Contradiction and consistency between multiple-segment ruptures and fault scaling laws

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To improve earthquake hazard assessments, we need to establish sophisticated fault models based on thoroughly examined fault-scaling laws. Here we review many papers and data already published, and emphasize the importance of fault segmentation and multiple ruptures associated with fault interaction. We then propose a concept of 'master segment'which has high slip relative to its length.

Many fault scaling laws that deal with Mo, Mw, L, W, and D have been empirically proposed (e.g., Matsuda, 1975). Although simple relations among them look to be well established, there are some misunderstandings, especially a relation between rupture length and displacement. If stress drops for most earthquakes are almost constant, the shapes expressed by those rupture lengths and displacements show self-similarity. Geologists however have hardly observed such simple rupture pattern but have frequently encountered multiple trapezoidal slip patterns developed in the rupture zones. Seismic analyses using waveform inversion techniques have also showed some of these complicated rupture processes in the actual earthquakes. Based on these observations, the state of California uses 'Cascade model' for long-term estimates of earthquake probabilities.

Recent developments for seismic waveform analysis allow us to change the traditional simple crack model to heterogeneous complex fault model. The recent model shows an amount of slip at any site along a fault is determined further before the rupture front reaches the fault end. In this model, the most important factors are heterogeneity of faults, healing process, and fault patch interaction. Because we cannot predict microscopically such heterogeneity along a fault, implication from macroscopic point of views, especially based on fault segmentation, would be extremely important. A master segment, which has high slip relative to its length, plays a role of further propagation of rupture because of its high stress drop and stress change to adjacent faults. It might resolve the controversial relation between rupture length and displacement. We found such master segment, for example, the Neodani fault in the Nobi earthquake fault system, and the Gofukuji fault in the Itoigawa-Shizuoka fault system.