Scaling Microseismic Cloud Shape during Hydraulic Stimulation using Permeability and In-situ Stress

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August 3, 2023

Abstract

Forecasting microseismic cloud shape as a proxy of stimulated rock volume is essential for the design of an energy extraction system. The microseismic cloud created during hydraulic stimulation is known empirically to extend in the maximum principal stress direction. However, this empirical relationship is often inconsistent with reported results, and the cloud growth process remains poorly understood. This study investigates microseismic cloud growth using data obtained from a hydraulic stimulation project in Basel, Switzerland, and explores its correlation with measured in-situ stress. We applied principal component analysis to a time series of microseismic distribution for macroscopic characterization of microseismic cloud growth in two- and three-dimensional space. The microseismic cloud in addition to extending in the direction of maximum principal stress expanded to the direction of intermediate principal stress too. The orientation of the least microseismic cloud growth was stable and almost identical to the minimum principal stress direction. Following the stimulation, the orientation of microseismic cloud growth was consistent with the in-situ stress direction. Further, microseismic cloud shape ratios showed good agreement when compared with in-situ stress magnitude. The permeability tensor estimated from microseismicity also presented good correlation in terms of direction and magnitude with microseismic cloud growth. We show that in-situ stress plays a dominant role by controlling the permeability of each existing fracture in the reservoir fracture system. Consequently, microseismic cloud growth can be scaled by in-situ stress if there is sufficient variation in the existing faults.