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Limiting the Magnitude of Potential Injection-Induced Seismicity Associated With Waste-Water Disposal, Hydraulic Fracturing and CO_2 Sequestration

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In this talk, I will address the likelihood for fault slip to occur in response to fluid injection and the likely magnitude of potentially induced earthquakes. First, I will review a methodology that applies Quantitative Risk Assessment to calculate the probability of a fault exceeding Mohr-Coulomb slip criteria. The methodology utilizes information about the local state of stress, fault strike and dip and the estimated pore pressure perturbation to predict the probability of the fault slip as a function of time. Uncertainties in the input parameters are utilized to assess the probability of slip on known faults due to the predictable pore pressure perturbations. Application to known faults in Oklahoma has been presented by Walsh and Zoback (Geology, 2016). This has been updated with application to the previously unknown faults associated with M >5 earthquakes in the state. Second, I will discuss two geologic factors that limit the magnitudes of earthquakes (either natural or induced) in sedimentary sequences. Fundamentally, the layered nature of sedimentary rocks means that seismogenic fault slip will be limited by i) the velocity strengthening frictional properties of clay- and carbonate-rich rock sequences (Kohli and Zoback, JGR, 2013; in prep) and ii) viscoplastic stress relaxation in rocks with similar composition (Sone and Zoback, Geophysics, 2013a, b; IJRM, 2014; Rassouli and Zoback, in prep). In the former case, if fault slip is triggered in these types of rocks, it would likely be aseismic due the velocity strengthening behavior of faults. In the latter case, the stress relaxation could result in rupture termination in viscoplastic formations. In both cases, the stratified nature of sedimentary rock sequences could limit the magnitude of potentially induced earthquakes. Moreover, even when injection into sedimentary rocks initiates fault slip, earthquakes large enough to cause damage will usually require slip on faults sufficiently large that they extend into basement. This suggests that an important criterion for large-scale CO_2 sequestration projects is that the injection zone is isolated from crystalline basement rocks by viscoplastic shales to prevent rupture propagation from extending down into basement.