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Time reversal stacking of P and S waves to determine location and focal mechanism of microseismic events recorded during hydraulic stimulation

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ABSTRACT

We present an automatic method of processing microseismic monitoring data acquired at the surface by a star-shaped array using the back projection approach that allows simultaneous determination of hypocenter position of events and of their focal mechanisms. We employ the availability of both – denser deployed vertical component geophone groups to use P-waves and sparsely deployed three-component accelerometers to use both P and S-waves. Hypocenter coordinates are searched in a grid by time-reversal stacking of the short-time-average to long-time-average ratio of absolute amplitudes at vertical components and polarization norm derived from horizontal components of P and S-wave, respectively. To make the location process more efficient we start with coarse grid and zoom to the optimum hypocenter using an oct-tree algorithm. The focal mechanism is then determined by stacking the vertical component seismograms corrected for the theoretical P-wave polarity of the focal mechanism, which is searched in the space of strike, dip and rake angles. We test the method on 34 selected events of a dataset of hydraulic fracture monitoring of a shale gas play in Northern America. We find that by including S-waves the vertical accuracy of locations improves by a factor of two and equals approximately the horizontal location error. A twofold enhancement of horizontal location accuracy is achieved if a denser array of geophone groups is used instead of the sparse array of 3C seismometers.