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Stress field sensitivity analysis within Mesozoic successions in the Swiss Alpine foreland using 3-D-geomechanical-numerical models

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The in situ stress conditions are of key importance for the evaluation of radioactive waste repositories. In stage two of the Swiss site selection program, the three siting areas of high-level radioactive waste are located in the Alpine foreland in northern Switzerland. The sedimentary succession overlays the basement, consisting of variscan crystalline rocks as well as partly preserved Permo-Carboniferous deposits in graben structures. The Mesozoic sequence represents nearly the complete era and is covered by Cenozoic Molasse deposits as well as Quaternary sediments, mainly in the valleys. The target horizon (designated host rock) is an $>$100 m thick argillaceous Jurassic deposit (Opalinus Clay).

To enlighten the impact of site-specific features on the state of stress within the sedimentary succession, 3-D-geomechanical-numerical models with elasto-plastic rock properties are set up for three potential siting areas. The lateral extent of the models ranges between 12 and 20 km, the vertical extent is up to a depth of 2.5 or 5 km below sea level. The sedimentary sequence plus the basement are separated into 10 to 14 rock mechanical units. The Mesozoic succession is intersected by regional fault zones; two or three of them are present in each model. The numerical problem is solved with the finite element method with a resolution of 100–150 m laterally and 10–30 m vertically. An initial stress state is established for all models taking into account the depth-dependent overconsolidation ratio in Opalinus Clay in northern Switzerland. The influence of topography, rock properties, friction on the faults as well as the impact of tectonic shortening on the state of stress is investigated. The tectonic stress is implemented with lateral displacement boundary conditions, calibrated on stress data that are compiled in Northern Switzerland.

The model results indicate that the stress perturbation by the topography is significant to depths greater than the relief contrast. The impact of fault geometry and frictional properties is observed within a distance of $<$1 km. The major impact on the stress state is caused by the variability of the geomechanical stratigraphy. The stress anisotropy increases when tectonic shortening is applied to the models. Stress magnitudes and anisotropy are largest within the stiff formations such as limestone. These stiff formations carry the load due to far field tectonic forces, whereas weak formations, like the argillaceous target horizon for the waste disposal, exhibits smaller stress magnitudes. Using the fracture potential as a more unambiguous indicator, the stiff overburden rocks are closer to failure than the target horizon for the repository, whereas stiff formations below the target rocks are far from failure.