Origin of Microseismicity Induced by Hydraulic Fracturing

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Abstract

The induced seismicity has been known for over 100 years from earthquakes induced by water reservoirs and mining activity. Especially the mining provides a great insight into triggering and seismicity of faults due to redistribution of stresses as the monitoring network allows 3D distribution of receivers. Since late 1970ies new observations of seismicity induced by fluid injections attracted attention, first geothermal projects (hot dry rocks later renamed as enhanced geothermal systems, because rocks are not really dry) and more recently hydraulic fracturing of oil and gas reservoirs. It is instrumental to see how the evolution of opinions on physics of seismicity induced by fluid injections evolved especially in the light of errors assumed by seismologists analyzing the data. A message from this evolution I will try to convey is to use as many measurements as possible while assessing errors of processing carefully before making interpretations.

The state of the art and our current understanding of the seismicity induced by hydraulic fracturing of the sedimentary rocks is rapidly evolving in the oil and gas as a result of shale gas revolution. We are still not sure about the relation of the induced seismicity to the hydraulic fracture itself. We are starting to understand the uncertainties of microearthquake locations. Relative locations can provide insight into the physical processes that govern interaction of fluids with seismicity. The more precise locations seem to suggest that diffusion may not play the key role. However even less consensus is reached on source mechanisms of the induced seismic events. The wide opinions range from observations of highly similar shear mechanisms to observations of mostly tensile and volumetric changes. The mutually similar mechanisms are consistent with tight clustering of locations and my own experience. Generally either interpretations of observed source mechanisms lead to conclusion that seismicity is closely related to hydraulic fracture itself and stress transfer or diffusion plays minor roles. This is indeed a great news for our industry as seismicity more clearly outlines injected fluids, proppants and stimulated reservoir, if correctly located and analyzed.