Impact of elastic material properties and discontinuities on the stress orientation

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The in-situ stress state in the upper crust is an important issue for diverse economic purposes and scientific questions as well. Several methods have been established in the last decades to estimate the present-day orientation of the maximum compressive horizontal stress ($S_{Hmax}$) in the crust. It has been assumed, that the $S_{Hmax}$ orientation on a regional scale is governed by the same forces that drive plate motion too. The $S_{Hmax}$ Orientation data, compiled by the World Stress Map (WSM) project, confirmed that for many regions in the world. Due to the increasing amount of data, it is now possible to identify several areas in the world, where stress orientation deviates from the expected orientation due to plate boundary forces (first order stress sources), or the plate wide pattern. In some of this regions a gradual rotation of the $S_{Hmax}$ orientation is observed.

Several second and third order stress sources have been identified which may explain stress rotation in the upper crust. For example, lateral heterogeneities in the crust, such as density, petrophysical or petrothermal properties and discontinuities, like faults are identified. Apparently, there are just a few studies, that deal with the potential extend of stress rotation as a function of second and third order stress sources. For that reason, generic geomechanical numerical models have been developed, consisting of up to five different units oriented at an angle of 60 degrees to the direction of contraction. These units have variable elastic material properties, such as Young's modulus, Poisson ratio and density. In addition, an identical model geometry allows the units to be separated by contact surfaces that allow them so slide along the faults, depending on a selected coefficient of friction.

The model results indicate, that a density contrast or the variation of the Poisson's ratio alone sparsely rotates the horizontal stress orientation. Conversely, a contrast of the Young's modulus allows significant stress rotations. Not only areas in the vicinity of the material transition are affected by the stress rotation, but the entire blocks. Low friction discontinuities do not change the stress pattern when viewed over a wide area in homogeneous models. This also applies to models with alternating stiff and soft blocks - the stress orientation is determined solely by the boundary conditions, not the material transitions. This indicates that material contrasts are capable of producing significant stress rotation for larger areas in the crust. Active faults that separates such material contrasts have the opposite effect, they compensate for stress rotations.