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Appropriateness of Source Models in Interpreting Microseismicity: Is a Penny-Shaped Crack Model Sufficient?

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Seismicity is being increasingly used to evaluate the effectiveness of different stimulation technologies: from the volumetric extent of hydraulic completions; to the containment of cyclic steam injections; to understanding how stress and structural elements may conspire to lead to larger events (that may exceed local traffic light thresholds for induced seismicity). The understanding that each event is generally connected with a plane of weakness that ruptures in the subsurface releasing some stress is a very valuable model in understanding the different processes associated with the deformation and propagation of fluid in the subsurface.

In order to make a quantitative connection between a microseismic event and a rupture of finite size, the source of the microseismicity needs to be described in terms of its “source parameters”, inevitably referring to a model of the rupture process. Since a penny-shaped crack model only has one dimensional parameter, the radius of the rupture area, this simplicity necessitates less demands on the seismic observations: a single corner frequency may be estimated from the waveforms to relate to the dimensions of the rupture. While the aphorism of “all models are wrong but some are useful” certainly applies to penny-shaped crack models, they are able to attribute different relative areas to different rupture areas, obtaining estimates of stress release and inferring relative degrees of co-seismic deformation. However, we wish to transcend the limitations of these simpler models. In particular, the ability to distinguish a more complicated shape to the rupture surfaces will enable the resolution of different barriers in the subsurface, recognizing the different roles that lithological constraints may place on the ability for ruptures have for staying bound within different formations, or if the ruptures have a strong directivity in response to underlying stress conditions. In this paper, we will discuss the next generation of source models that need to be employed by the microseismic community in order to answer these questions, coupled with the feasibility of observing the necessary nuances in the signal to arrive at such a higher-resolution image of the deformation.