In situ stress in potential siting areas in northern Switzerland from stress data and 3D geomechanical-numerical models

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For the geological documentation in phase 2 of the search of a deep geological repository site stress data for Switzerland and adjacent regions from the World Stress Map database release 2008 were re-assessed and updated. Furthermore, the revised data base contains 107 new data records; 34 data records were eliminated. In particular in northern Switzerland 15 new data records from 11 borehole locations from depth up to 2.5 km are of importance as well as the re-analysis of seven old Nagra boreholes. The stress pattern of Switzerland shows a long wave-length trend with a mean SH orientation of 155° ± 30°; in northern Switzerland the mean SH orientation is 160° ± 21°. Northeast of the Bodensee SH is N-S oriented and rotates gradually by ~ 40° along the alpine front from East to West to a WNW-ESE orientation in west Switzerland. The regional trend of the stress pattern as well as the mean SH orientation is independent from the chosen sub datasets and show no general difference when e.g. data records only from the basement or sediments are taken into account. SH is oriented perpendicular to the strike of the Alps and sub-parallel to the indentation direction of the Adriatic plate with Eurasia and the gradient of the Eurasia Moho. The main stress sources are the topography of the Alps and the lateral density contrast, respectively and, of probably smaller importance, the large-scale plate tectonic.

In order to describe the 3D in situ stress state in potential siting areas geomechanical-numerical models are essential. For the Nördlich Lägern and Zürich Nordost existing geological models of the subsurface, consisting of lithological interfaces and faults are used as a basis for geomechanical numerical models for the characterization of the state of stress in the siting area. Due to uncertainties regarding geometries and rock properties in the subsurface, the models presented exhibits generic features. Accordingly, the focus of the models is not so much on the precise quantification of the state of stress rather than on the estimation of the influence of individual factors contributing to the stress state and its spatial variability.

The model results show in general, that the relevant stress ratios SH/SV, Sh/SV and SH/Sh are considerably reduced in the Opalinus Clay in comparison to the formations lying above or below. In particular the competent formations of the Upper Malm and the Upper Muschelkalk are characterized by higher stress ratios and higher differential stress than the weak formations, show a more compressive stress regime and greater horizontal stress anisotropy. Therefore, they support the tectonic push from the far field.

To investigate the impact of topography, friction coefficient, fault geometry and potential ice loads a number of model variants are calculated. The model results show that higher fault friction coefficients increases stress ratios in the host rock. Particularly the horizontal stress anisotropy is increased because the fault's ability to slip and thereby weakening the push from the far field is reduced at higher friction. Whether faults reach below the Mesozoic sediments or not has little impact on the stress state within the sediments. Topography influences the stress state due to the spatially varying weight acting on the subsurface. Of great importance are those stresses that are induced by the topography as a response to the northward directed push from the far field. These induced stresses are positive below topographic depressions and negative below topographical highs and appear to depths of up to several hundred metres. An ice cover significantly lowers stress ratios and their lateral variability, particularly the ratio of horizontal to vertical stress is reduced.