy from information theory, and the relative entropy of size distribution of fracture volumes showed that it is closer to zero with the fractures being well connected. Moreover, the cumulative fracture volume shows a power-law growth towards the failure after a unique threshold to each sample. These results have been validated by previous acoustic emission studies and a 4D tomographic investigation on strain localization of shale. Therefore, despite the postmortem nature of the investigation, the new technique has opened possibilities to investigate the fracture properties and their evolution under elevated confining pressures.