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Variable behaviors of plate boundary faults deduced from crustal deformation related to the earthquake cycle at subduction zones

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In the plate subduction zones, shear stress is steadily accumulated by locking between a continental plate and a subducting oceanic plate, and the stress is intermittently released in terms of faulting. This process, called earthquake cycle, is governed by the spatio-temporal variation of interplate coupling. We can deduce the spatio-temporal slip distribution on the plate boundary from crustal deformation data, which reflect the interplate coupling. Such kinematic behaviors of the plate boundary faults provide important constraints on friction laws, rheological properties of fault materials, and the role of fluids in subduction zones.

In Japan, we observe crustal deformation caused by the subduction of the Pacific Plate and the Philippine Sea Plate. Especially, along the Nankai Trough and the Sagami Trough, where the Philippine Sea Plate is subducting, characteristic crustal deformation representing accumulation and release of tectonic stress is remarkable associated with the recurrence of M8 megathrust earthquakes. Interplate coupling on the plate boundary is mainly controlled by thermal structures. The locked zone corresponds to the area between isotherms of 100-350C, while the transition zone corresponds to 350-450C (Hyndman et al., 1995). Differences in the coupling status can be clearly recognized from a spatial pattern of crustal deformation. Coseismic slip of 1944 Tonankai and 1946 Nankai earthquakes occurred on the locked portion, and the postseismic slip occurred on the transition zone (Sagiya, 1995). Distribution of the interseismic slip deficit roughly coincide with the locked zone, but is much smoother than that of coseismic slip. After-slip is considered to be a process relaxing the coseismic stress change. The observed after-slip was very large during the first five years following the M8 earthquakes in the 1940's. The after-slip gradually slowed down and continued for about 30 years. Though the physical process of the after-slip is not well understood, we probably need to take both the fault friction law and viscoelasticity of the medium into account. The after slip and the healing process take place almost simultaneously, which makes the study of the healing process very difficult.

On the other hand, recent GPS observations resolved slow transient faulting with time constants of several days to more than one year in the Tokai, Bungo Channel, and Boso Peninsula regions. Some conventional geodetic survey data also indicate similar possibilities in the past. It is highly possible that these slow slip compensate the slip deficit deduced from the difference between the plate motion and coseismic as well as postseismic slip. So far, the estimated slip areas and the coseismic slip areas show a complementary distribution one another. We need to study more cases in order to generalize such results.