Crustal strain rate paradoxes of intralplate Japan: their solutions and implications

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There had been a long-lasting debate on crustal strain rate of the Japanese inland. Geodetic strain rates estimated based on triangulation or GPS surveys were on the order of 0.1 ppm/year, which is an order of magnitude larger than the geologic estimate (Wesnousky et al., 1982, Hashimoto, 1990, Sagiya et al., 2000). Ikeda (1996) hypothesized that geodetic strain rate mainly reflects elastic strain accumulation due to the interplate coupling at subduction zones and predicted a giant earthquake. The predicted earthquake occurred in 2011, as the M_w9.0 Tohoku-oki earthquake, releasing E-W strain on the order of 10 ppm over a wide area in northeast Japan, providing a verification of the Ikeda's hypothesis. The coseismic strain pattern of the Tohouku-oki earthquake also revealed that localized interseismic strain along the Japan Sea coast and in the northern part of central Japan was not released. This indicates that not all the interseismic strain was elastic, but a certain portion of the E-W shortening signal was inelastic, accumulating over recurrences of giant earthquakes at the Japan Trench. This persistent shortening strain rate signal was identified from both interseismic and postseismic strain rate pattern as the short-wavelength component. The location and the magnitude (0.04~0.10 ppm/year) of the localized contraction rate is consistent with the long-term shortening rate estimated from deformation of the late Cenozoic sedimentary layers (Meneses-Gutierrez and Sagiya, 2016). Thus, the original strain rate paradox was generally solved although there still remain significant differences between geodetic and geologic slip rate around many active faults.

Regarding the geodetic strain rate in northeast Japan, there was another paradox between the triangulation and GNSS strain rate pattern. While the GNSS data clearly showed that E-W contraction was prevailing, triangulation data showed N-S extension, not E-W contraction. This observation was one of the reasons why the 2011 Tohoku-oki earthquake was unexpected for many scientists. We investigate a possible cause of this discrepancy, and found that the original triangulation network was probably distorted by the 1894 Shonai earthquake. The Shionohara baseline, one of the baselines to define the scale of triangulation network, was located near the source region of the Shonai earthquake, and was surveyed a few months before the earthquake. Although the Shonai earthquake is supposed to have elongated the baseline length by about 10 ppm, the original baseline length was used for the network adjustment, resulting the underestimation of the triangulation network for the whole Tohoku region. 10 ppm is nearly equivalent to the tectonic strain accumulation over 100 years. As a result, we observed N-S extension but no E-W contraction from triangulation surveys over 100 years (Sagiya et al., 2018).

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