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# A Comparison between Deep and Shallow Stress Fields in Korea Using Earthquake Focal Mechanism Inversions and Hydraulic Fracturing Stress Measurements

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We are characterizing stress fields in Korea using two types of stress data: earthquake focal mechanism inversions (FMF) and hydraulic fracturing stress measurements (HF). The earthquake focal mechanism inversion data represent stress conditions at 2-20 km depths, whereas the hydraulic fracturing stress measurements, mostly conducted for geotechnical purposes, have been carried out at depths shallower than 1 km. We classified individual stress data based on the World Stress Map quality ranking scheme. A total of 20 FMF data were classified into A-B quality, possibly representing tectonic stress fields. A total of 83 HF data out of compiled 226 data were classified into B-C quality, which we use for shallow stress field characterization. The tectonic stress, revealed from the FMF data, is characterized by a remarkable consistency in its maximum stress ($\sigma_1$) directions in and around Korea (N79$\pm$2$^{\circ}$E), indicating a quite uniform deep stress field throughout. On the other hand, the shallow stress field, represented by HF data, exhibits local variations in $\sigma_1$ directions, possibly due to effects of topography and geologic structures such as faults. Nonetheless, there is a general similarity in $\sigma_1$ directions between deep and shallow stress fields. To investigate the shallow stress field statistically, we follow 'the mean orientation and wavelength analysis' suggested by Reiter et al. (2014). After the stress pattern analysis, the resulting stress points distribute sporadically over the country, not covering the entire region evenly. In the western part of Korea, the shallow $\sigma_1$directions are generally uniform with their search radius reaching 100 km, where the average stress direction agrees well with those of the deep tectonic stress. We note two noticeable differences between shallow and deep stresses in the eastern part of Korea. First, the shallow $\sigma_1$ orientations are markedly non-uniform in the southeastern part of Korea with their search radius less than 25 km. In this region, the average $\sigma_1$orientation based on the entire B-C quality stress data is calculated to be 77$\pm$37$^{\circ}$; however, the average orientation is somewhat meaningless because of the high standard deviation. The southeastern part of Korea consists mainly of Cretaceous sedimentary basin, geologically younger than the rest of the country, where regional scale faults are intensely populated. The highly scattered stress directions in this region may represent the effect of the geologic structures on shallow stress field. Second, shallow $\sigma_1$ directions in the northeastern part of Korea strike consistently to 135$\pm$12$^{\circ}$, which is deviated by as much as 56$^{\circ}$ from the deep tectonic stress direction. This region is characterized by high altitude mountainous topography (an elevation of an order of 1 km) with its major ridge axis in the NW-SE direction. We interpret, as a rule of thumb, that the ridge-perpendicular shallow horizontal stress components may be weak, leading to the ridge-parallel components to be the maximum. Overall, there are similarity and also difference between shallow and deep stress fields. Thus, it will be necessary to differentiate the strategy to tackle the stress-related problems based on their natures.