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Active morphotectonics related to the upper crustal shortening in the back-arc of the Northeast Japan arc, based on geomorphic terrace deformation and elastic dislocation models for reverse faults

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Knowledge of active morphotectonics, the relationship between active faults and morphological evolution, is important for understanding on-going active tectonic processes in the trench-arc system and evaluating the activity of faults. Especially in regions where the main active faults are concealed, such as in the back-arc of the Northeast Japan arc. The Dewa Hills in the back-arc of the Northeast Japan arc is a tectonic uplifted zone parallel to the main direction of the arc, bounded by Kitayuri thrust system (KTS) at western margin. The activity of reverse faults as a result of upper crustal shortening related to the subduction of the Pacific plate beneath the Eurasian plate has affected the morpho-tectonogenesis in the back-arc. This study examines the deep geometry and net slip rate of faults at seismogenic depth in the back-arc, and presents active morphotectonic models related to upper crustal shortening, by analyzing the deformation patterns of topography and geology, and through an examination of elastic dislocation models for reverse faults.

The Pleistocene fluvial terraces, a practical geomorphic marker for quantifying crustal movement in the late Quaternary, are developed along some antecedent valleys that truncate the Dewa Hills. Through an investigation of the chronology and correlation of Pleistocene marine and fluvial terraces based on geomorphological and tephrochronological investigations, M terraces correlated with MIS 5 have been widely identified in the back-arc. The maximum uplift rates in the back-arc in the late Quaternary are estimated as 1.0 mm/yr in the Oga Peninsula (Imaizumi 1977; Miyauchi, 1988), and 1.4 mm/yr in the Dewa Hills. The height distribution of geomorphic terraces shows two types of surface deformation patterns in the late Quaternary, and these are produced by the activity of reverse faults: a major deformation unit with a half wavelength of 20-40 km or more, and a secondary deformation unit with a half wavelength of less than 20 km.

Applying the elastic dislocation model for reverse faults to the surface deformation patterns has clarified the deep geometry and slip rates of reverse faults beneath the Dewa Hills. Characterizing fault geometries beneath the Dewa Hills are east-dipping low-angle reverse faults stretching from the surface KTS to the bottom of seismogenic layer, with a shallower detachment and ramps. These deep-rooted east-dipping faults play an important role in the long wavelength deformation (defined as the major deformation unit) characterized by asymmetrical warping with uplift. The modeled east-dipping reverse faults are accompanied by west-dipping reverse faults on the hanging wall. These faults are characterized as relatively high-angle reverse faults accompanied by folds on the hanging wall side. The short wavelength deformation (defined as the secondary deformation unit) is strongly controlled by the shallow structure of reverse faults (flat and ramps at shallower depth). The delineated modeled fault geometries are in reasonably good agreement with, and provide a consistent explanatory framework for a variety of data describing the subsurface geologic structures, geologic history, longitudinal topographic profiles and co-seismic surface deformations in the back-arc.

The 6.6-6.9 $\times 10^{-8}$/yr strain rate and the 2.0-3.3 mm/yr of horizontal shortening in the back-arc are obtained by adapting elastic dislocation models to the surface deformation. Horizontal strain rates deduced from elastic dislocation models are comparable to the horizontal strain rate calculated by geological methods (Sato, 1989). The obtained strain rate indicates that considerable horizontal crustal shortening continued after 3.5 Ma and that the activity of reverse faults with high strain rates has morphotectonically promoted the uplifting of the Dewa Hills. The obtained values indicate that approximately 2-4% of the convergence rate of the Pacific plate (80-90 mm/yr) has accumulated in the upper crust of the back-arc of the Northeast Japan arc as permanent strain in the late Qua-

ternary. The reverse fault systems play an important role in the upper crustal shortening and construction of the 20-50 km half wavelength topographic relief trending parallel to the direction of the arc in the back-arc.

In addition to these morphotectonics related to the activity of reverse faults, massive or east-west trending mountains are also developed in the back-arc. These mountains distributed at regular intervals and active faults are hardly developed in them. Considering the high strain rates related to reverse faults in the back-arc, upper crustal shortening seems to occur in the east-west trending mountains regions by other mechanism in the late Quaternary, such as by non-elastic warping or up-doming (e.g., Hasegawa et al., 2004). These active tectonic processes in the back-arc produce the small to medium scale geomorphology that results from a permanent strain accumulation in the upper crust.