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Repeating rupture of asperities and earthquake forecast

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Recently our understanding of the plate coupling and the recurrence of great earthquakes has deepened very much, which gives hope to improve reliability of long-term forecast of earthquake occurrence.

Two end-member models have been used to describe the plate coupling and the recurrence of great earthquakes at convergent plate boundary zones. One is the asperity model, in which the plate boundary is divided into areas where frictional coupling is strong and stick-slip dominates (asperities), and intervening areas where frictional coupling is weak and stable sliding dominates (stable sliding areas). The other is the uniform coupling model, in which the frictional coupling along the plate boundary is uniform.

In the asperity model, asperities are persistent features. Large slip areas of successive ruptures will be in the same places (asperities) in a given section of the plate boundary. Earthquakes may rupture one or more adjacent asperities; earthquake magnitudes will be large if the total size of the ruptured asperities is large. On the contrary, in the uniform coupling model, both the recurrence of great earthquakes and their slip distributions will vary with time. A large slip area of one great earthquake will be a small slip area of the next great earthquake in a given section of the plate boundary.

Nagai et al. (2001) obtained slip distributions of two successive large earthquakes along the plate boundary which strongly supports the asperity model. They comparatively studied two large earthquakes; the 1968 M7.9 Tokachi-oki earthquake and the 1994 M7.5 Sanriku-oki earthquake that occurred in a common source area east-off northeastern Japan. They found that the 1968 event ruptured three major asperities, one of which was ruptured again by the next 1994 event.

It was found that similar earthquakes have regularly occurred with a recurrence interval of 5.35+/-0.53 years on the plate boundary off Kamaishi (Matsuzawa et al., 1999). These events are perhaps caused by repeating slip of a small asperity patch surrounded by stable sliding areas. The next event was expected to occur by the end of November 2001 with 99% probability. Actually, M4.7 event occurred on November 13, 2001, exactly on the same patch along the plate boundary.

These observations suggest that asperities are persistent features and that the asperity model is a better representation to explain the recurrence of large earthquakes along the plate boundary zones.

GPS data also provide important information on the spatial distribution of the plate coupling. Nishimura (2000) estimated spatial and temporal distribution of seismic and aseismic slip along the plate boundary east off northeastern Japan based on back slip inversions of GPS data on land. Large forward slips were observed in the downward extension of the focal area of the 1994 M7.5 Sanriku-oki earthquake.

Igarashi et al. (2000) found many earthquake families (earthquakes with similar waveforms) along the plate boundary zone east off northeastern Japan. They interpreted that these earthquake families are caused by repeating ruptures of small asperities surrounded by stable sliding areas along the plate boundary. These repeating earthquakes also provide important information on the temporal and spatial distribution of aseismic slip along the plate boundary, since these repeating earthquakes are ruptures of small asperities which are caused by accumulated aseismic slips in the surrounding areas. Large forward slip areas estimated by the GPS back slip inversions have also large slip amount estimated from the repeating earthquakes. This suggests that repeating earthquakes can be used as the sensor for observing temporal and spatial distribution of the interplate slip.