Vertical crustal movements and horizontal shortening rate of the northeast Japan arc in the past 150 kyr.

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The Pacific plate is subducted beneath the northeast Japan arc in a direction perpendicular to the arc at a rate of about 8-9 cm/yr, and compressional deformation in the northeast Japan arc is attributed to this subduction. Rates and spatial distribution of crustal deformation in Japan are still unclear since reliable data on long-term deformation rates are not available except in coastal areas. In this study, first the rates and spatial distribution of vertical crustal deformation in the northeast Japan on a geologic time scale is estimated using fluvial terrace data. Next, the deformation mechanism and evolution process of the northeast Japan arc is discussed on the basis of the observed data of crustal deformation and other existing geological/geophysical data.

Distribution of TT/FS values, which represent uplift during about 120 kyr, has some characteristic features as follows: (1) Pattern of uplift is in accordance with topography. This suggests that similar pattern of uplift have been taking place since Pliocene time, resulting in the present topography of northeast Japan. (2) Spatial variations of uplift rates are frequent and significant in the inner arc, whereas they are scarcely recognized in the outer arc. (3) Uplift rates vary abruptly at known active faults. This indicates that the changes in uplift rates at active faults can be attributed to slip on these faults. (4) Even in the areas (volcanic areas) where no active fault is recognized, uplift rates vary spatially with wavelength of about 50 km.

On the basis of the spatial distribution of uplift, we infer that the deformation of the northeast Japan arc consists of the deformation with short wavelength (10-50 km) and the deformation with long wavelength (150-200 km). The short-wavelength deformation is likely to be caused by active faults. Two lines of evidence exist for this interpretation. One is that the points where uplift rates vary abruptly correspond to the surface traces of known active faults, and the other is that a lithosphere with normal elastic thickness cannot be deformed with a wavelength as short as 10-50 km. Four possible causes of the long-wavelength, whole arc deformation are pointed out as follows: (1) isostatic uplifts due to crustal thickening, (2) isostatic uplifts due to denudation, (3) isostatic subsidence due to load of volcanic deposits, and (4) crustal deformation due to steady plate subduction. Crustal thickening, in turn, is caused by crustal shortening and magmatic underplating. The crustal deformation style of the northeast Japan arc that is deduced from this study is schematically interpreted as follows; it is likely that the crust of the inner arc of northeast Japan has been thickened through compressional deformation due to active faulting in the upper crust, and due to ductile flow in the lower crust.

An average uplift rate over the northeast Japan arc is 0.24-0.32 mm/yr. By subtracting isostatic responses due to denudation and load of volcanic deposits from the average uplift rate, we obtain the rate of isostatic uplift due to crustal thickening at 0.21-0.31 mm/yr. From this value, crustal thickening rate can be calculated at 1.3-1.7 mm/yr. If we ignore the effect of magmatic process, and assume that (1) arc-parallel deformation is negligibly small, and (2) crustal material are incompressible (no change in volume), maximum shortening rate and horizontal strain rate of the northeast Japan arc in recent about 150 kyr are calculated at 6.6-8.5 mm/yr and 4.2-5.6*10^-8 /yr, respectively. However, we should note that actual shortening and strain rates are smaller than these values, because uplift due to subduction of the Pacific plate and crustal thickening due to magmatic underplating are not counted in this estimate. Obtained crustal shortening rate (6.6-8.5 mm/yr) indicates that only 10 % of the plate convergence has been accommodated within the northeast Japan arc as permanent (plastic) deformation of the arc crust.