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Effect of rock mechanical property heterogeneity on crustal stress

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We are trying to understand the crustal stress condition around Pohang, southeastern Korea, where the 2017 M5.4 Pohang earthquake occurred. The region is located near coast, where sedimentary rocks of different ages cover the area, thus exhibiting heterogeneous rock mechanical properties. Measured stress orientations at depths shallower than 1km at different locations (on- and off-shore) through borehole stress indicators (such as borehole breakouts) vary significantly, showing $>40^{\circ}$ rotations of the maximum horizontal principal stress (S_{Hmax}). We note that S_{Hmax} azimuth onshore near coast where rock is relatively more rigid deviates systematically from the stress orientation dominant in Korea, while that offshore consisting of relatively younger sediments remains consistent with the dominant stress orientation. To understand possible causes of the observed stress perturbation, we explore two factors that can perturb the stress state: topography and rock mechanical property heterogeneity. The topographic effect on stress perturbation, which is estimated by an analytic solution for gravity-induced point load is not so significant enough to rotate stress orientation. The effect of rock mechanical heterogeneity represented by Young's modulus variation, which is modeled by a finite element numerical method, is significant such that stress orientation rotates near the rock mechanical boundary when the boundary is oblique to the prevailing stress orientation. We compare the model result with the measured stress orientations at the boreholes in the region, and find that they are quite comparable. Our study suggests that the shallow stress may be perturbed by rock mechanical property heterogeneity and may not represent the regional tectonic stress state at greater depths (>4km) where a single type of basement rock exists.