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Effects of topography and lithology variation on in situ stress at shallow depths in South Korea: results from statistical characterization of stress data

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In situ stress state at shallow depths (<1 km) is important for designing underground systems for various projects such as nuclear waste disposal, carbon dioxide geological sequestration, and geo-resource development. Stress characterization for such projects rely largely on stress measurement data (such as hydraulic fracturing test data). We compile a large number of hydraulic fracturing test data measured in a total of 226 boreholes in South Korea, and attempt to characterize shallow crustal stress over the country. These data are measurements at depths down to 850 m, and classified mostly low-quality based on World Stress Map quality ranking scheme (B-quality: 7%, C: 42%, and D: 51%). We grid the country by 0.25°×0.25°, and find a circular bin size at each grid point using two statistical methods (weighted standard deviation and quasi interquartile range), by which the uniformity of stress orientation can be estimated. As many data are low-quality, we apply this process to two subsets of data (B-C and B-D) to find an optimal stress characterization. Our most optimal characterization results show that bin diameter in most of the country vary between 100 and 200 km, except for southeastern Korea. Bin diameters in southeastern Korea range between 0 and 60 km, which means that stress heterogeneity is especially significant in the region, where lithology varies markedly and several active faults are clustered. The stress orientations in the northeastern part of the country are characterized as intermediate stress uniformity (bin size of ~120 km in diameter) but a systematic horizontal stress rotation (up to ~60°) from that of the deep-seated regional stress. This region is mountainous with altitude as high as 1.4 km. To verify whether the stress rotation is a result of topographic effect, we model stress perturbation using the digital elevation model (DEM) data of the region, which yields stress rotation comparable to measurements. We find that lithology is a particularly important factor that affects stress magnitudes over the country, as the stress magnitudes at the same depth tend to be markedly smaller in sedimentary rocks than in crystalline rocks. Our study, although given data are of fairly low-quality, can provide a basis for shallow stress map of South Korea.