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Using Passive Seismic Data in Discrete Fracture Network Models

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Abstract

The presence of natural fractures is well known in tight reservoirs; however, their roles in influencing hydraulic fracture growth and production are less well understood. In this presentation we look at how passive seismic data can help in building discrete fracture network (DFN) models that include three types of fractures -- new hydraulic fractures, existing conductive natural fractures, and natural fractures that are enhanced as a result of hydraulic fracturing treatments. We also look at two types of passive seismic data – hypocenter center data from microseismic events and Tomographic Fracture Images.

A DFN model uses data from image logs, outcrop analogs, and other downhole information to define the geometry of the natural fracture system. The geometric description includes fracture intensity, orientations, and fracture sizes. We have implemented hydraulic fracture growth into a DFN model using a material balance approach that either (1) accommodates injected mass in the natural fractures if they are appropriately oriented with the in situ stresses, or (2) creates new hydraulic fractures if they are not. The model grows the affected region incrementally creating synthetic microseismic events where fractures are opening or being propagated. Observations of actual hypocenter distributions commonly show a range of spatial distributions from diffuse to highly oriented. DFN simulations show that these behaviors may reflect the presence or absence of an influence of natural fractures.

A second application of passive seismic monitoring uses tomographic fracture images from an Eastern US Devonian gas shale. These images indicate that the effects of hydraulic fracturing may extend further than the hypocenters of the microseismic events would suggest. A DFN model of this reservoir included four fracture types:

1. Hydraulic fractures based on the microseismic hypocenter mapping data,
2. Conductive natural fractures identified from monitoring gas returns in nitrogen that was used for drilling the wells,
3. Natural fractures aligned with lineaments based on seismic tomographic images, and
4. Stochastic fractures with locations based on the geometric statistics of the lineaments.

DFN simulations of production data showed that production behaviors could be simulated with either hydraulic fractures alone or with a combination of hydraulic and natural fractures. The simulations using natural fractures showed that the major portion of the production was coming from the region with the footprint of the hydraulic fractures, however, the natural fractures significantly extend the drainage volume.