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Simulation of secondary fault shear displacements - method and application

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We present an earthquake simulation method to calculate dynamically and statically induced shear displacements on faults near a large earthquake. Our results are aimed at improved safety assessment of underground waste storage facilities, e.g. a nuclear waste repository. For our simulations, we use the distinct element code 3DEC. We benchmark 3DEC by running an earthquake simulation and then compare the displacement waveforms at a number of surface receivers with the corresponding results obtained from the COMPSYN code package. The benchmark test shows a good agreement in terms of both phase and amplitude. In our application to a potential earthquake near a storage facility, we use a model with a pre-defined earthquake fault plane (primary fault) surrounded by numerous smaller discontinuities (target fractures) representing faults in which shear movements may be induced by the earthquake. The primary fault and the target fractures are embedded in an elastic medium. Initial stresses are applied and the fault rupture mechanism is simulated through a programmed reduction of the primary fault shear strength, which is initiated at a pre-defined hypocenter. The rupture is propagated at a typical rupture propagation speed and arrested when it reaches the fault plane boundaries. The primary fault residual strength properties are uniform over the fault plane. The method allows for calculation of target fracture shear movements induced by static stress redistribution as well as by dynamic effects. We apply the earthquake simulation method in a model of the Forsmark nuclear waste repository site in Sweden with rock mass properties, in situ stresses and fault geometries according to the description of the site established by the Swedish Nuclear Fuel and Waste Management Co (SKB). The target fracture orientations are based on the Discrete Fracture Network model developed for the site. With parameter values set to provide reasonable upper bound estimates of target fracture displacements, the model generates primary fault slip and slip velocities that are both high compared to those found in real earthquakes. The calculated target fracture movements reach some tens of millimetres on 300 m diameter fractures. We also present results indicating the sensitivity of primary fault slip and target fracture movements to e.g. variation of primary fault residual strength, change of hypocenter location and variations in the initial stress field.