Variation of slip tendency of a seismogenic fault associated with fluid extraction and injection in the Hutubi underground gas storage, China

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We conduct geomechanical study for a seismogenic fault in Hutubi underground gas storage site, northwestern China. The Hutubi reservoir has undergone active production from 1990s to 2012, leading to a complete depletion, and then sequential gas injection and extraction from 2013 for the gas storage project. First, we constrain the orientation and magnitudes of the stress state at the reservoir depths (~3.6 km depth) at the time of a complete depletion in 2012, using image-logged wellbore breakouts in a borehole. Then we estimate the variation of the stress state with time as a result of pore pressure change based on a simple assumption of coupling between horizontal stresses and pore pressure. Our results show that the stress state was initially in a reverse faulting regime before production and switched to a strike-slip faulting regime during production. Gas injection from 2013 turned the stress regime again in favor of reverse faulting. We use the estimated variation of the reservoir stress state with time to calculate temporal changes of slip tendency of the major earthquake fault (Hutubi fault) in the reservoir. Slip tendency of the fault decreased continuously with production, and then increased with injection. The first earthquake swarm associated with gas injection occurred ~2 months after the commencement of injection, possibly due to slow pore pressure diffusion. Thereafter, earthquakes were induced whenever gas was injected, while few earthquakes were detected during gas extraction phases. Our preliminary assessment of slip tendency suggests that earthquake swarms are induced during increasing phases of pore pressure when slip tendency reaches a value between 0.4 and 0.5, which can provide information on friction coefficient of the fault.

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