PSP28

Characterisation of Uncertainties in Microseismic Monitoring through Analysis of Numerically Modelled Events

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SUMMARY

Passive monitoring of induced microseismic (MS) events provides a unique means for imaging fracture propagation in response to engineering operations. Particularly during hydraulic treatment of hydrocarbon-bearing reservoirs rock MS monitoring provides feedback to field operators on the effect of the treatment and the changes imposed on the fracture network and fluid conductivity within the rock.

The first order estimation about the effectiveness of a hydraulic fracture treatment can be obtained from the MS event location and the geometry of the MS cluster and is used later to interpret the intensity and extent of the induced fracturing. A more detailed understanding of the fracturing process, i.e., crack opening, fault slipping, and the combination of both, is obtained from the analysis of waveform amplitudes to characterize the source. This study analyzes uncertainties underlying the location of MS events and the determination of source mechanisms.

The main factors controlling the accuracy of MS locations are the quality of the recorded waveform, the accuracy of the velocity model used for the forward modelling of travel times and the configuration of the monitoring array. The effect of the velocity model and array geometry on source locations is analyzed through the location of a cluster of 200 synthetic events with a mixture of shear and tensile source mechanisms with full waveforms generated using a continuous spectral-element method (SPECFEM3D, Komatitsch and Tromp, 1999) through a velocity model based on the conditions in the Barnett Shale (Figure 1a). Colored random noise (see Figure 1b) is added to the signal to reproduce field monitoring conditions and the events are relocated using variations of the true model including a homogeneous simplification. The robustness of individual event locations and overall cluster geometry is tested against the velocity model and different array configurations with varying aperture, number of instruments and azimuthal coverage.

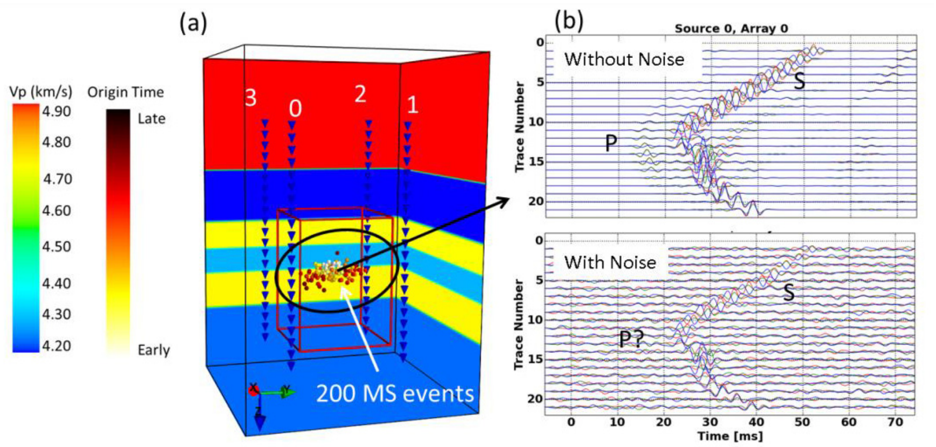

Figure 1: (a) shows the 3D layered model based on well logs from Barnet shale. In total 200 MS sources are modeled at the center of the model and the waveform is recorded by four arrays of three-component (3C) geophones. The MS sources are distributed along XY direction mimicking a fracture developing along North-East direction due to the treatment at the center of the model. The color of each event refers to its occurrence time. (b) shows synthetic waveform generated by the first MS source and recorded by 3C geophones from array 0 with and without noise contamination.

The effects of varying number of borehole arrays and different monitoring geometries on the inverted source mechanism is also investigated creating a numerical simulation of four typical source modes bonded particle model (BPM) in which the rock material is modelled as an assembly spherical particles bonded together at their contacts by parallel-bonds (e.g. Potyondy and Cundall, 2004) (Figure 2). Seismic sources can then be modelled by joining clusters of source particles by a fault plane modelled by a smooth joint (e.g. Mas Ivars et al., 2011). Different force histories are applied to these source particles along certain directions to simulate different types of source mechanisms. The body forces directly exerted by source particles are then monitored using linear sets of particle arrays which record the displacement simulating the waveforms recorded by sensors in field operations (Figure 2).

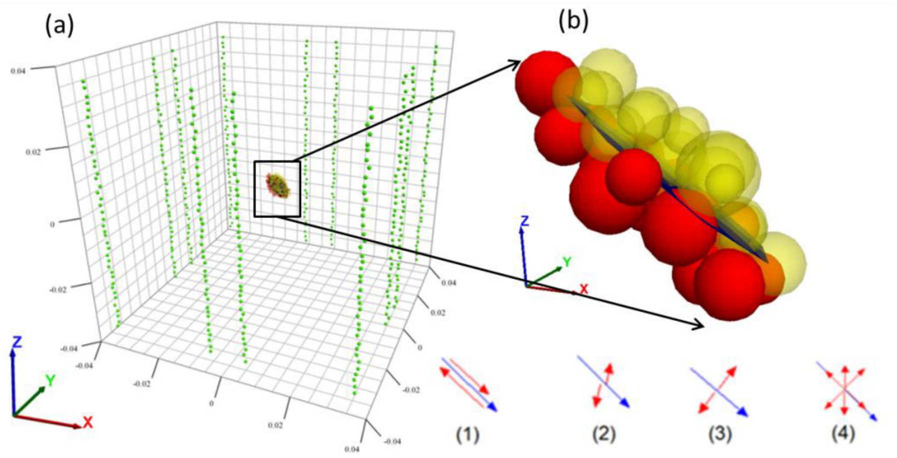

Figure 2: a Synthetic Rock Mass (SRM) model. (a) Receiver (green spheres) and source particles. (b) Source particles associated the fault plane (blue surface) in detail. The symbolic figures below represent the moving directions of the source particles for modelled four source modes: (1) dip-slip, (2) strike-slip, (3) tensile, and (4) explosion.

With the above numerical experiments, effects of signal quality, velocity model, and acquisition geometry on the source characterization will be investigated to help us optimize the monitoring and enhance the fracture imaging.

References

Komatitsch, D. and J. Tromp, 1999, Introduction to the spectral-element method for 3-D seismic wave propagation, *Geophysical Journal International*, vol. 139, p. 806-822.

Mas Ivars, D., M. Pierce, C. Darcel, J. Reyes-Montes, D. O. Potyondy, R. P. Young, and P. A. Cundall, 2011. “The Synthetic Rock Mass Approach for Jointed Rock Mass Modeling.” *Int. J. Rock Mech. & Min. Sci.*, v.48, p.219-244.

Potyondy, D.O., and Cundall, P.A. 2004. A bonded-particle model for rock. *International Journal of Rock Mechanics and Mining Sciences*, **41**(8), 1329–1364.