Reconsideration of the asperity model

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Recent studies have revealed that the interplate earthquakes can be explained by the asperity model originally proposed by Lay and Kanamori (1980, 1981). They named regions in faults where fracture strength is relatively high 'asperities.' In this paper, however, I redefine an asperity as a region where seismic slip is dominant because it is hard to define the fracture strength of the aseismic regions surrounding asperities. I also call a region where large seismic moment was released 'large-slip area' and term a region where large high-frequency seismic energy was released 'strong-motion-generating area.'

Yamanaka and Kikuchi (2001) studied source processes of large earthquakes off Sanriku, and they found that locations of peaks in the moment-release distributions were quite similar for plural events. Off Kamaishi, Iwate prefecture, an earthquake cluster was found where M4.8 events had repeatedly occurred with an interval of about five years (Matsuzawa et al., 2002), and moment-release distributions for these events were also found to be quite similar (Okada et la., 2003). Nadeau et al. (1995) and Ellsworth and Diets (1990) found many small repeating earthquake clusters in California. Such small repeating earthquake clusters were also found off Sanriku (Igarashi et al., 2003). These studies indicate the perpetuity of asperities.

Long-term prediction is possible to some extent for the next M4.8 event in the off-Kamaishi cluster mentioned above because of the periodicity of the occurrence. On the other hand, Kato (2002) pointed out from a numerical simulation based on a rate- and state-dependent friction law that repeatabilities in the rupture patterns and recurrence intervals were sometimes poor for the cases in which plural asperities were located closely each other. If there were regularities in the rupture patterns, however, the recurrence intervals also had regularities even if plural asperities ruptured together as a multiple shock. In some cases in the simulation, asperities ruptured one after another just like a chain reaction (swarm type activity). Actually, such chain reaction type behaviors of events were found off Sanirku (Uchida et al., 2002). In these swarm activities, the largest event can be predicted to a certain extent if only we know the distribution and properties of the asperities and surrounding regions. Therefore, I believe some of the large earthquakes can be predicted to some extent although it seems to be hard to predict all of them.

It should be noted that a 'strong-motion-generating area' does not always coincide with an asperity itself. Kato (2002) showed the slip pattern in an asperity of which stress had been high at the edge because of the stress concentration. In his simulation, rupture was propagated along the edge at first; and after the rupture front completely encircled the asperity, the rest was broken with a very large slip velocity. This phenomenon is a candidate of causes of strong-motion-generating areas.

The real rupture processes, of course, are very complex. We should treat very complex fault geometry for the study on strong motion generation process in particular. Yamashita and Umeda (1994) showed that if there were plural faults subparallel to each other locally and rupture was propagated along one of the faults to reach the region, these faults began to rupture one after another to radiate large seismic energy. Such a model should be taken into account when we investigate the strong motion generation process.

In order to reveal the nature of the strong-motion-generating areas, it is very important to investigate the rupture processes of many earthquakes using various frequency band records. Studies on the detailed structures in and around the fault surfaces are also important to understand the asperities and strong-motion-generating areas.