Role of Long Period Long Duration Seismic Events in Hydraulic Stimulation of the Barnett Shale

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Abstract

Long period, long duration (LPLD) seismic events are relatively low amplitude signals that have been observed during hydraulic stimulation of several shale gas and tight gas reservoirs. Long duration of the events, several distributed sources constituting each event and a remarkable semblance to tectonic tremor sequences observed in subduction zones and transform fault boundaries, imply that they result from slow slip on relatively large faults in the reservoir. Analysis of two different data sets from the Barnett Shale in Texas revealed that LPLD events are predominantly composed of shear waves but weaker P waves can sometimes be identified. In some cases, few micro-earthquakes are also observed to occur during the events. We interpret the LPLD events to result from the superposition of seismic signals from numerous small contiguous shear sources, embedded within a large fault, failing in close succession of each other. We estimated the energy content of the larger LPLD events to be about ~1000 times greater than the typical ~M_W -2 microseismic events that occur during hydraulic stimulation in these types of reservoirs. This indicates that just a few LPLD events have more energy than all microearthquakes recorded during the entire stimulation. Within the limitations of the recording geometry, we were able to determine the approximate location in the reservoir from where these events are coming from by a) estimating the backazimuth from the apparent velocity of arrival and b) stacking of the amplitude after correcting for arrival times from all positions within a 3D grid. In one of the Barnett data sets, LPLD events evidently occur in the region where density of natural fractures (as seen in image logs and inferred from 3D seismic data) and fluid pressure experienced during pumping is highest. We believe the larger fault, induced to slip slowly by the high fluid pressure, loads smaller rougher patches that fail in close succession as the slow slip propagates along the fault. The signals from each individual failure overlap with each other and generate the long duration signals. In one data set, the LPLD events occur near the stages where gas flow is highest, thus indicating that slow slip on the faults responsible for the LPLD events is playing an important role in stimulating production.