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Millennial coastal uplift rates and the seismic cycle in the 2011 Mw 9.0 Tohoku-oki earthquake area, Japan

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The Mw 9.0 Tohoku-oki earthquake and the record of major historical seismic events including the AD 869 Jogan earthquake on the Japan trench illustrate the active tectonic capability on the subduction zone. The recent coastal deformation is revealed by the 2011 coseismic subsidence (up to 1.2 m) and postseismic uplift (up to 20 cm within 1.5 years) obtained from leveling and GPS measurements. 100 years before the earthquake, subsidence at a rate of $\sim$1 mm/a was documented. The correlation between these short-term geodetic results and long-term geologic data is decisive for understanding of the tectonic process and the related earthquake cycle on the subducting Pacific slab.

Thus, we study the millennial vertical deformation along the coastline of northern Honshu Island (38.2°N to 41.2°N) in the frame of the PALET project (ANR-JST Flash program). The exposure of emerged marine terraces, wave-cut platforms and notches allow us to determine the deformation rate during the Late Pleistocene and Holocene. Coastline terraces of marine isotope stages MIS5e (124 ka) to MIS19 ($\sim$780 ka) indicate uplift rates of 0.2-0.4 mm/a and 0.1-0.2 mm/a in the northern and southern study area, respectively. Numerous younger notches and wave-cut platforms are identified at several height levels between 1 and 10 m above sea level. Two radiocarbon samples of wood remnants yielded an age of $\sim$2.8 cal ka BP for a 3.2 m high terrace in the north (40.7°N), and a shell fragments on a notch in resistant conglomerates (39.7°N) revealed an age of 47.1 $\pm$ 2.2 cal ka BP. After correction for sea level change, both data points yield uplift rates of $\sim$1 mm/a, which denotes clear acceleration in uplift during the Late Quaternary.

An elastic dislocation model of the co-, post- and interseismic slip distribution shows how the successive coastal subsidence during M9-class earthquakes is concealed by the long-term uplift due to deep creeping deformation. The distribution of lower uplift rates in the southern area coincides with the region of the strongest 2011 coseismic subsidence and this implies the repetition of M$\sim$9 earthquake deformation with several cycles of coseismic subsidence on this section of the subduction zone. Furthermore, a different seismic behavior with recent large earthquakes (Mw 7.4-8.2) exists in the north, whereas a pre-2011 seismic gap of M>7.5 earthquakes prevailed in the seismically coupled southern part of the Japan trench. All factors attest for a segmentation of the subduction zone that prevailed in its actual position since at least 780 ka, and that the southern segment presumably generated several M$\sim$9 earthquakes in the past.