Active morphotectonics related to the upper crustal shortening in the back-arc of the Northeast Japan arc

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Reverse faults and narrow uplifted zones in the back-arc of the Northeast Japan arc are formed as a result of upper crustal shortening under a compressional stress field since the Pliocene, which is due to the subduction of the Pacific plate beneath the Eurasian plate.

This study examines the deep geometry and net slip rate of faults at seismogenic depth in the back-arc of the Northeast Japan arc, and presents active morphotectonic models related to upper crustal shortening.

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 as iso-geomorphic markers for quantifying crustal movement in the late Quaternary 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 Kitayuri thrust system 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 x 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 on the time scale of 10^4-10^6 years. The calculated 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 construction 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 Quaternary. The reverse fault systems play an important role in the upper crustal shortening and the small to medium scale morphotectonics in the back-arc.

In addition to the reverse faulting, non-elastic warping or up-doming are presumed to occur as a mechanism of upper crustal shortening in regions of pre-Neogene rocks or Quaternary volcanic rocks in the back-arc, and these construct the domed or east-west trending mountains. 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.