Depth-dependent state of stress revealed by fault-slip analysis in the Niigata area, central Japan

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Fault-slip analysis is effectual for estimating the state of stress in the crust. However, it is not clear whether stresses revealed through the analysis coincide with regional stress field especially in highly deformed regions. Growth of map-scale structures may produce local variation of stress. To address this problem, fault-slip analysis was applied to the Niigata area where folds have been growing mainly in the Quaternary. The results showed depth-dependent state of stress in the area.

We used two kinds of data sources, i.e., meso-scale faults observed at outcrops, shear fractures in borehole cores and focal mechanisms of mid-crustal earthquakes. The meso-scale faults were observed in the Neogene and Quaternary soft sediments exposed in the Nishiyama-Chuo Oil Field and Hachikoku-Higashikubiki mountains, Niigata fold belt, central Japan. More than 400 faults were found in the oil field, we author obtained 222 fault-slip data in the Hachikoku-Higashikubiki mountains. In addition, we used 30 focal mechanisms from mid-crustal earthquakes since January 1st, 1997 to September 30th, 2005 under the study area for understanding stress state in the basement.

As a result, complicated stress field was found. The stresses that were determined from the faults at outcrops were discordant with the growth of folds. However, the reverse faulting regime of stress at depths has the sigma_1-orientation perpendicular to the folds, concordant with the folding. This stress regime is also consistent with the regional stress field in the Japan Arc (Seno, 1999).

The depth-dependency of the stress state was interpreted as the manifestation of the vertical variation in the strength of the crust. The reverse faulting regime at depths reflects the regional stress field, because the strong mid-crustal level works as the stress guide of the crust. The regional stress may have activated the basement faults that have orientations favorable to the regional stress and have the folds with coherent trend of axes in the shallow level of the crust as their surface expressions. In contrast, young and soft over strata are relatively free from the regional stress. The folding resulted in an average horizontal shortening of ca.13 % in the Niigata region (Sato, 1989). Such a large deformation by folding must have locally affected stress field. In addition, the soft sediments in the anticlinoria may be susceptible to gravitational spreading of structural highs, giving rise to the local stress field discordant with folding.

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