

Interpreting Microseismicity Generated by Hydraulic Stimulation: Is Surface Monitoring Biased Towards Specific Source Mechanisms?

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ABSTRACT

In the past several years, a handful of authors have pointed out the existence of peculiar source mechanisms patterns observed during hydraulic fracture stimulation. A vast majority of microseismic events indeed exhibits a “dip-slip”-like source mechanism with polarity reversals. Similarly, other authors have reported the existence of strike-slip sources, striking (sub-)parallel to the maximum horizontal stress and also showing polarity reversals. Such distributions of source motion could shed light on the fracture geometry itself, and are therefore critical to capture and assess properly. The above results however assume that the monitoring network is able to completely capture the seismicity above a given magnitude level (the magnitude of completeness). While it is well-known that borehole arrays, due to their very limited focal sphere coverage, show spatially varying sensitivity, it has always been accepted that surface arrays are immune to such an issue thanks to their broad aperture. In this paper, we demonstrate that the magnitude of completeness of a surface network also depends on source radiation patterns. In particular, the sensitivity to strike-slip events is shown to be lower than the sensitivity to dip-slip events, thus skewing the retrieved microseismicity and potentially leading to mis-interpretation. To this effect, we have generated two synthetic microseismic catalogues in which events are characterized by a random spatial distribution constrained to a finite volume (thus simulating the spatial extent of a microseismic cloud) and with magnitudes verifying the Gutenberg-Richter law, which gives the probability density $f(m)$ of magnitude m . Each catalogue is then attributed a dip-slip or a strike-slip dominant source mechanism. The resulting amplitudes are calculated at the surface for different acquisition geometries, and compared to randomly varying noise distributions following a Gaussian distribution through the bootstrapping method so as to estimate the detection probability of each event in the two considered cases, being compared through the retrieved Gutenberg-Richter characteristics. Doing so, we show that the difference in magnitude of completeness between strike-slip and dip-slip mechanisms can reach an order of magnitude. This highlights the fact that source-mechanism based interpretation when monitoring microseismicity from the surface should be performed with the utmost caution.