# What Have We Learned After 10+ years of HFM Monitoring of Microseismicity

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## Abstract

Hydraulic fracture monitoring with microseismicity is a continuously evolving science which is more closely aligned with concepts of classical earthquake seismology than traditional seismic imaging processes that the oil and gas community is more familiar with. There have been numerous technical advances in processing methodologies and algorithms, each advance more often than not is accompanied by fundamental shifts in our understanding of the hydraulic fracturing process. Early models of the hydraulic fracture process envisage the fracture as a symmetric, bi-wing vertical fracture that extends evenly into the formation. Early mapping of the microseismic events revealed that this picture is often not adhered to. Fractures can be highly asymmetric, and their growth can be strongly influenced pre-existing fabrics in the rock as well as the regional stress regime. In fact, many of the events recorded during these hydraulic stimulations are revealed not to have a direct connection to the fluid stimulation, but can be generated due to the stress shedding onto optimally oriented fractures. The main thrusts of the advances in the last decade have been towards understanding the role of these pre-existing fractures and induced lineation's in propagating the fracture outward from the treatment wells and into the formation. Towards this end seismic moment tensor inversion has done much highlight the orientations and fracture styles representing the deformation on the Discrete Fracture Network (DFN). Further to characterizing the DFN, more recently we have had to step back and re-examine whether the instrumentation typically used to monitor hydraulic fracture treatments is imposing a maximum size scale on the fractures. Typically, these stimulations are monitored with 15 Hz geophones, tacitly imposing a maximum size scale (maximum magnitude) on the events. However, by using a heterogeneous network of 15 Hz geophones, lower-frequency geophones (eg., 2Hz, 4.5 Hz) and accelerometers that have very low- frequency limits, then this maximum detectable size can be expanded to characterize events with $M > 0$, thereby providing a complete monitoring range from –M4 to M4. When such networks have been deployed, then larger events are accurately characterized, thereby providing for a more complete understanding of discrete fracture networks and interpretation of potential fluid pathways and hydraulic fracture stimulation effectiveness.