

EGU21-2573, updated on 16 Oct 2021

<https://doi.org/10.5194/egusphere-egu21-2573>

EGU General Assembly 2021

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Can plasticity explain microseismic source mechanisms?

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The microseismic events can often be characterized by a complex non-double couple source mechanism. Recent laboratory studies recording the acoustic emission during rock deformation help connecting the components of the seismic moment tensor with the failure process. In this complementary contribution, we offer a mathematical model which can clarify these connections. We derive the seismic moment tensor based on classical continuum mechanics and plasticity theory. The moment tensor density can be represented by the product of elastic stiffness tensor and the plastic strain tensor. This representation of seismic sources has several useful properties: i) it accounts for incipient faulting as a microseismicity source mechanism, ii) it does not require a pre-defined fracture geometry, iii) it accounts for both shear and volumetric source mechanisms, iv) it is valid for general heterogeneous and anisotropic rocks, and v) it is consistent with elasto-plastic geomechanical simulators. We illustrate the new approach using 2D numerical examples of seismicity associated with cylindrical openings, analogous to wellbore, tunnel or fluid-rich conduit, and provide a simple analytic expression of the moment density tensor. We compare our simulation results with previously published data from laboratory and field experiments. We consider three special cases corresponding to "dry" isotropic rocks, "dry" transversely isotropic rocks and "wet" isotropic rocks. The model highlights theoretical links between stress state, geomechanical parameters and conventional representations of the moment tensor such as Hudson source type parameters.