End-to-End Workflow for Real-Time Analysis of Induced Seismicity Using DAS-Acquired Data

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Abstract

Real-time passive seismic monitoring is a useful tool to understand hydraulic fracture development, mainly in unconventional formations. It is increasingly being considered a viable, cost-effective way to observe long-term caprock integrity in carbon capture and sequestration projects as well as stimulation effectiveness in geothermal projects. Decades ago, sensors used for such monitoring campaigns were mainly 3C. Using distributed acoustic sensing (DAS) technology is gaining traction as the scientific community values its versatility and ease of deployment. The distributed nature of the sensing coupled to the large aperture array enabled by long cable(s) provides robust passive seismic monitoring systems. Stemming from lessons learnt using 3C-based microseismic monitoring campaigns, we propose a DAS-based workflow that encompasses all the steps typically attached to a passive seismic monitoring operation.

First, we assess event detectability and location uncertainty for different sensor configurations to select an optimal monitoring geometry leveraging the 3D velocity field information available at the time. Second, we model the waveforms associated with the various types of failure mechanisms likely to occur considering known geological and geomechanical data to compare with waveforms issued from the failure loci seen by the sensors. Third, we use a simulator of DAS-acquired passive seismic data for either a hydraulic fracturing job or geothermal injection monitoring that outputs data at real-time speed to verify the viability and effectiveness of the acquisition geometry and the processing system evaluated to monitor the long-term passive seismic activity.

Fourth, we employ a new real-time processing flow that involves image processing techniques applied to induced-seismic datasets. This approach mimics the expert geophysicist's view to identify passive seismic events acquired using DAS data leveraging an algorithm integrating both image processing and traditional geophysical processing. Fifth, knowing that an accurate velocity model is required to properly estimate source location, source parameters, and source mechanism of a detected microseismic event, we use a new method to simultaneously invert for the hypocenter and the velocity model to provide a robust long-term monitoring workflow. This enables bypassing the repeated use of manually controlled sources to calibrate the velocity model while including scenarios when the velocity field evolves with time due to induced changes associated with operations.

The presented workflow relies on newly developed techniques benefiting both traditional 3C sensor–based acquisition and the more recent optical fiber–based acquisition to minimize uncertainty attached to hypocenter determination. Each element of the workflow has been used successfully in passive seismic monitoring surveys. Some elements remain to be improved. However, the method presented helps refine the interpretation, and its integration with measurements such as distributed temperature sensing, distributed vibration sensing, and distributed strain sensing provides additional insight into the reservoir characterization, thus, increasing confidence in the safe execution of any passive monitoring campaign.