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Magnitude, scaling, and spectral signature of tensile microseisms

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The spatial dimensions and rupture characteristics of microseismic events are encoded in the spectra of radiated seismic waves. Compared with the determination of seismic moment tensors, source spectral analysis can be performed with limited aperture coverage around the source region. Provided that wave attenuation is well constrained, P- and S-wave spectral corner frequencies can be used, in principle, to estimate rupture velocity, source radius and stress-drop, but these paramaters are strongly model dependent. In addition, the ratio of S/P amplitudes may be used to distinguish between shear and tensile events, since tensile events are characterized by S/P < 5 whereas for shear events S/P is generally > 5. Several models are available to calculate seismic moment from the low-frequency displacement spectrum. In the case of tensile rupture, there is less ambiguity and source radius (a) can be related to moment magnitude (Mw) and internal fluid pressure within the fracture (P) by a recently discovered scaling relation: $\log10(a) = [9-\log10(2)]/3 + 0.5Mw - \log10(P)/3$. Source spectra may also contain notches that are diagnostic of rapid opening and closing of tensile fractures – so-called “clapping” mechanism – during hydraulic fracture treatment. Finally, slow rupture mechanisms may give rise to distinctive low-frequency tremor or long-period long-duration (LPLD) events that are typically overlooked during routine processing of microseismic data. By analogy with low-frequency phenomena that characterize volcanic and earthquake fault systems, such features may be indicative of gradual tensile opening, fluid resonance or slow slip on fractures that are misaligned with the present-day stress field.