Temporal change in quasi-static slip estimated from small repeating earthquake data and its effect on the rupture of asperities

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Various sizes of repeating earthquakes were found on the plate boundary in the NE Japan subduction zone. One of asperities that ruptured during the 1968 off Tokachi earthquake (M7.9) coincides with the largest asperity of the 1994 Far-off Sanriku earthquake (M7.5)[Nagai et al., 2001]. M6 class repeating earthquakes with similar waveforms were found off Miyagi and Fukushima prefectures [Hasegawa et al., 2002]. Many small repeating earthquakes with magnitudes of around 3 to 4 were found on the plate boundary [Igarashi et al., 2003]. These repeating earthquakes were probably caused by repeated rupture of perpetual asperities of various sizes surrounded by aseismic slip areas on the plate boundary.

Igarashi et al. [2003] showed that distribution of quasi-statically slipping areas and slip histories of the areas can be estimated from the activities of small repeating earthquakes in the NE Japan subduction zone. If aseimic slip rate is uniform in a certain area and asperities located in the area are small compared to the surrounding aseismic slip region, quasi-static slip rate estimated from small repeating earthquakes will correlate closely with ruptures of larger asperities in that region.

M4.8+/-0.1 earthquakes have been occurring repeatedly with a recurrence interval of 5.52+/-0.68 years since 1957 off Kamaishi, NE Japan. Okada et al. [2003] compared source areas of the latest (2001) and the previous (1995) events to find that they were caused by the repeated ruptures of the same asperity on the plate boundary. The periodicity of the earthquake occurrence is probably caused by almost stable sliding around the asperity. Strictly speaking, however, the recurrence intervals are not completely the same. Among all, the intervals before and after the 1995 event were the shortest (4.65 years after the 1990 event) and the longest (6.68 years before the 2001 event), respectively. The fluctuation of the recurrence intervals can be explained by small change in slip rate around the M4.8 asperity.

In this study, we examined distribution of quasi-statically slipping areas, and compared temporal change in quasi-static slip rate off Kamaishi with intervals of the M4.8 earthquake sequence. We used small repeating earthquake data, which were identified from events with magnitude 2.5 or larger from July 1984 to October 2001 using waveform similarity [Uchida et al., 2002]. There are many repeating earthquake groups off Sanriku (38.5-40.0N, 142.0-143.0E) including off-Kamaishi sequence. Quasi-static slip is probably dominant in this region. We estimated cumulative slips of repeating earthquake groups by using a relationship between the slip and seismic moment of a repeating earthquake proposed by Nadeau and Johnson [1998]. We averaged these cumulative slips in several regions, and assumed that the averaged cumulative slip was representative of quasi-static slip in each area.

As a result, we found that the quasi-static slip rate in the area around 142.5E (east of the M4.8 asperity) accelerated from the middle of 1993 to the middle of 1994. This period corresponds to the shortest recurrence interval, which supports a hypothesis that the 1995 event was advanced by high slip rate in the surrounding area. Moreover, around 143.0E (east of the area mentioned above), slip rate was also high in the period from the beginning of 1992 to the beginning of 1993. These results indicate that acceleration of the slip was propagated from east to west. On the other hand, in the period between the 1995 and 2001 events, the slip rate east of the asperity was much slower than the former period. This is consistent with the fact the recurrence interval was longer for this period. Thus, the advance and delay of occurrence times of M4.8 repeating earthquakes off Kamaishi can be explained by rate change in the quasi-static slips estimated from small repeating earthquake data.