Fault Reactivation Assessment Based on Microseismic and Field Dynamic Data: A Case Study from the Sultanate of Oman

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Abstract

Water injection into fractured formations can cause changes to the state of the stress and result in induced microquakes. Injections near pre-existing faults can initiate fault slipping and therefore trigger strong microseismic events. The study was conducted in a faulted giant field having a relatively low relief structure. The field consists of stacked cretaceous carbonate reservoirs overlain by shale cap rocks. The main reservoir is highly compacted chalky limestone. At an early stage, compaction was anticipated, hence, the field operator implemented a set of aerial surveillance techniques such as passive microseismic, InSAR, and GPS. In this study, we focused on utilizing data from the passive microseismic monitoring system that is comprised of 12 wells equipped with 8 downhole geophone arrays and surface accelerometers. The microseismic system can detect both induced seismicity and naturally occurring small earthquakes. Historically, the microseismic data show high seismicity along the major mapped faults that are parallel to the horizontal maximum stress. Some of those microseismic activities are attributed to gas depletion in the last decade. Furthermore, a cluster of events has been observed near a water injection well. Recently, unexpected seismicity was observed in the northern-west area of the field away from the gas producers with a moment magnitude range between -0.7 to 2.7. These events are located 800 meters away from closest wells. In this study, we focused on investigating the relationship between the cumulative seismic moment, magnitude range, and b-value of two induced microseismic event clusters. Additionally, we examine the spatio-temporal correlation between seismicity and cumulative water injected into the reservoir. The main objective is to highlight the potential risk that could be caused by fluid injection near pre-existing major faults. The spatio-temporal characteristics of the detected microseismicity indicate a reactivation of a NW-SE fault despite being oriented perpendicular to the regional maximum stress orientation. The detected events were found to have a larger moment magnitude compared to the fracturing-related cluster of events. The b-value calculated for the northern-west area is 0.51, which suggests fault-related induced events. On the other hand, the analog cluster of events used in this study has a b-value of 1.38, which indicate fracture-related induced microseismic events. Determining the main cause of these event triggers will help to optimize water injection and avoid targeting critically stressed faults.