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# Representation of micro-earthquake sources with plastic strain tensor

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The moment tensor is a useful representation of seismic sources. It can be used for efficient solution of forward and inverse problems of seismic wave excitation and propagation. The full moment tensor solutions based on seismic waveform inversion e.g. induced by hydraulic fracturing and borehole breakout processes can be used to understand the volumetric failure mechanisms associated with microseismic events. The characteristics of the moment tensor can be linked to the stress state in the reservoir rocks. Yet, the physical interpretation of the seismic moment tensor remains somewhat ambiguous. The moment tensor as a seismic source has been interpreted by introducing a stress or strain "glut" of some inelastic nature which cannot be described by the Hooke's law. Here, we suggest an alternative interpretation of this inelastic strain in the framework of time-independent non-associated plasticity theory. Thus, the previously introduced an inelastic strain "glut" acquires a meaning of plastic strain tensor. We show that this interpretation is practical since: i) it is consistent with continuum mechanics approach, such as applied in numerical geomechanical modeling of fault and fracture growth; 2) captures results of laboratory deformation and acoustic emission experiments; 3) explains the observed non-double-couple component of moment tensor solutions (dilatant plastic failure); 4) gives correct first-order estimates of scalar moment of moment tensor. As a numerical setup, we consider a classical problem of wellbore failure when stress is applied externally. Our analytical model provides first-order insights into the magnitude of scalar moment and scaling relations. Numerical finite element model in 2D plane strain combines both the yield function and flow potential describing the shear and tensile failure regimes. We observe and classify several modes of deformation, obtained in numerical experiments such as localized (shear bands) and distributed failure around wellbore. We systematically explore the effects of boundary conditions, heterogeneity of material parameters and elastic anisotropy. The source type and distribution of seismic events, obtained in our numerical model, agrees with observations of borehole breakouts, tunnel collapse and early growth of fluid-filled cracks such as hydraulic fractures and magmatic dikes.