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The role of magnitude saturation, accounting for seismic energy release and fracture surface area development associated with hydraulic fracture stimulations

Ted Urbancic, Andy Cochrane and Adam Baig

ESG, Kingston, Ontario

Summary

Recently, it has been considered that larger magnitude events may be associated with hydraulic fracture stimulations, particularly in unconventional shale plays in North America. We have had the opportunity to supplement traditional downhole recording utilizing high frequency 3C 15 Hz sensors with a sparse eight station near surface network consisting of low frequency force balance accelerometers (>0.1Hz) and 4.5Hz geophones. During the stimulation, a total of 4500 events were recorded on the downhole array situated close to the reservoir, ranging in magnitude from M-1 to M-2.6. The near surface network recorded a total of 28 events ranging from M-0.4 to M1.35; these events were also recorded on the downhole array, however the downhole signals exhibited magnitude saturation affects, which on average, resulted in underestimates of magnitude of about M-1.8. Significant to the study was the assessment of seismic energy release, which showed that the larger magnitude events detected with the near surface network accounted for a full 71% of the total seismic energy released during the stimulations. Additionally, these events accounted for an additional 11,870 m2 of activated fracture surface area, approximately 10,295 m2 more than would have been estimated from the downhole array alone. Overall, the additional surface area as derived from the near surface network accounts for <1% of all the recorded events but adds an additional 4% to the total liberated surface area when combined with the surface area generated by the 4500 events recorded downhole. Overall, the inclusion of low frequency sensor network can have significant implications when assessing the effectiveness of stimulation programs and in design considerations.